A Commentary on
The Sceptical Chymist
of Robert Boyle
Vol. 1 of 2

by

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Submitted in fulfilment of the requirements for the

Degree of Doctor of Philosophy to

Maynooth University

Presented to:

The Department of Philosophy

31st October, 2014

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James Joyce, *Finnegans Wake*

ACKNOWLEDGEMENTS

First of all I would like to thank my supervisor, and head of the Philosophy Department, Dr Michael Dunne, for accepting this, my second project with him and for his continuing sensitive, yet thorough supervision of my commentary-in-the-making, and Prof. Alan Chalmers for his helpful remarks on the commentary.

I wish to express my gratitude to all those, family and friends alike, who maintained an ongoing interest in my undertaking, for their encouragement during these past four years; to the members of the Philosophy Department of Maynooth University, especially during the Philosophy Postgraduate Workshop meetings, for their useful comments and support, and to the current and recently graduated doctoral students of the Department, who not only maintained contact with, and inspired my project, but also set a standard of excellence for me to aspire to.

I am grateful also for the financial support I received from the Pat and John Hume Scholarship Scheme during the first year of my project, and from the Irish Research Council for the subsequent three years.

Finally, my thanks to Breege Lynch for employing her keyboard skills and unending patience in converting my fair copy into this typescript.

Conleth Loonan

Maynooth, September 27th 2014.

ABSTRACT

The purpose of this project is to elucidate Robert Boyle's *The Sceptical Chymist* to the contemporary reader – in particular one with a knowledge either of philosophy or of chemistry. The body of the work divides naturally into three distinct sections:

Literature Review in which some twenty articles treating of the work in question are reviewed. The intention here is to offer varying opinions and analyses of the book, so that the reader might have a broader perspective on it, followed by the Prelude to Commentary in which is described the broader context within which *The Sceptical Chymist* is located;

The Commentary proper in which Boyle's text is narrated to the reader, with both the philosophical and scientific content of the work explained, information on obsolete or unusual words, translations as appropriate, and biographical details on many of those mentioned in the work supplied;

The Discussion and Conclusion identifies some of the most important themes running through Boyle's book and elaborates on these, the aim being to offer the reader a more detailed exposition of some of the notions which preoccupied or influenced Boyle.

INTRODUCTION

INTRODUCTION

Explanatory Notes.

The readership envisaged for this commentary are the new-comers to *The Sceptical Chymist*, having either a philosophy or chemistry background, with an effort being made to explain the philosophy to the chemist, and the chemistry to both the philosopher and the reader conversant only with contemporary chemistry.

This commentary is based on a facsimile of the first edition of *The Sceptical Chymist* of 1661.

References of the original text are made by citing the page and line number, for example 359.11-13 refers to page 359, lines 11 to 13.

Some of the page numbers in the original work are given incorrectly. Where this occurs the correct page is given in square brackets on all quotations from such pages.

Square brackets, in all cases, have been added by the present author.

Boyle's *A Praeface Introductory*, in the edition under consideration, lacks proper pagination, so the page references are adapted and extended from the alphabetical designations given at the bottom of the first few pages, beginning with A1. The right hand side of the page is labelled 'r.' (abbreviated from *recto*), and that on the left 'v.' (*verso*). Thus, the first page is identified as A1r., and that of the second A1v.. The pagination on the book itself runs out after A4, so the next leaf is labelled A5r. and A5v.. These 'virtual' page designations are identified with square brackets.

Introduction to Commentary

The primary objective of writing this commentary is to explain *The Sceptical Chymist* to the reader who, even though they may have already studied philosophy or chemistry, remains a newcomer to Boyle's writings. For many would-be readers of Boyle, this may well be the only work of his they intend to read, although it is to be hoped that, having been assisted to read one work by him, they may develop the confidence, and find the interest, to tackle some others as well.

The reader who comes to this work as their first encounter with Boyle, apart from, perhaps, their learning – even proving Boyle's Law – is sure to find it a difficult, even perplexing, read. The qualities of the book, both positive and negative, are well rehearsed in the Literature Review, but whatever the merits or otherwise of the work, it does offer a vista on the state of knowledge of the physical sciences in Boyle's time, in particular, a perspective on the science of chymistry or proto-chemistry, as it gradually hived off from its alchemical antecedents.

What is taken for granted in our time, was novel in Boyle's, that of material change explained in terms of rearrangements occurring at the most fundamental – atomic – level, and had to be argued for against the rival, and more firmly established, accounts: that of elemental transmutation, as the Aristotelians would have it, or as the expression of the three principles of the Paracelsians. As a consequence of this, much of *The Sceptical Chymist* is given over to opposing these doctrines, especially the Paracelsian, with Boyle taking every effort to undermine and overturn this latter teaching through his spokesman, Carneades.

Time after time he speaks out against the inconsistency, obscurity and unconvincing explanations of the Paracelsian doctrine, all the while relating detailed accounts of his own laboratory experiments, as he strives to settle such questions as to the nature and number of the elements, and the role of fire in the analysing of bodies.

In presenting his dialogue Boyle illuminates the scientific and philosophical landscape of the decades both before and during his own lifetime, with numerous references to those who were active at those times, and to their beliefs. Apart from the frequent citing of matters relating to philosophy and chemistry, there are mentions to mineralogy, biology, mechanics, astronomy and travel, all of which combine to produce a lively portrayal of the state of knowledge of the natural world as seen through the eyes of a curious, perceptive, well-informed, discriminating writer.

It is hoped that the reader who works through this commentary will receive a real insight into *The Sceptical Chymist*, then through it a better understanding both of the emerging science of chemistry and of the philosophical and scientific background from which it emerged, and that he or she will be adequately provided with information on those areas in need of explanation or elucidation throughout the text.

In *A Praeface Introductory* to *The Sceptical Chymist* Boyle, first of all, explains why it is that a work which he acknowledges ‘so maim’d and imperfect’ (A1r. 3-4) should have been published. He explains rather apologetically the series of events which led to its appearance, in the course of which he speaks of ‘Discourses’ (A1v. 23) in which he ventures ‘to write of matters Philosophical’ (A1v. 25) but wishing to make it known that their author is ‘not altogether a stranger to Chymical Affairs’ (A2r. 3-4).

And this is, perhaps, as good an attempt at explaining the rationale behind *The Sceptical Chymist* as one might wish for: it is a philosophical discourse written by a practitioner of chemistry, presented not as the confident summation of a lifetime spent in pondering the results of practical research into the observed behaviour of materials under controlled conditions, but rather the work of a man who was still quite young, and still a student of chemistry, who felt in some way motivated to write of a subject which has confronted philosophy and (later) science as one of the fundamental questions: what is the nature of matter?

It could well be argued that Boyle could have made his task much easier by simply giving his own account of matter – that of matter subsisting in a corpuscular form differentiated by size, figure and shape, with motion superadded to it by its Divine Creator – and attempting to vindicate this account by treating of chemical change as rearrangements or transformations occurring at the corpuscular level. In so doing, Boyle could have published his account and allowed it to find its own level among the then current theories of matter: the atomistic theories, that of Descartes, as well as those of the Aristotelians and Paracelsians. Instead, Boyle deliberately chose to debate the issue and thereby confront the two most entrenched theories of matter of his day – the latter two of those just mentioned – both of which view matter as non-atomic in nature.

He did not, however, choose to present his opinions under his own name, preferring to attribute what were more or less his opinions to Carneades (214-129 BCE) the scholarch of Plato's academy, noted for his scepticism. So, rather than Boyleanism being added as another doctrine on matter to the other theories then current, Carneades is allowed to represent Boyle's innate scepticism whilst at the same time offering details of some of his (Boyle's) chemistry experiments.

Carneades, as spokesman for Boyle, goes along with Aristotle in considering the primal state of matter as a *materia prima* or universal matter (although, of course, Boyle accepted the Biblical account of Creation). He says that 'according to Aristotle, and I think according to truth, there is but one common Mass of all things, which he has been pleas'd to call *Materia Prima*' (145.22-26). Carneades believes that this *materia prima* or 'Universal Matter' (37.3) 'was actually divided into little Particles of several sizes and shapes variously mov'd' (37.5-7).

One might draw a parallel between Boyle and Aristotle on their respective theories on matter: both believed in the existence of a prime matter, Boyle saw this as being divided into corpuscles which had motion imparted to them by their Creator, whereas for Aristotle the simplest form of actual matter was that of the four elements – earth, air, fire and water. However, this is where the similarities end: the Aristotelians (at least as they are portrayed by Boyle) are content to identify their four elements in the decomposition products of fresh wood, but for Boyle the corpuscles are simply the rationally derived foundation for an experimental programme having as its objective the establishment of an empirical justification for his corpuscular philosophy. He carries out an extensive range of experiments which yield an impressive set of results, but invariably interprets his findings in the light of changes to materials at the corpuscular level. It is the corpuscles which by their associations, dissociations, movements and transformations enable Boyle to found an understanding of material change.

It was not for nothing that Boyle was given the title 'Father of Chemistry' – however much it might be disputed – and in *The Sceptical Chymist*, more perhaps than anywhere else, is demonstrated how he earned this appellation. It is the title 'Chemist' he applies to himself, or rather to his *alter ego* Carneades, but qualifies it with the adjective 'Sceptical', taking this word to mean 'a seeker after truth, an enquirer who has not yet arrived at definite conclusions'.[1] And it is the 'Sceptical' part of his title which causes Boyle to resort to a philosophical consideration of the items discussed in the dialogue and causes him to enquire not only into the opinions of his philosophical adversaries and their justification, but also into his own experiments, seeking always to understand what they reveal about the fundamental structure of the natural world.

Boyle reserves the greater part of his invective for those who present their understanding of the nature of matter without a satisfactory justification for their beliefs. He rails against those whose explanations are cloaked in obscure, almost impenetrable terminology, even though founded upon a rational foundation. He consistently maintains that beliefs and opinions must always be presented in clear, easily accessible explanations. Boyle did admire Aristotle (although frequently at

[1] OED online – consulted 02-08-2011.

odds with his medieval followers) praising, for example, his work on zoology, but he held that reason alone could not provide secure knowledge of the created world. Reason, he argues, must act co-operatively with experiment if one is to obtain a reliable understanding of material things.

At the other end of the scale between the rational and the experimental were the ‘sooty Empiricks’, the men who devoted their efforts to manipulating matter with an impressive array of laboratory equipment, all centred on the furnace from which came the energy enabling materials to be transformed. Although praising of their industry and dexterity in carrying out their tasks, Boyle decried their lack of a theoretical framework to their consideration of matter. It was, he believed, equally important to have a rationally-based explanatory system which would serve to account for the observed changes occurring during chemical reactions.

It could be argued that the only defensible reading of Boyle in *The Sceptical Chymist* is that of philosopher-chemist. Seeing him as a philosopher only ignores his diligent experimental efforts at justifying his corpuscular theory of matter, but he is done an equal injustice if viewed as purely an experimenter contentedly accumulating an extensive repertoire of chemical experiments with the intention only of establishing chemistry as a purely experimental science. For all his superb experimental technique, and despite the great pleasure afforded to him by his practical work, Boyle seems little interested in carrying out experiments for their own sake, instead always endeavouring to explain the observed changes in terms of transformations at the corpuscular level. And wherever possible – as in the case of experiments involving growing things – invariably attempting to trace those changes back to their original source, that of the Biblical waters of Creation. Boyle, of course, believed in the Genesis account of Creation as historical fact.

So, when readers with a background in the sciences come to *The Sceptical Chymist* for the first time they may be surprised to find more of discussion than of experiment. This reaction is perfectly understandable – modern chemistry is presented in a more concise, overtly scientific manner, with an account of the experimental work, followed by a discussion focused on the results and findings of the experimenters. However, such concentration on the details of the work in hand is possible only because the foundations of their science have long since been agreed and accepted by chemists. A mass of information on matter – its nature, identity and behaviour – has been built up over the last two and a half centuries or so, allowing the modern experimenters to investigate only those questions which now confront them.

The intellectual environment in which Boyle worked was, by contrast, far different from that which obtains today. The 'Father of Chemistry' was faced with establishing a new branch of physical science: that of the rational and empirical study of matter and the changes it undergoes. His primary task was to establish a definition of matter which would facilitate his experimental programme, and this he did by arguing for his understanding of matter with those who had alternative opinions on the subject.

By way of conclusion, one might sum up the task faced in attempting to present the philosophical content of *The Sceptical Chymist*. Four strands may be identified:

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i. Boyle's promotion of his own understanding of the fundamental constitution of the created world – his Corpuscular Philosophy, with its reduction of all material entities and physical processes to deriving from matter and motion.

ii. An understated acceptance of some, at least, of Aristotle's beliefs, which seems to have derived from Boyle's knowledge of the Stagyrite's writings. Although not openly acknowledged by Boyle, this is sometimes hinted at by him, and is also apparent from some of his explanations for natural phenomena.

iii. A further strand of philosophical influence expressed in *The Sceptical Chymist* is that of Descartes, whom Boyle clearly admired, and which becomes apparent, for example, when Boyle upbraids his Paracelsian adversaries for lacking clear and distinct perceptions in relation to their *tria prima* of salt, mercury, and sulphur.

iv. Finally, Boyle also gives expression to British Empiricist sentiments and can be viewed as a precursor to John Locke – who did incorporate Boyle's corpuscular understanding of matter into his own empiricist enterprise.

Methodology

General Considerations

The Rationale Underlying Commentary

The Sceptical Chymist is without doubt Boyle's most famous work, and, judging by the number of editions on offer, his most frequently purchased. Most Boylean scholars admit that it is not an easy read, whilst acknowledging its relevance to the history of chemistry. The intention underlying this commentary is to narrate *The Sceptical Chymist* to a reader with either a basic understanding of chemistry, or to one with a knowledge of philosophy, the intention being to explain the philosophical content to the one, and the scientific content to the other. The presumption of some prior knowledge either of philosophy or of chemistry was deemed necessary as otherwise a more detailed commentary would have been required.

Choice of Edition

It was determined at the outset that the best version of the work to comment on was the one bearing the least input by scholars or editors, so as to eliminate any possibility of disagreement as to the provenance of any part of the commentary, or of the opinions and such like, as expressed in the present work, and the decision clearly fell to a facsimile of the first (1661) edition of the book. This proved to be a good choice as questionable points in the text could be checked against the second edition of 1680.

Style of Commentary

In many respects Boyle had a fine writing style, with an extensive vocabulary, and an admirable ability vividly to convey his meaning, though prone to prolixity and circumlocution. It was decided that the best approach to adopt was to capture as much of what is best about Boyle's text by narrating the work to the reader line by line, interspersing quotations from the original work, all the while striving to keep these to a manageable length.

Practical Considerations

A general survey of the work revealed that the most sensible approach was to mark off the Latin and Greek quotations and passages and set about translating these, the reason being that although some of the Latin text contained minor uncorrected typographical errors, some of the Greek text was simply corrupt. This difficulty was overcome by checking the various editions of the work until one yielded Greek quotations which made sense, and translating these.

The next process, that of marking unusual or obsolete words,[2] supplying biographical information on the personages mentioned in the text, identifying philosophical terms, scientific references, and names of chemicals and chemical reactions, was best done by dividing the work into short sections. Most of the difficult words were explained using the online *Oxford English Dictionary*, and sometimes the *Complete Collins Dictionary* was resorted to. The most useful works in interpreting the chemical content of Boyle's book were Partington's *History of Chemistry*, Vol. 2 of 4, and his *General and Inorganic Chemistry*. The former was also valuable in providing biographical information on many of those mentioned in the text. Other works of particular assistance were the *Oxford Dictionary of Chemistry* and Crosland's *Historical Studies in the Language of Chemistry*. Two

[2] Boyle sometimes employs 'then' as a conjunction in place of 'than'. Such usages have been normalised to 'than' as appropriate.

works of considerable benefit in interpreting the philosophical content of Boyle's work were the *Routledge Encyclopaedia of Philosophy*, 10 vols, and the *Oxford Companion to Philosophy*. Of course, in sourcing reliable information of many details in need of explanation, many sources – dictionaries, encyclopaedias, other reference works, text books, and the literature, both Boylean and on the Scientific Revolution – were consulted.

The Process of Commenting

Having experimented with various methods of commenting, it was concluded that the most effective one was to take a section of about four to five pages in length, mark off the unusual features such as proper names or obscure places or materials. This was followed by an initial examination of the philosophical points or terms and the chemical reactions, then by a survey of the language employed in the text, noting unusual or obsolete words or grammatical forms. Next, the section of text was read for the noteworthy points, arguments and digressions made by Boyle. These were typically half a page to a page in length. A draft commentary was worked up for the passage in question with the most relevant parts of the unfolding discussion glossed and linked together by an explanatory text. All quotations from the book were located by page and line number.

Apart from doing justice to Boyle's actual words, in identifying each quotation by page and line number, readers could easily locate their exact place in the original work – an important consideration in a book structured for the most part with rather long chapters or parts without sub-divisions.

LITERATURE REVIEW

Literature Review

Introduction

In this Literature Review an attempt has been made to capture the opinions and analyses expressed on *The Sceptical Chymist* over the last several decades. The works surveyed fall into two (somewhat indistinct) categories. Part 1 consists of comments made concerning *The Sceptical Chymist* in works which do not deal specifically with it, but in the course of speaking about it do make some mention of it. These works are typically Histories of Chemistry or of Alchemy, treatises on the Scientific Revolution, and one deals specifically with Boyle in the context of the chemistry of his times.

Part 2 treats of studies of *The Sceptical Chymist* itself which take the form of journal articles, book chapters or sections, and the introduction to two editions of the work in question. Mentions of *The Sceptical Chymist* are scattered throughout the literature, but reviews of it are rare. Consequently, Part 1 is selective: Part 2, comprehensive.

Part 1

The Sceptical Chymist has received a rather mixed reception over the last fifty-odd years, and it is the intention of this part of the Literary Review to convey a sense of just what has been written about it. The items surveyed are generally short references to, or accounts of, the work in question, and the things typically repeated in this review are not the recurring tropes of Boyle's definition of the elements, for example, but rather those pithy and telling phrases which marks off the particular writer's overall opinion of the book. These writings are presented thematically, and within a given sub-grouping, chronologically, beginning with works on the History of Chemistry and of Alchemy, then some dealing with the Scientific Revolution, and ending with a book about Boyle and the chemistry of his times. Leicester's book of 1956 is the earliest one reviewed, the latest is Newman's of 2005.

Works on the History of Chemistry and of Alchemy

The first work considered is that of Leicester[1] who presents Boyle's project as primarily to treat of chemical reactions in mechanical terms, without recourse to occult forms and qualities, in which the behaviour of substances is analogous to that of a machine, and in particular with the world itself considered as a large clock-work device. He states that Boyle considered it essential to be rid of such obsolescent ideas as the Aristotelian elements and Paracelsian principles, and the notion that destructive distillation by fire could reduce bodies to their ultimate level of subdivision. This task, he argues, was undertaken in Boyle's:

> most famous book, *The Sceptical Chymist*, published in 1661 (114).

He describes the books as:

> In the form of a dialogue between supporters of the older theories and Carneades, the sceptical chemist (Boyle himself), he presented convincing arguments to destroy most of the former beliefs (114).

He adds that:

> The book was exceedingly influential in establishing the newer outlook among chemists of the seventeenth century (114).

Leicester goes on to make the telling point that:

[1] Henry M. Leicester, *The Historical Background of Chemistry*, rev. ed. (New York: Dover, 1971), 114.

> True to its title, however, the book did not present a substitute for the ideas which were cast aside. This has led some to believe that Boyle was a complete sceptic in science, performing experiments for their own sake and not attempting to evolve a unifying theory to explain his work (114).

He continues that this view, although far from true, is supported by both the:

> extreme variety of his experiments and the apparently unsystematic order of their publication (114).

Leicester gives a succinct account of what Boyle set about to do in *The Sceptical Chymist* and the world-view he challenged, then goes on to outline some of his other achievements.

The next book to be considered, that of Holmyard[2] views Boyle as instrumental in destroying alchemy, and who founded:

> this rational system, from which our science of chemistry has arisen (273).

He says that Boyle:

> in 1661 published his – literally – epoch-making book entitled *The Sceptical Chymist*. In this book he struck at the root of all alchemical speculation by denying that the four Aristotelian "elements" had any right whatever to that description (273).

He goes on to say that, although alchemy survived in 'apparent vigour' (273) for another century:

> The publication of *The Sceptical Chymist* was the death-warrant of alchemy (273).

He adds in defence of alchemy:

> Yet it must be remembered that to the alchemists was due much of the practical chemical knowledge upon which scientific chemistry was based (274),

then explains that:

[2] E.J. Holmyard, *Alchemy*, repr. (Mineola, NY: Dover Publications, 1990), 273-274.

> until the reorientation initiated by Boyle there was nothing strange or inconsistent in the idea that one metal might be converted into another (274).

Of course Boyle did believe in transmutation, a fact reiterated by Partington in his four-volume History of Chemistry[3] when he says that:

> Boyle, like Helmont, accepted the possibility of transmutation and the reality of alchemy (499).

He notes that *The Sceptical Chymist* is:

> written in a good, though rather prolix, style, enlivened with touches of humour (497),

and adds that:

> It contains the germs of many ideas elaborated by Boyle in his later publications (497).

Partington goes on to speak of the work's origins and some of its contents, including quotations from the book itself.

Next, Crosland[4] mentions *The Sceptical Chymist* in relation to Boyle's opinion on the proper use of descriptive language, and in a brief comment on the work says that Boyle:

> in his *Sceptical Chymist* (1661) made it clear that in a science it is to be expected that language will be used precisely and not figuratively (61),

then goes on to aver that:

> Much of the *Sceptical Chymist* is concerned with attacking, on the one hand, the idea of the four Aristotelian elements and, on the other, the three principles of Paracelsus (61).

Moving on from Boyle, the author then outlines how Nicolas Lémery (1645-1715) also attacked the terms used by his contemporaries.

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[3] James R. Partington, *A History of Chemistry*, vol. 2, repr. (London: Macmillan, 1969), 497-499.
[4] Maurice P. Crosland, *Historical Studies in the Language of Chemistry*,repr. (New York: Dover, 1978), 61.

LITERATURE REVIEW

Multhauf[5] makes some remarks about *The Sceptical Chymist*, as when he notes that this work:

> deals for the most part with “experiment” (more accurately, demonstrations) (252).

As a consequence of this, he states that the book gives most of its attention to the ‘chemists’ (252) or adherents of the Paracelsian doctrines of the three principles of salt, sulphur and mercury, and little to that of the followers of the four-element Aristotelian system of earth, air, fire and water. He notes, correctly, that in this work, the Aristotelian dialogist:

> Philoponus is practically mute (252).

In a later chapter Multhauf opines that in light of Boyle’s subsequent work, we must assume that his conclusion:

> in the *Sceptical Chymist*, that we do not know what the elements of bodies may be, carried the implication that it doesn’t much matter (278).

It could be argues against Multhauf that Boyle’s inability to name the elements does not stem from any disinterest in the question on his part, but rather from his never having arrived at a convincing means by which they might be definitively revealed.

Brock[6] offers this account of the work under review:

> In 1661 Boyle published *The Sceptical Chymist*, a critique of peripatetic (Aristotelian), spagyric (Paracelsian and Helmontian) chemistry and the substantiation of physical and chemical properties into pre-existent substantive forms and qualities (56).

He further explains that:

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[5] Robert P. Multhauf, *The Origins of Chemistry* (London: Oldbourne, 1966), 252, 278.
[6] William H. Brock, *The Norton History of Chemistry* (New York: W.W. Norton & Co., 1993), 56.

> Although designed as an argument in dialogue form between four interlocutors, Carneades (a sceptic), Themistius (an Aristotelian), Philoponus (a Paracelsian) and Eleutherius (neutral), Boyle's rather verbose, digressive and rambling style makes it difficult for the modern reader to follow his argument (56).

Newman,[7] in the context of Boyle's critique of the traditional distinction between art and nature, says that:

> *The Sceptical Chymist* argues against the view that decomposition of bodies by means of fire necessarily reveals their true components, as opposed to artifacts of the fire itself. In particular, Boyle casts doubt on the claim of some Scholastics and chymists that the fire merely separates substances into their preexisting four elements or three principles (273).

He goes on to quote some arguments from the work itself.

Works on the Scientific Revolution

Dijksterhuis[8] says that the task of discrediting both the Aristotelian and Paracelsian doctrines on matter was accomplished in:

> Boyle's best known work, *The Sceptical Chymist* (1661; 2nd ed. 1680), which may be regarded as the beginning of a new era in the history of chemistry in that it terminated an older period (434).

He explains that:

> The title perfectly describes the contents: it is exclusively sceptical and critical in character (434),

and continues that:

> The author only wishes to show, on the ground of experiment, the untenability of the Aristotelian and Spagyristic theories, while of his own corpuscular conceptions he publishes none but the principles, and those only in the form of possibilities (434).

He displays an insight into Boyle's character by observing that:

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[7] William. R. Newman, *Promethean Ambitions. Alchemy and the Quest to Perfect Nature*, paperback ed. (Chicago: Chicago University Press, 2005), 273.

[8] E.J. Dijksterhuis, *The Mechanization of the World Picture*, trans. C. Dikshoorn (Oxford: Clarendon Press, 1961), 434-435.

> The plan reflects his personality, which was marked, especially at the beginning of his scientific career, by great caution in accepting or proclaiming binding dogmatic statements (434),

then quoting Boyle:

> (*I met with very few opinions that I can entirely acquiesce in*, he confesses, and elsewhere he adds that the opinions of others can satisfy him scarcely less than his own) (434),

adding that he had:

> a pronounced desire to reconcile divergent views (434).

He elaborates that, in contradistinction to the doctrines of the Paracelsians:

> Carneades (who is Boyle's mouthpiece) has argued plausibly that the decomposition products obtained by heating a compound body are neither simple nor three in number nor the bearers of certain qualities (434).

What Carneades is perfectly willing to admit it that:

> all mineral bodies probably consist of a salt-like, a sulphur-like, and a mercury-like component (434),

and that most bodies of vegetable and animal origin can be divided by the fire:

> into five substances, which may be called salt, spirit, oil, phlegm and water (434).

In addition he believes that:

> these different substances, though not simple, can yet be looked upon as elements of the compound bodies; and that in particular the curative properties displayed by compounds can be considered to reside in one of these elements (434-435).

Dijksterhuis notes that, even though:

> the criticism in question was thus largely withdrawn again does not alter the fact that after the appearance of *The Sceptical Chymist* Aristotle's doctrine of the four elements as well as Paracelsus' theory of the three *principia* gradually passed into disuse (435),

and going on to mention the further development of chemistry, adds perceptively that:

> To speak of *The Sceptical Chymist* as the first modern handbook of chemistry, as is sometimes done, is thus possible only if one either has never read the work or attaches excessive importance to the definition (435),

so far, so good, but he then adds, erroneously:

> of chemical elements (435),

as Boyle never mentions 'chemical' elements. Dijksterhuis continues:

> given in the second edition of the book (435).

This definition of elements appears in the first edition as well.

He accurately contrasts Boyle's position on the elements with that of Lavoisier, more than a century later, by stating that:

> In contrast with Lavoisier, who was to require no more than the practical impossibility of decomposition with the available chemical means and who therefore defined the so-called analytical elements, Boyle thus demands essential impossibility of analysis (435),

and consequently:

> finds himself obliged to add at once that he dare not yet state for certain that elements actually exist, so that he is also unable to describe or number them (435).

Apart from a couple of inaccuracies, Dijksterhuis gives a perceptive and well-balanced account both of Boyle and of the work in question.

Hall[9] adopts a clear-sighted attitude towards the work in question. He remarks that:

> Boyle's first attempt to bring organisation into chemistry has been curiously misunderstood, and probably overestimated (228),

and goes on to relate that:

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[9] A. Rupert Hall, *From Galileo to Newton*, rev. ed. (New York: Dover Publications, 1981), 228-229.

> The composition of the *Sceptical Chymist* (1661) was begun some years before and the book has all the faults of Boyle's youthful endlessly wordy, shapeless style cast into the form of an unlikely dialogue (228).

He explains that Boyle:

> made the mistake of adopting a negative pose, as though intending no more than to point out the insufficiencies of the philosophers' four elements and the chemists' three principles without making way for an alternative opinion (228).

He denies any great originality in the work, saying that:

> Boyle's account of elementary principles and of their role in chemical theory contained nothing new nor (228),

he continues:

> did he succeed in effacing belief in their reality (228),

although he concedes that:

> he gave some good knocks against the evidence presumed to prove their existence in all substances (228).

He asserts that:

> Contrary to popular mythology Boyle drove neither the Aristotelian elements nor the spagyric principles out of chemistry (228).

Hall states perceptively that:

> more accurately, what he was about was the undermining of the Aristotelian doctrine of forms and qualities and of the chemical explanations that depended upon them (228),

arguing that:

> In so doing he appealed to the indestructibility of matter (228),

and noted the persistence of gold and silver through chemical change.

Moving on to mention the mechanical philosophy, he makes the plausible objection that:

> the allusions to the mechanical philosophy in the *Sceptical Chymist* are not elaborately worked out (228).

He goes on to consider the question of Boyle's attitude towards the elements, and after that to discuss some of his other works.

A Work Treating Specifically of Boyle

Boas[10] has mixed opinions on the book under consideration, noting that it is written in the form of:

> a literary, Galilean dialogue, and it became a rather tedious, very long-winded discussion, in which the argument is often lost in the intricacies of the literary device; the title, *The Sceptical Chymist*, is the only compact thing about it.

Adopting a more positive tone, she remarks, correctly, that:

> *The Sceptical Chymist* does presuppose a corpuscular theory of matter, and in fact, the corpuscular philosophy was defined with some rigour by means of several so-called propositions in the first book.[11]

She goes on to observe, accurately, that:

> By the time he had finished demolishing the established theory of elements, either Aristotelian, Paracelsan or Helmontian, Boyle was increasingly dubious about the possible existence of any elements.

Reverting to a more critical tone, she states, again correctly, that:

> He did, to be sure, give an excellent definition of an element, which is especially good if one does not quote it in full, for the full version shows that he was neither original in his definition, nor inclined to believe that the concept of elements was a very useful one.

She goes on to quote Boyle's definition of elements, and thereafter, to discuss it.

Part 2

Scholarly articles treating of *The Sceptical Chymist* are rare, though a number have been produced over the last century or so. Although the articles reviewed herein do not

[10] Marie Boas, *Robert Boyle and Seventeenth-Century Chemistry* (Cambridge: Cambridge University Press, 1958), 95.
[11] By which she obviously means 'the first *part*'.

present a unitary approach to the study of the work in question, apart from the two articles serving as introductions to the Everyman's Library editions of *The Sceptical Chymist*, all are obviously written out of an attempt at providing a coherent examination of the book, and provide a convincing rationale behind it, its composition, stylistic features, and influence.

The earliest article, Pattison-Muir's introduction to *The Sceptical Chymist*, is placed first, followed by Moelwyn-Hughes's introduction to the same work; all other items are placed in chronological order. Pattison-Muir's article dates from 1911, the latest ones, those of Duddy and José R. Maia Neto & Elene C. Pereira Maia, appeared in 2002.

M.M. Pattison-Muir[12]

In his introduction to *The Sceptical Chymist* Pattison-Muir gives a succinct account of the book. It deals, he says:

> with the experimental evidence, and the reasoning based thereon (vii),

adduced by the proponents of the four-element Aristotelian system, and the *tria prima* of the 'vulgar spagyrists'.

He then sets about elaborating on this by explaining at some length the world-view out of which these beliefs emerged, a world-view which was pre-scientific, with the alchemists adhering to:

> a magical conception of the world (x),

in which material objects are invested with:

[12] M.M. Pattison-Muir, (Introduction to) *The Sceptical Chymist*, in Robert Boyle, *The Sceptical Chymist*, rev. ed. (London: Dent, 1911), vii-xxi.

> qualities, emotions, and moral tendencies (xi),

qualities actually attributable to human beings only. This outlook was based on the supposition of the unity and simplicity of nature, with the order observable in the natural world, and the rules governing it, emanating from the minds of those who upheld this purview.

This understanding of things he contrasts with the scientific method being devised by Boyle, in which the natural world is *not* simple and the laws governing it have to be arrived at through patient observation and careful experiment, free from any pre-conception as to how nature should operate. The author explains that *The Sceptical Chymist* embodies the reasoned conceptions which Boyle had gained from the experimental investigation of many physical phenomena, and employed as guides in the further prosecution of his enquiries. For Pattison-Muir:

> The book is more than an elegant and suggestive discourse on chemico-physical matters; it is an elucidation of the true method of scientific enquiry, and a powerful vindication of that method against the vain conceits of mere intellectualists (x),

adding that:

> *The Sceptical Chymist* is a real, living book for intelligent men and women today (x).

Pattison-Muir contrasts the experimental methodology employed by Boyle with that of his adversaries, saying that the alchemist:

> found it very hard to conduct transmutations in his laboratory; it was much easier to transmute his facts so as to bring them into harmony with his theory (xii),

adding that:

> Most of the "hermetic philosophers" and "spagyrists" in Boyle's time – we would call them physicists and chemists – took the second of these courses. Boyle followed the first course, and besought others to follow it likewise (xii).

Why Pattison-Muir considers this distinction between the 'hermetic philosophers' and the 'spagyrists' is rather strange as both terms are synonyms for 'alchemist', with 'spagyrist', one who takes matter apart and puts it together, being attributed to Paracelsus. Boyle did employ this term when referring to the Paracelsians, although it did more widely apply to the alchemists.

He goes on to explain that the hermetic philosophers:

> assumed, without proof, that fire is "a great opener of bodies;" that is, they supposed that the action of fire on a substance is to separate or resolve it into simpler constituents (xii),

and says that the Aristotelian participant in *The Sceptical Chymist* believes that the burning of a piece of wood reveals the four elements – earth, air, fire and water.

Pattison-Muir sensibly interrupts his account of the work under review to present a brief biographical sketch of Paracelsus and the origin of his *tria prima* or three principles of salt, sulphur and mercury, then continues that *The Sceptical Chymist* is:

> written in the form of a dialogue, chiefly between *Themistius*, who upholds the doctrines of the "hermetick philosophers," and *Carneades*, who expresses the opinions and urges the arguments of Boyle (xv-xvi).

Why the author should present these two characters as the principal protagonists of the dialogue is unclear, as *Themistius* actually plays only a minor role in it, and disappears after a few pages, with *Carneades* left as *Eleutherius'* sole interlocutor for the rest of the dialogue, and with Boyle himself present throughout the duration of the discussion as a silent note-taker.

He elucidates the difference in approach between the two dialogists. *Themistius*, the Aristotelian, is:

> very averse to descend to experimental evidence (xvi).

By contrast, *Carneades*, Boyle's spokesman:

> insists on dragging the philosopher back to facts and reasoned hypotheses (xvi),

and on the necessity of conducting a series of skilfully executed experiments for the accumulation of facts about the natural world.

Pattison-Muir gives Boyle's widely quoted definition of element, stated in *The Sceptical Chymist*, and adds that:

> the only thing wanting is an experimental method of determining whether a given substance is, or is not, an element, in Boyle's meaning of the word element (xviii).

He understands that the weak point in Boyle's argument is his failure to find an experimental means by which a given material's elemental status can be determined. He points out that Boyle:

> had not shaken himself quite free from the trammels of the hermetic, or to use a more modern term, the intellectualistic method of examining nature (xix),

that experimental methods for precise measurement of weight, which became available only in the next century, allowed Lavoisier to give a pragmatic definition of element and:

> found the test of elementariness after which Boyle was seeking; Dalton began the teaching of how to measure the relative weights of the minute particles of bodies (xx).

Pattison-Muir acknowledges that, although the arguments deployed against the elemental systems of his adversaries in *The Sceptical Chymist* are of little interest to the scientists of today, nevertheless, he is fulsome in his praise of Boyle, both as experimental philosopher and as dialogist:

> The acuteness of Boyle's reasoning must impress every intelligent reader, the soundness of his philosophy must come home to scientific students of nature, the wide and generous views he takes of natural phenomena and of the scope of natural science must encourage all who seek clear and imaginative knowledge, and his constant striving after lucidity both of thought and expression, his justness of phrasing, and his humorous fairness to his opponents, must delight every admirer of literary power (xx).

He rounds off his introduction by saying that *The Sceptical Chymist's* great importance consists in Boyle's:

> reiteration of proofs that nature is *not* simple (xxi),

that facile means to the uncovering of nature's secrets are to be doubted, that it is unwise to adopt specious, experimentally untested arguments, and to be awestruck by high-flown language or:

> strange experiments or high-sounding phraseology (xxi).

Pattison-Muir gives a positive relation of the book, with a well-presented account of the intellectual climate with which Boyle had to contend. It is set forth as a struggle between Boyle as proto-scientist and his adversaries helplessly mired in their medieval mind-set. In delivering the background to Boyle's life and work he provides a useful guide even to the contemporary reader. Some questionable judgements on points of detail may well be overlooked in the wider consideration of the work. Of the two introductions to *The Sceptical Chymist* written for the Everyman's Edition of the book, this one, though the earlier of the two by some fifty years, is the fuller, more detailed, and more helpful account.

LITERATURE REVIEW

E.A. Moelwyn-Hughes[13]

The author has decided to begin his introduction to *The Sceptical Chymist* with a cleverly compiled account of Boyle's life. He goes on to initiate his account of the work in hand by saying that:

> *The Sceptical Chymist* is the best known, but not the best, of Boyle's books (x).

He refers to the Aristotelians as physicists, or 'hermetick philosophers', and to the disciples of the later school of Paracelsus as chemists – Boyle's vulgar spagyrists. Moelwyn-Hughes states that the work is in the form of a dialogue between Carneades, representing Boyle, and Eleutherius. He does not name the other participants in the dialogue – Themistius the Aristotelian, and Philiponus the Paracelsian – who are present for the early part of the debate only, although he does refer to the dialogists as 'contestants', 'spagyrists' and 'peripatetics', and differentiates between the outlooks of the adversaries by saying:

> The spagyrists and peripatetics come armed with relatively little knowledge and heavily handicapped by a profusion of antiquated preconceptions (x).

By contrast:

> Boyle comes with erudition, an open mind and a healthy scepticism of all statements concerning nature that are not based on experiment (x).

Moelwyn-Hughes presents an analysis of the book in which he views it as a vehicle for Boyle's own opinions, delivered by his representative Carneades, the other major participant in the discussion, Eleutherius, is depicted as representing the popular case. He sees Boyle's knowledge of chemical operations as providing him with a secure

[13] E.A. Moelwyn-Hughes, (Introduction to) *The Sceptical Chymist*, in Robert Boyle, *The Sceptical Chymist*, rev. ed. (London: Dent, 1967), v-xii.

means of winning the debate, and acknowledges the adroit use to which he puts his knowledge of experimental techniques, which combined with an:

> exceptionally clear insight, he almost always drew the correct inference from the results of his experiments (xi).

He cites gold both as a material from which Boyle challenges his adversaries to extract one of their principles and present it to him:

> Or consider the possibility, on the other hand, of ranking gold among the elements (xi),

and goes on to quote Boyle on how gold may by chemical reaction be converted into a variety of products quite distinct from the metal, yet which can be returned to its original condition.

The author seems to be referring to gold's status as an element and that somehow Boyle, though not his opponents, realised this fact. Of course Boyle never did definitively recognise gold, or any other material, as elemental.

Moelwyn-Hughes points up Boyle's role in undermining the opinions of his adversaries and:

> in blowing them sky-high (xi),

and that in providing the clearest definition of an element, he concluded from the observations that there were more than four:

> though he did not say how many were required (xi).

He acknowledges that the style of this work can be 'repetitive' and 'prolix', but:

> it occasionally reaches a Baconian level (xii),

a reference to the passages where Boyle provides a well-judged and succinctly expressed insight. He concludes that *The Sceptical Chymist* is a firm:

> classic in the annals of science (xii).

Moelwyn-Hughes sees Boyle as a forward-thinking early chemist whose insights into his subject, combined with his chemical experiments, were instrumental in advancing the cause of chemistry at the expense of his adversaries. It presents him as a pioneering scientist with a recognisably 'modern' outlook, an opinion of Boyle which resonates with that of Moelwyn-Hughes's contemporary, Marie Boas-Hall, with little or no reference to the alchemical undertones present in the work under consideration.

It does include a succinct account of Boyle's life and conveys a good sense of *The Sceptical Chymist*, presented from the perspective of a modern chemist surveying a work which was of fundamental importance to the development of chemistry, endeavouring to place both it and its author in context for the modern scientist.

Tenney L. Davis[14]

Davis offers an account of the first publication of *The Sceptical Chymist*, concentrating on its production and appearance as a printed book rather than its contents. He does, however, state his opinions on the work itself, which are worthy of comment.

In a brief introduction to his paper he makes the claim that:

> the ideas which brought about the change from the chemistry of the alchemists to the modern chemistry of the present time were the ideas which Lavoisier put to

[14] Tenney L. Davis. "The First Edition of the Sceptical Chymist". *Isis* 8, no. 1 (Feb. 1926): 71-76.

> work in the laboratory in the course of his brilliant quantitative researches on oxidation (71).

He argues that in this work Boyle criticises earlier teachings on elements and principles, then introduces his own definition of element:

> which has lately weathered the discovery of radioactive phenomena and remains the accepted definition at the basis of the chemistry of today (71).

He opines that Boyle seems not to have known how to make experimental use of his definition, but says that:

> others made unconscious use of them until, more than a century after the appearance of his book, Lavoisier brought them clearly to the surface of thinking, exploited them experimentally, and obtained their almost immediate and entirely general acceptance (71).

He finishes this section by remarking that:

> *The Sceptical Chymist*, then, marks the beginning of modern chemistry (71).

Davis follows this with an account of the circumstances surrounding the publication of the first edition, reproducing its title pages, and describing some of its characteristics. He mentions some early editions of the work which he has been able to trace through correspondence with various libraries.

Davis makes the curious observation that Boyle believed that the earlier editions of the work:

> did not start the discussion or evoke the reply for which the author had hoped, for he says in the preface to the Experiments and Notes[15] that he wrote in an aggressive style in the hope that he might thereby stimulate chemists to reply (75).

He points out that:

[15] *Experiments and Notes about the Producibleness of Chymicall Principles*, published in 1680, the title page of which Davis reproduces in his paper.

> Neither of the title pages of the second English edition[16] show the author's name (75).

The reason why, Davis believes, has less to do with Boyle's modesty, than with the fact that *The Sceptical Chymist* had become so well known, during the interval between its first appearance in 1661 and its second edition in 1680, that:

> mention of its authorship was entirely unnecessary (76).

Louis Trenchard More[17]

More begins his analysis by making some claims for the work under review, beginning with:

> The *Sceptical Chymist* is undoubtedly the most famous of Boyle's works. It might almost be said to be the only one still alive – or rather it is the one known by title by most scientists (244).

He goes on to state perceptively that:

> few have read it, for the mistaken notion has been early fixed in their minds that the study of the great classics of science is of little value in their education (244).

He considers it regrettable that this should be so, adding correctly that:

> the *Sceptical Chymist* is usually misrepresented as the first modern treatise on chemistry, which it certainly is not (244).

Strangely, he then asserts that this work contains Boyle's:

> celebrated and original definition of a chemical element, which actually first appears in the second edition some twenty years later (244).

Boyle's definition of elements (and not referred to by him as "chemical element") is certainly celebrated, though not truly original, and does actually appear in the first edition of *The Sceptical Chymist*.

[16] Published in 1680.
[17] Louis Trenchard More, *The Life and Works of the Honourable Robert Boyle* (New York: Oxford University Press, 1944), 244-251.

More continues that:

> As interesting and as important as it may be, the *Sceptical Chymist* is surpassed in value by his later and more mature treatises to which it is propaedeutic (245).

What exactly he means by 'value' is unclear. He may be referring to the quality of its composition, or of the debate it narrates and the questions it poses, then seeks to answer, or perhaps of the experimental issues it addresses. He may really have in mind the worth of the work in terms of the developing mechanical philosophy, and of Boyle's Corpuscular Hypothesis.

It is surely the case that the development of Boyle's thought is revealed in his later works and that he did revisit, and restate, much of the content of *The Sceptical Chymist* subsequently, but it can hardly be claimed dogmatically that later works exceed it in value.

More goes on to offer a succinct exposition of the work under review. He explains that Boyle had already established his competence as an experimenter and had demonstrated the practical as well as theoretical value of Bacon's 'inductive philosophy':

> Now he would consider critically and sceptically the natural philosophies from the earliest classic times down to his own tentative corpuscularian hypothesis. He would not examine them to see whether or not their conclusions followed logically from the postulates which had been assumed as true; but he would test their postulates and conclusions in regard to their consonance with the then-known experimental facts (245).

He adds perceptively that:

> The reader is not to expect positive decisions (245),

then quotes from *The Sceptical Chymist* itself:

> if you remember, that it is a sceptic speaks to you, and that it is not so much my present task to make assertions as to suggest doubts, I hope you will look upon what I have proposed, rather as a narrative of my former conjectures touching the principles of things, rather than as a resolute declaration of my present opinions of them (245).

More offers two quotations expressing Boyle's doubt on the number of the elements and of both the Aristotelian and Paracelsian elemental systems, then explains that Boyle adopted the dialogue form:

> In order to assume the role of the impartial and impersonal critic (245),

and elaborates on this:

> The chief speaker is Carneades, a corpuscularian, who can occasionally quote a Mr. Boyle as an authority; the others are a Peripatetic, a Spagyrist or modern Chemist, and an inquisitive guest (246).

The last-named participant in the dialogue is obviously Eleutherius, who acts as informal moderator of the discussion. The Peripatetic is Themistius, and the Spagyrist, Philoponus. The dialogists are to conduct their debate in a gentlemanly fashion, without recourse to vacuous forms of language.

Boyle retains his sceptical position, withholding his support from all hypotheses relating to chemistry, and acknowledging only the three principles of matter, motion and rest, as postulated by himself. More relates how Themistius, the Peripatetic or Aristotelian, opens the dialogue:

> with a eulogy glorifying that admirable philosophy which needs, according to him, only to be known to be accepted (246-247).

He goes on to relate how Themistius gives a glowing account of the rationally deduced Aristotelian philosophical system, then elaborates by giving Themistius' description of a piece of green wood burning as an illustration of the presence of the four Aristotelian elements of earth, air, fire and water in natural bodies.

More relates that Carneades believes that what he has just heard needs no answer, instead he rejoinders that:

> the discussion is on the question whether the four elements, or the three hypostatical principles, actually explain the analysis of all compounds into simple *primae materiae*, or whether they are mere names, signifying nothing, and could be called by any other words. Also, the question is to be answered, whether fire is the one and only agent to accomplish such analyses, which is held to be true by Aristotelians and Paracelsians alike (248).

Adopting Carneades' perspective, he lists a number of facts about the fire, noting the difficulty of determining its true effects, complaining that:

> chemists are very lax in stating how the fire is used (248),

and that chemical *menstrua* and even extreme cold are agents active in changing bodies.

He continues, pointing up the important consideration that Themistius' example betrays his failure to differentiate between fire as applied directly to wood, and the same wood being distilled in a retort, then questions where the four Aristotelian elements can be identified from processes such as these. More observes that Carneades claims that fire may actually generate some substances not present in the original material. He notes that instead of pursuing this line of thought Carneades goes on to quote van Helmont's tree growing experiment, in which the experimenter took the tree to have been formed from water alone. More asks:

> And yet if he had distilled the tree with fire, would he not have found the usual products instead of such a preponderance of water? (249).

What More means here is unclear, in that wood on distillation does indeed yield a variety of organic products, though the major product is still water, but surely this is not the point at issue. Van Helmont believed that the water fed to the tree during its five years of growing in the tub was transmuted into woody tissue, demonstrating to his own satisfaction that wood, and by extension all growing things, derive from water.

More exclaims:

> What an illustration of a false hypothesis being blasted by an erroneous explanation! How excited Boyle would have been if he had but known that most of the accrued weight of the tree was terrene carbon sequestered from the air by light (249).

Of course Boyle did suspect that some things present in the air and in rain-water might actively participate in the growth of wood. In growing a small plant himself, as related in *The Sceptical Chymist*, he notes that rain water 'is more discernably' (112.6) a kind of panspermia and seems to contain in it 'besides the Streams of several Bodies wandering in the Air, which may be supposed to impregnate it, a certain Spirituous Substance, which may be Extracted out of it' (112.9-14).

Van Helmont's tree was planted in rain-water, and watered with rain-water or distilled-water, but of course Boyle as careful observer of nature, and no doubt aided by the newly-emerging science of microscopy, was able to see for himself the impurities present in rain-water. Apart from this, Boyle hints that the rain-water may contain a substance which originates in the air and which plays a role in plant growth, and although he had not realised the necessity of carbon dioxide to plant growth, he is nevertheless willing to entertain the idea that the air may play a part in the growth of trees and plants.

Moving on from the putative elements to considerations of colour, More quotes from Boyle's account of colour and its origins – not in matter but in glass prisms – and the last section of the review has him taking issue with the chemists, with Boyle having endeavoured:

> and successfully he thinks, to prove that substances separated by fire have not the purity and simplicity requisite for *primae materiae* (250).

He explains that for Boyle:

> The task has been made more difficult by the intolerable ambiguity of the chemists and the unreasonable liberty they take with words (250).

More goes on to offer substantial quotations from *The Sceptical Chymist* in support of Boyle's opinions, finishing with one in which he criticises:

> the prevailing confusion of ideas and terms in the chemistry of the time (251).

He rounds off his review with a positive assessment of the book and of its 'youthful' author, for whom More makes no less a claim than that:

> Boyle had with an extraordinarily successful effort demolished the dogmatic hypotheses which had held almost undisputed authority for centuries (251).

So great was the work's influence, that right from its publication:

> belief in the four essential elements of earth, water, air, and fire, or in the three hypostatical principles of a mystical salt, sulphur and mercury, quietly died (251).

Not that this meant that Boyle's objective as harbinger of a new order as to how the created world was perceived, was now fulfilled. More cautions that:

> He still had before him the harder task of instituting in their stead the still prevailing hypothesis of an atomistic and mechanistic universe (251).

More presents a perceptive, well structured and helpful account of *The Sceptical Chymist* in which the reader is guided through the text itself and introduced to its ideas, arguments and style. Occasional lapses of interpretation, and one obvious error of fact, do not greatly detract from the value of his review. It might also be borne in mind that

More's book concerns itself with some of Boyle's other works, indicating that his review of *The Sceptical Chymist* of necessity is placed within the context of a longer work by More.

Marie Boas[18]

In this, the second article by this author to be reviewed, Boas examines Boyle's first version of *The Sceptical Chymist*, written in the decade before the final work, and unpublished during its author's lifetime. In her essay she also presents some analysis of *The Sceptical Chymist* itself, which is worthy of review in its own right.

Early in the study she makes the interesting observation that the 'Discourse' (A1r.10) referred to at the beginning of A Praeface Introductory to *The Sceptical Chymist* was 'almost certainly' (153) the earlier version of that work. Contrasting the earlier version, referred to as the *Reflexions* by her, with *The Sceptical Chymist*, she offers a concise, accurate analysis of the latter book, noting that it:

> deals with some one aspect of the theory of elements in each of its six parts (154).

She goes on to elaborate on this:

> Part I of the *Sceptical Chymist* argues that fire is not the genuine universal analyzing agent (154);
>
> Part II argues that not everything separated from a body is necessarily pre-existent in it, and uses Helmont's work as an example (154);
>
> Part III argues that not all bodies are resolved into precisely three elements and Part IV that substances separated by fire are not always elementary (154);

[18] Marie Boas, 'An Early Version of Boyle's: Sceptical Chymist', *Isis* 45, no. 2 (July 1954): 153-168.

> Part V, where Boyle explains why he thinks the doctrine of chemical elements an inadequate basis for a general chemical theory, and Part VI, which denies the validity of any theory proclaiming the existence of true, immutable elements, are addenda and cover material nowhere mentioned in the *Reflexions* (154),

acknowledging that:

> a few experiments from the *Reflexions* are used in the last two parts of the *Sceptical Chymist* (154).

Going on to offer some further comparisons between the two works she notes that:

> The *Sceptical Chymist* is fundamentally based upon the acceptance by Carneades of the "corpuscular philosophy" which Boyle later elaborated in complete detail (155).

Boas continues that:

> In the so-called Propositions laid down by Carneades at the beginning of the First Part of the dialogue, a corpuscular theory is enunciated and discussed in conjunction with empirical evidence. Throughout the *Sceptical Chymist* there are constant references to atoms, particles and corpuscles (155).

Contrasting the difference in the definition of heat between the two works, she observes that:

> The *Sceptical Chymist* states that "the true and genuine property of heat is, to set a moving, and thereby to dissociate the parts of bodies, and subdivide them into minute particles," a view developed in some detail (155).

She argues that Boyle's understanding of heat:

> is a developed theory, consonant with the emphasis always placed in Boyle's corpuscular philosophy upon the *motion* of the particles as essential for the production of all chemical and physical properties (155).

She further argues of Boyle:

> It is the Sixth Part of the *Sceptical Chymist*, the so-called Paradoxical Appendix … in which Boyle (or at least Carneades) appears as the genuine corpuscular philosopher (155),

then offers the plausible opinion that:

> and it is chiefly because of his atomic view of matter that Boyle was finally led to doubt the existence of any elements whatsoever (155).

Boas makes an interesting contrast between the endings of the two works, arguing that the growth of Boyle's knowledge through a great deal of experimental work, combined with his acceptance of the corpuscular philosophy:

> explains the difference between the merely sceptical conclusion of the *Reflexions* and the genuinely agnostic end of the *Sceptical Chymist* (156).

She opines that even in the *Reflexions* Boyle was far more interested in overturning the Paracelsian *tria prima* than the four-element Aristotelian theory. The reason for this may be:

> Perhaps as Boyle hints in the *Sceptical Chymist* belief in the Aristotelian elements among the chemists whom he knew had already been partially destroyed by the attacks of the Paracelsian alchemists (156).

She then suggests another, more dubious, reason:

> More probably Boyle himself found the chemical elements the more convincing and the better grounded in experiment and therefore reserved his more powerful attacks for them (156).

It could equally be argued that Boyle respected the Paracelsians for their devotion to chemical experiment, whilst at the same time denying their *tria prima*.

Boas goes on to mention Boyle's high regard for the work and opinions which were given some credence by his own experiments, noting that:

> In the *Sceptical Chymist* far less space proportionally is given to the Helmontian theory, but the theory is accepted in so far as it offers an argument against the chemist by showing the possibility of producing chemical principles *de novo*, so that their appearance during analysis by fire may be by synthesis and is not necessarily a consequence of their being pre-existent in the substance analysed (157).

All of the above seems a justifiable analysis of Boyle's opinions on the Helmontian philosophy. She continues that:

> But of course Boyle's disbelief in any true elements at the time of the *Sceptical Chymist* implied that water, too, was only an agglomeration of particles, not a true element (157).

This is questionable as it could also be argued that in *The Sceptical Chymist* Boyle held that water, and to a lesser extent, earth, dating as they do from the time of creation, occupy a unique category in his understanding of the elements, making them the two primal elements for him.

Boas's essay reveals a close reading of *The Sceptical Chymist* by her, and it offers valuable insights into this work, its origins and the scientific understanding of its author in the earlier part of his experimental career.

Jan V. Golinski[19]

Having stated some traditional notions about *The Sceptical Chymist* Golinski goes on to question these, and offers as an alternative his own analysis of the work. He states that:

> My claim is based upon a reading of the *Sceptical Chymist* which exposes the rhetorical intentions of the work (59),

and further explains that:

> Boyle deployed scepticism as a textual strategy, to challenge the authority of a particular discursive tradition (59).

This reading of Boyle stems from his adoption of a historiography which focuses on the rhetorical dimensions of scientific writing, and he lists the authors under whose influence he writes, from Gadamer, Derrida and Rorty, to Foucault, Kuhn, Hannaway, Shapin, Shapiro and Shaffer.

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[19] Jan V. Golinski, 'Robert Boyle: scepticism and authority in seventeenth-century chemical discourse', in Andrew E. Benjamin, G.N.Cantor and J.R.R. Christie, eds. *The Figural and the Literal – Problems of Language in the History of Science and Philosophy, 1630-1800*. (Manchester: Manchester University Press, 1987), 58-82.

Golinski seems unwilling to enter the debate on the quality and structure of *The Sceptical Chymist*, preferring instead to accept it as an amalgam of more than one work, referring to Boyle's having:

> cast the *Sceptical Chymist* in the form of dialogues (61),

arguing that in so doing he could:

> communicate his ideas in a didactically-effective way, while also dramatising the rituals of proper philosophical debate (61).

He reinforces the dramatic structure of the work by noting that Carneades, the sceptic:

> assumed the mantle of an examining magistrate, announcing his intention to examine "only the experiments of my adversaries, not their speculative reasons" (70).

He quotes Boyle himself, saying that Carneades, his spokesman, assumes:

> the dramatic persona of the sceptic (61).

This, Golinski argues, obviates the need to express his theoretical assumptions, requiring only to express his doubts as to the opinions of his interlocutors, and to posit alternative hypotheses, so long as they are as plausible as the ones under scrutiny, and for Boyle in his dialogues:

> the voice of the sceptic served as a rhetorical tool, to challenge the authority of certain beliefs, by sowing the seeds of doubt (61).

He contends that the introduction of the chemistry textbooks in the decades before Boyle's time established a textual tradition, which was complemented by the use:

> in prefaces and on title-pages, of a rhetorical component of the tradition (62).

In proposing a new written form of chemical discourse Boyle wished to challenge these rhetorical claims of his adversaries, even though he himself employed rhetoric in the furtherance of his own knowledge claims, with Golinski quoting Shapiro as arguing that, despite the attacks on rhetoric, for Boyle and his fellow Royal Society members:

> their project remained implicitly rhetorical (68).

Although Boyle fundamentally believed in the evidence of the senses, and especially in the direct observation of experiments, he still had to argue for these and did so by developing:

> the rhetorical apparatus which would enable him to convey the persuasive power of experiments in written form (68).

Golinski recognises *The Sceptical Chymist* as a text in which the characters, as gentlemen-scholars, set about delivering their opinions in a leisurely, well-mannered and elaborate way. They may disagree as to their doctrines but must at all times maintain the politeness and civility appropriate to their elevated status.

Boyle calls up a succession of witnesses of unimpeachable credit to confirm experimental findings related by Carneades, and laid great store on the insight that:

> He that hath seen [an experiment] hath more reason to believe it, than he that hath not (68),

and that if the account of the witness can be presented in an appropriately painstaking and detailed manner, their testimony can be effective in convincing others.

A strength of Golinski's account is that he sees a deliberate rationale underpinning *The Sceptical Chymist*; he does not interpret the oft discussed characteristics of the book as either defects or weaknesses. Even Boyle's much maligned verbosity is justified on the grounds that:

> prolixity of circumstantial information (69)

is one of a suite of literary devices employed by Boyle to ensure credibility. Furthermore, Golinski avers that he rejected the Baconian method:

> in which philosophical theory was sought through a process of systematic ordering of phenomena (76).

Instead of adopting a succinct means of reporting on discrete pieces of experimental results, Boyle intentionally chose a more loquacious style of expression, the better to provide a fuller, more detailed and more convincing account of his work.

Golinski almost uniquely views Boyle's *The Sceptical Chymist* in positive terms, with each of its literary features explained not as examples of Boylean excess or lack of attention to the crafting of the work, but rather as purposeful features. Boyle's use of language, with its rhetorical flourishes, its long-windedness and its elevated register, are all explained in an analysis which interprets these devices as the working out of Boyle's philosophical, literary and scientific ideas into purposefully wrought dialogues, and not merely as stylistic idiosyncrasies.

He interprets each device employed by Boyle as component parts of an overall dramatic and literary structure, and it is these devices which enable him to present a unitary work answering to the exigencies of presenting his critique of earlier knowledge claims regarding elemental and scientific methodologies, whilst at the same time proposing and defending his own doctrines and reporting his experimental findings, all the while being conscious of, and making full use of, those devices pertinent to his task.

Antonio Clericuzio[20]

Clericuzio begins by saying that *The Sceptical Chymist*:

> had a long and difficult gestation (79),

and goes on to discuss how it emerged from an earlier treatise entitled 'Reflexions on the experiments vulgarly alledged to evince the 4 peripatetique elements, or ye 3 chymicall principles of mixt bodies'. He continues that the work under consideration was given its particular structure in Oxford, though as published, was quite incomplete, adding the possibility that only the first part of the work:

> the 'physiological considerations' was in definitive form (80).

He opines that Boyle had published the unfinished work under pressure from some friends, with the result that:

> the dramatic structure of the dialogue is virtually lost after the first part (80),

as once the discussion has commenced and the arguments of the four participants first stated:

> Themistius and Philoponus no longer intervene, and Carneades does not argue simply as a sceptic, but proposes certain positive arguments concerning the composition of mixed bodies (80).

He adds that:

> The largest part of the work is in fact a monologue by Carneades, interspersed with occasional observations of Eleutherius (80).

Clericuzio explains that the:

> hasty publication of *The Sceptical Chymist* was responsible for the imperfect form of the dialogue (81),

[20] Antonio Clericuzio, 'Carneades and the Chemists: a study of *The Sceptical Chymist* and its impact on seventeenth-century chemistry', in *Robert Boyle Reconsidered*, ed. Michael Hunter, repr. (Cambridge: Cambridge University Press, 2003), 79-90.

and goes on to consider the reasons which prompted Boyle to cast his work in this particular form. The first is that this form was well suited to a project which its author believed was:

> primarily intended to suggest doubts on the Paracelsian view of principles, not to assess new theories (81).

Secondly, he postulates that Boyle chose the dialogue form in an effort:

> to clear chemistry of the often-repeated charge that is was a purely practical discipline (81).

Furthermore, the literary form enjoyed the mark of respectability during its widespread application in the Renaissance, and represented a literary tradition to which Boyle aspired. His decision to create a Ciceronian-style dialogue:

> was part of his attempt to make chemistry palatable to those Oxford professors who were suspicious of those, like John Webster, who championed chemistry in opposition to the traditional University curricula (81).

Boyle's intention was to reform chemistry and make it a respectable discipline both socially and intellectually:

> The tone of the conversation, the emphasis on the style of philosophical discussion among gentlemen, the statement that the book was written by a gentleman and that only gentlemen were introduced as speakers, were part of Boyle's attempt to reform chemistry (81).

This dialogue is offered as a model of how gentlemen could conduct a philosophical disputation in an agreeably civilised manner, far removed from the railings of the chemists, and demonstrates that a gentleman may defend the truth without resorting to impoliteness or discourtesy.

Not only did Boyle reject the chemistry of his day at a purely conceptual level, he also wished to improve its status and make it more accessible to gentlemen-scholars knowledgeable both in philosophy and practical chemistry, in addition:

> The purpose of Carneades' arguments was to make those who had been "bewitched" by the chemists' doctrines aware of their mistakes (81).

One might take issue with Clericuzio when he states, perfectly justifiably, that Boyle's intention in writing *The Sceptical Chymist*:

> as is unambiguously expressed by Carneades at the beginning of the work – was "to question the very way of probation employed by Peripatetics and Chymists, to evince the being and number of the elements" (82),

rather than 'to provide the tools to construct experimental essays in chemistry', which he attributes to Golinski. Looking at the context of the quotation from Golinski, it could be argued that an alternative opinion on Boyle's purpose might be identified as:

> Boyle cast the *Sceptical Chymist* in the form of dialogues, in order to communicate his ideas in a didactically-effective way, while also dramatising the rituals of proper philosophical debate,[21]

and that Boyle's 'ideas' would surely include his opinions on the manner in which the Paracelsian principles might be named and enumerated by their proponents.

Clericuzio argues that Boyle's preoccupation with the means employed by his adversaries to establish the existence and number of the elements runs right through the work, and is pointed up in Carneades' (following van Helmont) doubting the results of the chemists' interpretation of their thermal analysis.

[21] Jan Golinski, 'Robert Boyle: Scepticism and authority in seventeenth-century chemical discourse', 61.

He states that Boyle criticised the received chemical terminology, including that found in *The Sceptical Chymist*, and the casual and haphazard manner in which even eminent writers:

> do so abuse the termes they employ (82).

Clericuzio then observes a difference in the way in which two different categories of practitioners write of their laboratory efforts:

> Boyle found it legitimate that alchemists should "write darkly, and aenigmatically, about the preparation of their *Elexir*, and some few other grand *Arcana*, the divulging of which they may upon grounds plausible enough esteem unfit" (82),

adding that, although Boyle adopted this mode of writing, it:

> was not appropriate in natural philosophy (83).

It is not obvious from Clericuzio's text as to who exactly is making this judgement, but it is clear from the text of *The Sceptical Chymist* that it was Boyle himself.

The author gives an account of the manner in which Boyle considers the corpuscles to aggregate to form larger entities, saying that he identifies two kinds of agglomerations, one of which is so tightly formed as to be inseparable. In the second of these, the corpuscles may be prised apart by the action of external particles, allowing them to recombine into a new aggregate. Clericuzio infers that:

> This undermines the chemical doctrine of principles, which postulated that the *tria prima*, being the ingredients of all mixed bodies, could always be extracted by fire analysis (83).

He goes on to quote a passage illustrating Boyle's opinion on principle, arguing that it indicates that he:

> did not rule out the existence of elementary and homogeneous chemical substances (84).

What he did rule out was:

> the chemists' procedure for establishing their number, and their methods of drawing them from mixed bodies (84).

Clericuzio outlines the influence of *The Sceptical Chymist* on both continental and English workers, and argues that:

> the impact of Boyle's work was not negligible, albeit difficult to recognise. *The Sceptical Chymist* was widely known, often quoted, though very seldom properly understood (84).

He acknowledges that the reception of the work was uneven, though he notes that it had a considerable influence on Lémery (1645-1715) who:

> denied that the five principles remain in their former condition in the mixed body, and stated that they could not be obtained again by fire analysis (84),

and notes that Lémery's notions played a considerable part in the development of chemistry in France towards the end of his lifetime. Boyle's doctrines also had impact in Germany, despite the continuing influence of Aristotelianism there. In England there was a three-fold reception, with the Oxford physiologists not adopting Boyle's opposition to the Paracelsian principles, and the Helmontians employing it selectively in support of their doctrines. He says that:

> Among the Fellows of the Royal Society, Daniel Coxe is the only one who thoroughly understood Boyle's outlook on chemical analysis (86),

adding that Coxe agreed with Boyle in believing that the methods of analysis advocated by the upholders of the three Paracelsian principles:

> failed to yield the actual components of mixed bodies (86).

Clericuzio's study of *The Sceptical Chymist* provides a comprehensive, though succinct, survey of the origins, manner of publication, style and structure of the work. In addition, its core and secondary purposes, impact on chemists and their writings in France, Germany and England, is summarised. He gives a useful précis of the book, and of its impact both in the short- and longer term. His analysis is based on a close reading of the works under review, and of the writings of Boyle which are associated with it. Without applying value judgements to *The Sceptical Chymist* he provides a clear-sighted account of it, and, given its relatively short length, produces a laudably positive and accurate article.

Lawrence M. Principe[22]

Principe says of his study:

> I have purposely limited this chapter to a single point: Against whom or what is the *Sceptical Chymist* written? (30),

and whilst it is not the intention of the present review to engage with Principe in his search for an answer to the question just posed by him, he has expressed some insightful and well observed remarks about the book.

His first remark is that:

> There are few other books that have been so long considered crucial to the development of science yet remain so little read critically and in context (27).

He states that this work has been regarded as marking a crucial break between alchemy and modern chemistry, citing upholders of this view from the eighteenth century and the

[22] Lawrence M. Principe, 'Skeptical of the *Sceptical Chymist*', in *The Aspiring Adept* (Princeton: Princeton University Press, 1998), 27-62.

twentieth. Furthermore, high praise has been accorded to the book by historians of chemistry in the earlier decades of the last century. He adds wryly that:

> Modern readers may, however, find it difficult to attach such laudatory sentiments to it (27),

then adds intriguingly:

> I suspect historians of chemistry have enshrined the *Sceptical Chymist* less owing to its content than to their own anxiety to locate a *Principia* or *De revolutionibus* of chemistry (27).

One may empathise with those same historians of chemistry in their efforts to identify a convincing locus upon which to ground their discipline, and one could well debate whether Boyle is to chemistry what Copernicus or Newton are to cosmology or physics. He continues that:

> Praise for the *Sceptical Chymist* centres on the beliefs that it accurately and for the first time defined an element in the modern sense (27-28).

Principe notes that even though Marie Boas Hall rejected this claim she, nevertheless, in common with some other writers, was more favourable to the notion that the work:

> dealt the deathblow to alchemy (28).

He goes on to remark that:

> The *Sceptical Chymist* is a very difficult text, perhaps the most difficult of all Boyle's works in terms of readability and coherence. It displays an ample measure of Boyle's notorious prolixity and digressive style, and fully indulges his penchant for equivocation (28),

then treats of the inconsistencies to be found within the text, explaining that:

> This patchwork format is probably due to the incorporation of elements from at least two separate works, and a rather hurried plastering over the seams (29).

He goes on to acknowledge that:

> Boyle himself remarks in the preface that the book is "maim'd and imperfect" (29),

and that it is:

> an agglomeration of several dialogues involving the same speakers (29).

Principe believes that the manner in which the work is presented, with the:

> convoluted and repetitious (occasionally contradictory) nature of the book (29),

facilitates the finding of:

> supporting quotations for prevailing historical models by biased selection (29-30),

which is true enough, but then, the same could be said of many other works.

Principe's analysis of *The Sceptical Chymist* clearly results from a close study of the work, and whilst he perceives shortcoming in it he acknowledges that Boyle himself admitted that the book as going to press was less than perfect.

Thomas Duddy[23]

Duddy begins by relating a brief description of the work under review, saying that in *The Sceptical Chymist*, his best known work:

> Boyle sets out to show the superiority of the new experimental methodology over the approaches of the Aristotelians and the alchemists or "chymists" (64).

He elaborates on this, then explains that:

> Boyle's explicit aim in *The Sceptical Chymist* is not to completely discredit either alchemy or "chymistry" but to exhort their practitioners to avoid "Phantastick and Unintelligible Discourses" (64).

[23] Thomas Duddy, '"A Piece of Green-Wood Burning", Boyle against the elements', in Thomas Duddy, *A History of Irish Thought* (London: Routledge, 2002), 64-68.

He draws attention to the fact that this:

> is his *stated* aim, and may have more to do with the requirements of civility than with his heartfelt convictions (64),

by which Duddy seems to mean that Boyle would have preferred to discredit chymistry or alchemy, but chose not to do so due to his innate good manners and unwillingness to offend his well-bred readership. In response one might observe that although Boyle in *The Sceptical Chymist* did have a preoccupation with politeness and courtesy, nevertheless he does say that a gentleman, debating with other gentlemen, 'may confute an Opinion without railing to Them that hold it'.[24]

He then astutely observes that:

> For the most part, *The Sceptical Chymist* reads like a sustained critique of both the doctrine of the elements and the theoretical assumptions that support alchemy and chymistry (64-65).

He notes Boyle's grudging respect for the experimental endeavours of the various practitioners of chemistry, though noting his opposition to both the Aristotelian and Paracelsian elemental systems. He goes on to opine that:

> The main concern of *The Sceptical Chymist* is the composition of material bodies (65).

Duddy quotes Themistius as offering a practical example of the burning of a piece of green-wood as proof of the presence of the four Aristotelian elements in material bodies, and estimates that:

> It is in fact a very good example (65).

[24] *Sceptical Chymist* [A6r]. 26-27.

It may indeed be just that, but it is one of only a few examples that can be adduced as revealing four types of decomposition products, which themselves may be identified as the four Aristotelian elements, in a single body.

He goes on to relate how Carneades:

> Boyle's mouth-piece (65),

replies to the claims of Themistius and of other practitioners of chemistry, expressing his doubts regarding the fundamental assumptions of his adversaries about the nature of thermal decomposition products, and the number of ingredients which constitute compound bodies.

Duddy observes – correctly – that Boyle rejected the claim of both Aristotelians and Paracelsians that only fire is capable of separating a body into its putative elements, whereas some chemicals can separate compound materials into their component parts, and cites as the example the ability of *aqua fortis* or nitric acid to separate a fused mass of gold and silver. Fire is unable to separate these two metals from their mixture.

He understands one of the core issues addressed by Boyle in the work under consideration:

> Even in those cases where fire reduces a compound to a number of substances, there is no guarantee that these residual substances are the original, let alone the elementary, components of the compound. These by-products or residues may be nothing more than new compounds produced by the very action of the fire and may not be any simpler than the original compound (66).

Continued heating may lead to the production of new compounds, and even if the fire does reduce a complex material to its original compounds, it does not follow that the number of elementary substances must necessarily be four as the Aristotelians believe, or three as the Paracelsians hold. He goes on to remark that:

> Boyle again cites examples where the number of separated elements is more than four or less than three (66),

which is true, as Boyle did discuss, for example, the number of different fractions retrieved from the destructive distillation of plant or animal bodies. Boyle himself says of these:

> for ought has yet been made to appear, do consist either of fewer or more similar substances than precisely Five.[25]

Duddy says that Boyle:

> has particularly interesting observations to make about the ability of gold to resist analysis (66).

This is indeed the case, as Boyle would taunt his adversaries to extract their full complement of elements or principles from the thermal analysis of gold. He asks what Aristotelian can show us, not all four, but 'any one of them extracted out of Gold by any degree of Fire whatsoever'.[26]

He goes on to opine that:

> Although he stops short of discovering that gold is in fact an element (66),

then explains:

> possibly because he is unduly suspicious of the concept of *element* (66).

Quite what he means here is unclear, then continues that Boyle:

> writes intriguingly of attempts to reduce gold to its "components" (66),

[25] *Sceptical Chymist*, 288.19-22.
[26] *Sceptical Chymist*, 33.13-15.

by which he may mean that Boyle writes of the ability to prepare compounds of gold, which he does, as when he prepares auric chloride by reacting gold with *aqua regia*:[27]

> and is incredulous of reports that some experimenters have recovered salt from gold (66).

What Duddy may be referring to here is Boyle's account of the production of *Lithargyrium Auri*, or litharge of gold, prepared by heating gold and lead together.[28] This chemical compound is actually lead monoxide, which is yellow or yellow/red in colour, and, as its name implies, was mistaken for a gold derivative. Duddy adds that:

> his own position on the theory of elements is that some things which are assumed to be compounds (such as gold) may not be compounds at all (66).

What he means here is unclear, perhaps he is referring to Boyle's stating that:

> since the Corpuscle of Gold and Mercury, though they be not primary Concretions of the most minute Particles of matter, but confessedly mixt Bodies.[29]

Gold and mercury, though compound materials at the most fundamental level, nevertheless behave as simple bodies in resisting all attempts at further reduction.

Duddy continues that:

> all genuine compounds are composed of varying numbers of elements, sometimes less than three, sometimes more than four (66).

Boyle does speak of the inability to obtain as many as four ingredients from some bodies, but that from others, more than four may be obtained.[30]

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[27] For which see: *Sceptical Chymist*, 39-40.
[28] For which see: *Sceptical Chymist*, 28.
[29] *Sceptical Chymist*, 41.17-21.
[30] *Sceptical Chymist*, 33-34.

He goes on to discuss Boyle's contribution to modern elemental theory, and instead of giving Boyle's most often quoted definition of element, substitutes the following passage from *The Sceptical Chymist*:

> [I]f it be granted rational to suppose … that the Elements consisted at first of certain small and primary Coalitions of the minute Particles of matter into Corpuscles very numerous, and very like each other, it will not be absurd to conceive, that such primary Clusters may be of far more sorts than three or five (67).

Duddy perceptively understands that in this passage Boyle:

> is postulating not only the existence of primary particles but also the bonding of some particles into primary clusters or elements (67).

What Duddy does not do, however, is point out that in the passage just quoted from *The Sceptical Chymist*, Boyle is also positing that there may be many more primary agglomerations than the three or five mentioned in the quotation. He is drawing attention to the possibility of the existence of a large number of elements. Duddy goes on to say:

> Though he is a long way from postulating the complex atomic structure of elements in the modern sense, nevertheless he is groping in the right direction (67).

Of course our contemporary definition of element postulates that one atomic unit equals one elemental unit, or that one atom is actually a unit of a particular element, which realisation did not emerge until the century following Boyle's. Duddy may have in mind that in positing elements as aggregates of corpuscles, Boyle was presaging the understanding that atoms themselves are complex bodies, which understanding did not emerge until the late nineteenth century.

Duddy concedes that, despite Boyle's failure to discover the modern elements, he still deserves his place in the story of modern chemistry, but says, rather confusingly, that:

> Under his influence alchemy and "vulgar chymistry" were transmuted into natural philosophy (67).

Although the various forms and tendencies of chymistry gradually did lead to the development of the science of chemistry, this discipline in earlier times was part of natural philosophy, which in turn developed into what is now called physics.

He opines that:

> Though it is perhaps too much to claim that he was the father of modern chemistry (67),

he quotes Marie Boas-Hall as saying that he was certainly:

> a great and influential preceptor who infused chemistry with an exceedingly fruitful and rewarding attitude and method of attack (67).

Duddy's account of *The Sceptical Chymist* is included in a general survey by him of some of Boyle's works, in the context of a lengthier historical survey of Irish thought. Clearly, he had read the text itself and whatever secondary literature on it was available to him. It would seem that his intention was to offer his readers a synopsis of the work, providing an overview of its structure, and sketching out some of the arguments made and developed in it, as well as conveying a sense of its style and general intention.

What Duddy's summary does not do is give a reliable assessment of Boyle's contribution to scientific knowledge or of his influence on the subsequent development of science, and in fairness, one can hardly expect a précis of a work such as this to deliver any more than it has done.

José R. Maia Neto and Elene C. Pereira Maia[31]

The authors explain in their first footnote that Boyle chose 'Carneades' as the most important character in *The Sceptical Chymist*, and in two other short dialogues viz. 'An Examen of Antiperistatis as it is wont to be taught and proved', and 'Of the Positive or Privative Nature of Cold'. Of course, Carneades also appears in a short fragment 'The Requisites of a Good Hypothesis breefly Consider'd in a Dialogue. Between Carneades, Eleutherius, Themistius, & Zosimus'.[32]

They point up Boyle's use of scepticism, both in its ancient and modern guises, as a means of undermining the doctrines of his adversaries, and as a tool for elaborating his own corpuscular philosophy. They note that:

> Boyle's *Sceptical Chymist* is a critical work (98),

in which the opposing elemental theories of Aristotle, and its newer rival of Paracelsus, are examined. They state that:

> Boyle finds the instruments of his criticism in the intellectual context of his time (98).

Acknowledging the revival of Greek philosophy before and during Boyle's time, they argue that:

> Objections inspired by ancient scepticism and a corpuscular theory inspired by Epicureanism are the two main instruments Boyle uses in his attack on Aristotle and Paracelsus (98).

The systematic application of ancient scepticism enabled him to scrutinise and refute the two doctrines under consideration. The authors explain that:

[31] José R. Maia Neto and Elene C. Pereira Maia, 'Boyle's Carneades', *Ambix* 49, no. 2 (July 2002): 97-111.
[32] See also: *Works of Boyle,* 13: 270-272.

> Although scepticism and Epicureanism were conflicting philosophical schools in antiquity, they were revived and modified in the seventeenth century by Pierre Gassendi in a way such as to make them partially compatible (98).

They opine that Gassendi was one of those referred to by Boyle in *The Sceptical Chymist* as:

> no mean Philosophers (98),

responsible for reviving the ancient atomic theories. They add that:

> Gassendi, together with Bacon and Descartes, is one of the main philosophical influences on Boyle (98).

They correctly point out that:

> Boyle compares his dialogue with Cicero's *De Natura Deorum*, which is the probable model of *The Sceptical Chymist* (101),

and continue that the work just cited, along with his *Academica*:

> are the works in which Cicero details the views of the Academic sceptics (101),

one of the most famous of these being Carneades.

They opine that Cotta in *De Natura Deorum* occupies a similar role to that of Carneades in Boyle's book. They state that:

> Cicero sympathises with his main character (the Academic sceptic Cotta) without committing himself entirely to Academic scepticism (102).

Similarly Boyle says of his character Carneades that he:

> "make[s] not all that he says, especially in the heat of Disputation, mine", implying here as in many other passages his great sympathy for, but not identification with, his character (102).

The authors explain that the means by which Carneades examines the experiments of the alchemists fall into four modes:

> In the first Carneades compiles experiments and observations which introduce sceptical doubts about the instrument (fire) applied by the Paracelsians to extract their three basic elements from material substances (103).

They go on to say that:

> The second mode raises sceptical doubts about whether the supposed elements obtained from compounded substances were present as such in these substances (104).

They offer brief sketches of the two remaining modes:

> In the third Carneades doubts if the elements would be precisely three (104).
>
> Finally, in the fourth he doubts the simplicity of the products obtained by the action of the solvent (105).

They cite as an example of the first mode Boyle's experiment on the heating of sulphur:

> When sulphur is heated in a receptacle, it produces "flowers" (a volatile substance that rises dry and insipid) (103),

which is true, as when sulphur is caused to boil, the vapour condenses to form the yellow, crystalline flowers of sulphur. They go on to say, confusedly, that when it is:

> exposed directly to fire it becomes a liquid that is salty and bitter (103).

This is a reference to the formation of sulphuric acid by burning sulphur in air to form sulphur dioxide, which if captured under a bell-jar, and oxidised, forms sulphuric acid when it dissolves in water.

The authors cite these two experiments as examples of Pyrrhonian equipollence, by which Carneades argues that one cannot favour one experimental outcome over another. They then ask:

> In which of these circumstances does one get the simple elements? Or, to put it another way, which of the two products is the element? (103).

It could be argued that Boyle was attempting in these examples not to show which of the two reaction products was elemental, but rather to establish that it was not possible to regard fire as separating bodies into their elemental constituents. As he himself says in relation to the processes just discussed: ‘it will be hard to make it appear, how the Fire, as Chymists are wont to imploy it, can resolve them into Elementary Substances’ (63.22-25).

The authors offer another example from Boyle’s text:

> *Guajacum* (for Instance) burnt with an open Fire in a Chimney, is sequestred into Ashes and Soot, whereas the same Wood distill’d in a retort … is resolv’d into Oyl, Spirit, Vinager, Water and Charcoal (104).

The authors make an ambiguous statement when they assert that:

> Many of the experiments related by Carneades seem unconvincing, in particular to the modern reader (105),

though without actual examples it is difficult to assess what they mean by the word ‘unconvincing’. They go on to make the credible assertion that:

> the ancient sceptics did not claim that their arguments were cogent. They just needed to be efficacious, that is, as persuasive as those of their opponents (105).

The authors relate that another:

> typical sceptical strategy used by Carneades is “to have the Assistance of one of my disagreeing adversaries against the other” (105),

and offer a rather unconvincing example involving van Helmont’s *alkahest* or universal solvent, and the three Paracelsian principles.

From the context of Boyle’s statement it could be argued that the adversaries he was referring to were the disagreeing dialogists. Boyle offers an apposite example when he has Themistius critique both Philoponus and the Paracelsian doctrine he espouses (23.27 – 25.9).

The authors identify two further features of the dialogist Carneades which locate him in both the ancient and modern sceptical traditions. Firstly they draw attention to:

> his modesty and politeness: "*Carneades* hopes that he will be thought to have disputed civilly and Modestly enough for one that was to play the Antagonist and the Sceptick" (106).

They explain that this stance:

> distinguishes the sceptic from the dogmatist, who pretends to know the truth and who exhibits anger at those who contest his or her beliefs (106).

The authors add perceptively that what Carneades finds most objectionable is the Paracelsian conviction of the veracity of their doctrine, then quote Carneades as saying that if Paracelsus' followers:

> "had been so modest, or so Discreet, as to propose their Opinion / of the *Tria Prima*, but as a Notion useful among Others, to increase Human knowledge, they had deserv'd more of our thanks; and less of our Opposition" (107).

They go on to offer the opinion that Boyle's corpuscular philosophy is consistent with his scepticism. They state that Carneades suggests the greater explanatory power over that of its rivals, and quote as an example Boyle's hypothesis on the perception of colour, which, unlike its rival theories of the alchemists and Aristotelians:

> the corpuscular theory could explain the efficient mechanism of visual perception (108).

The authors pose, then answer, a pertinent question regarding the foregoing:

> Is Boyle's chemist still a sceptic when he favours the corpuscular theory? We think he is (108),

and go on to opine that:

> Like Gassendi, and even more than Gassendi, Boyle's Carneades assumes the theory as a hypothesis, without claiming that it is true (108-109).

They quote Carneades as saying of his corpuscular theory that:

> he is willing to "lay aside for a while the Person of an Adversary to the Peripateticks and Chymists; and … acknowledge to you what may be (*whether truly or not*) tollerably enough added, in favour of a certain number of Principles of mixt Bodies" (109),

and cite this as evidence that he is prepared only to suspend his opposition to his adversaries, but not his role as sceptic, thereby adopting a constructive position. This they assert demonstrates that, even though Carneades retains his corpuscular theory as a fundamental postulate, he neither claims ownership of it nor fully assents to it. They offer further evidence of this by stating:

> That Carneades does not give a complete assent to the corpuscular theory is also evident in the appendix when he presents his "conjectures" about the elements (109),

by quoting examples drawn from Carneades' statement which indicate that he was not fully accepting of Epicurus' atomic philosophy, contrary to what many considered to be the case. In so doing Carneades:

> denounces the dogmatic attitude of those who think a natural philosopher must be committed to some doctrine (109).

They further explain that:

> Assenting to doctrines compromises the sceptic's autonomy and intellectual integrity (109).

The authors opine that the reason why Boyle calls his theory on matter 'corpuscular' and not 'atomic' is because, in agreement with Gassendi, he rejects those Epicurean postulates which are contrary to Christian doctrine. The authors state that:

> Carneades (and Boyle in his other works) calls the corpuscular theory a hypothesis (109),

and give some examples drawn from *The Sceptical Chymist*. They go on to argue that:

> the main indication that Carneades exhibits a favourable, albeit sceptic, attitude with respect to the corpuscular theory lies in his concluding remark in the book (110),

consisting of two statements by Carneades. They cite Eleutherius' efforts to persuade Carneades to adopt a middle position between:

> his objections and the alchemical principles (110).

Of these two statements, they argue of the first:

> that once sufficient reasons be provided he will promptly assent, was always implicit in the ancient sceptics' engagement with the dogmatists (110).

In the second statement Carneades says that:

> "I can yet so little discover what to acquiesce in, that perchance the Enquiries of others have scarce been more unsatisfactory to me, than my own have been to myself." (110).

This position, where detachment is expressed even in relation to one's own belief system:

> be it in relation to arguments, doubts or perhaps even to some preferable theory, is a characteristic feature of the ancient sceptics, of Carneades in particular (110).

The authors argue that the reason why Boyle chose Carneades, and not another sceptic is due, in part only, to his fame. The most important feature of Carneades' position is, that of all the important sceptics, he is:

> the one who presents a positive doctrine, the doctrine of probabilism (110),

which, they explain, states that:

> although no appearance may be said to be true, some are more persuasive or plausible than others and those more "probable" may be followed by the sceptic in his practical life, without compromising his suspension of judgement (110).

The authors quote Cicero as stating that:

> Carneades makes a distinction between assenting and approving. Approving a phenomenon does not imply assenting to its being true but just acting upon it (as if it were true) (110).

They argue that just as the original Carneades adopted probability as a rule in conducting his life:

> Boyle's corpuscular hypothesis provides a guide for his scientific endeavours (110).

Taking the comparison with the ancient sceptics to its limit they argue that the last remark made by Carneades in *The Sceptical Chymist*, and quoted above:

> might also indicate that his use of the corpuscular theory is merely dialectical, a mere device to refute the rival theories in the same way that he cites experiments and theories of alchemists against the Peripatetics, and opposes conflicting positions held by different alchemists (110-111),

which position would hold good only for *The Sceptical Chymist*.

The authors opine that a position between these two opinions could provide:

> the interpretative key to *The Sceptical Chymist* (111),

and adroitly reconcile the respective preoccupations of Boyle and Carneades, as they observe that:

> Robert Boyle, the experimental chemist (111),

whom Carneades frequently mentions by name in the work:

> holds the corpuscular hypothesis, which seems to him the most adequate to explain natural phenomena (111).

They state that Carneades is presented as his *alter-ego*:

> who takes a sceptical stance with respect even to his favoured theory, the dialogical form of the book being wholly appropriate to express this double position (111).

The authors offer a careful analysis and thoughtful reading of *The Sceptical Chymist* from the perspective of its main protagonist: Carneades. The sceptical context of the book is well captured through a considered account of this philosopher's version of scepticism, as revealed in earlier works, then skilfully exploited by his namesake in Boyle's work.

Conclusion

There is little doubt but that the work under consideration has generated mixed opinions from those who have reviewed it, with most writers adopting a rather negative attitude towards it.

In writing about the development of modern science, historians of science are faced with the problem of determining when exactly a particular discipline could be identified as breaking away from the earlier belief system which it, at some point in its development, must have supplanted, as chemistry came to supplant alchemy.

If, for example, one argues that the science of classical mechanics was initiated by Galileo and perfected by Newton, one can maintain that neither man dealt the death-blow to Aristotelian mechanics, as this latter system continued to be argued for, in some places, at least well into the eighteenth century. But Aristotelian mechanics did eventually wither away, to be replaced by the system developed by the workers just mentioned, among others. And whereas Copernicus and Newton had to contend with a rival system dating from antiquity, which even in Copernicus's time, was beginning to be discredited, Boyle lived at a time when alchemy still held sway, and he himself seems to have been greatly influenced by this discipline.

It is hardly surprising that *The Sceptical Chymist* should be identified by historians of science as a crucial work in the transition from alchemy to chemistry, as Boyle does identify himself as a chemist when he states that:

> I who am but a young Man, and younger Chymist (428.27-28).

It could well be argued that in this work Boyle does establish chemistry on a new footing, and that this does seem to be the consensus of the majority of the writers on the subject.

PRELUDE TO COMMENTARY

Prelude to Commentary

The Case for *The Sceptical Chymist*

The importance of *The Sceptical Chymist* may be considered from twin perspectives: that of its impact at its time of writing, and that of its importance in more recent times. Boyle explains in his *Praeface Introductory* that he allowed this work to be published, despite its imperfections, at the prompting of an unidentified gentleman. He does not hesitate to justify his writing of the book, as one skilled in chemical matters, and explains that educated men have begun to study chemistry even though they had earlier disparaged it. He confidently assures those who read it that they will be offered nothing but truthful accounts of reliable chemical experiments. Clearly Boyle perceived the need to provide details of his experimental program, with the reader not having to doubt either the competence with which it was carried out, or the veracity of its findings.

A read through the Literature Review reveals a range of opinions on *The Sceptical Chymist*, not one of which views it as an easy read, whilst acknowledging it as a significant work, as when Hall (*q.v.*) accepts that even if it didn't overturn the pre-existing teaching on the elements, it did at least weaken their standing. The Literature Review reveals differing estimations of the claim that *The Sceptical Chymist* is the first text-book of chemistry, yet it is acknowledged as one of the earliest in this *genre*, and certainly the most persistent of them. More (*q.v.*) referred to this work as one of the great classics of science, whilst Pattison Muir (*q.v.*) calls it 'a real, living book for intelligent men and women today'.

The fact that this book is a transitional work, in reading it one comes into contact with the older beliefs, philosophical concerns, and personalities that came before, on the one hand,

and with the newer ideas, personages and new learning then gaining an unstoppable momentum, on the other.

Boyle's enthusiastic pursuit of the study of chemistry, and of its promotion among the learned, his carefully detailed chemical experiments, all explained in the context of an exposition of his Corpuscular Philosophy, is contrasted strongly, even mockingly with the feebleness of the Paracelsians' *tria prima* and of its inability to provide a clear, rational explanation of the composition and behaviour of the materials constituting the natural world. He complains that they cannot even agree on the composition of the individual *tria prima* – whether they are truly elemental or consist of the Aristotelian elements – nor agree on which of the *tria prima* explains colour, for example. He contrasts this with his own system with its principles of matter and motion, and of his ability to trace these back to the primal matter of creation.

Yet this work displays the influence of older considerations, characterised by Boyle's preoccupation with water's role as a primal element and its transmutation into other substances, and of how earth too might subsist as a primal element, which could transmute into specific metals and minerals. His definition of element, even if not the first 'modern' one of its kind, nevertheless offered a workable, rational definition of the term and facilitated future experimenters to develop practical criteria for arriving at a set of elements through empirical means.

Boyle's promoting of an atomistic account of matter, and his interpreting material change as being effected through corpuscular rearrangement, combined with his offering of texture or structure as alternatives to the Aristotelian concept of form, allowed the notion of form as accident to be retained, whilst insisting that matter exists as corpuscles. The continued fame of *The Sceptical Chymist* marks it off as occupying a special place as few scientific/philosophical works of its vintage continue to be sought out and read. In it Boyle well illustrates how a work proposing both a corpuscular understanding of matter, and a devotion to chemical experiment, coupled with an empiricist interpretation of the means of investigating the natural world, would point the way towards a fuller development of British Empiricism, later atomic theories, and the emergence of chemistry as a science.

Boyle, Paracelsians and Aristotelians

What Boyle does not like about the Paracelsians

A recurring theme in *The Sceptical Chymist* is Carneades' criticism of the Paracelsians' use of language. He mentions the 'intolerable Ambiguity they allow themselves in their Writings and Expressions' (200.1-3). They are apt to apply just one name to many things, or the opposite: give several names to one thing. Worse still, with 'Technical Words or Termes of Art' (200.29) they are liable to call a given substance by turns the sulphur and the mercury of a body. He further accuses them of offering such intricate descriptions of mercury as to render them unintelligible even to those who set about writing intelligently about them (201.5-16).

Equivocal language and difficult terms are applied to their principles in such a way as to add to the mystique of their art, or to withhold from the readers some knowledge which the writers consider to be of immense value. Yet the reason why the Paracelsians write so obscurely is not because they wish to guard highly esteemed knowledge, but because if it were elucidated, readers would see that their doctrines were vacuous (201-202).

Another reason for Boyle to discredit the Paracelsians consists in their inability to decide just what in the created world can be explained by their doctrine, on the one hand, and their inability to account for several mundane phenomena, on the other. He explains that Paracelsus taught that not only terrestrial bodies, but all the celestial ones as well, are constituted of salt, sulphur and mercury. By contrast, the 'Learned *Sennertus*' (234.17-18), and the more cautious Paracelsians, reject this notion, yet many others of them believe that the *tria prima* themselves are composed of the four Aristotelian elements, whilst still others hold that earth and water combine with the three Paracelsian principles to form compound bodies.

In *The Fifth Part* of *The Sceptical Chymist* Boyle, to quote Boas (*q.v.*) 'explains why he thinks the doctrine of chemical elements an inadequate basis for a general chemical theory', and poses several rigorous objections against the Paracelsian *tria prima*. A selection of these is given hereunder.

He asks searchingly what this doctrine teaches about the nature of the sun and stars, or of the ethereal substance which seems to comprise interstellar space (300), or what it reveals of the reason why a magnet aligns itself as it does (301). He queries how much of the *tria prima* is required to produce a chick or a pumpkin, and even if this can be explained, he asks what is the principle that organises these ingredients into the various part of the chick's body (302). The agent which guides and directs the production of these natural things – an '*Architectonick* Spirit' (302.26) – must also be accounted for by the Paracelsians. Carneades argues that the agent which itself directs the *tria prima* cannot be produced of these same principles. He challenges the proponents of the *tria prima* to specify how these principles convincingly account for the phenomena of fluidity and firmness, colours and shapes of stones, minerals and other compound materials. Equally he asks how they account for animal or plant nutrition, and the higher density of gold or of mercury by comparison with wine or alcohol. He answers that any such attempt to account for these phenomena will 'be much more likely to discredit' (303.22-23) the Paracelsians and their hypothesis 'then satisfy an Intelligent Inquirer after Truth' (303.23-25).

Carneades accuses the Paracelsians of not agreeing as to which of the *tria prima* is responsible for the production of colours, arguing that the common chemists attribute them to mercury, Paracelsus himself, to salt, and Sennert to sulphur. He adds confidently that '*Mr. Boyle*' (328.15) has carried out some experiments which demonstrate that colour is a surface phenomenon of bodies. Furthermore, Carneades considers the refraction of sunlight and its separation into its constituent colours on passing through a glass prism, and wonders to what increment or decrement in the amounts of the individual *tria prima* can the triangular shape of the prism be attributed. He goes on to assert that the colour fringes generated by the heating of hardened iron are in no way caused by either the addition or subtraction of any one of the Paracelsian principles (330).

He quotes the example of amber, on a block of which static charges may build up, but not on any of its decomposition products, and explains that it is the particular structure of bulk amber which accounts for its capacity to accumulate static electrical charges on its surface. Then, wishing to vindicate his own understanding of the structure and disposition of parts as being responsible for many physical properties, avers that in the case of a clock, the movement of its hands and its ability to strike are not specific to any particular set of materials, but that other suitable materials would serve as well, with silver, lead or wood being suitable for use in its wheels, and stone or clay in its weights, whilst acknowledging that brass and steel do make better clock-wheels than lead or wood.

Those behind the Etiquettes 'Paracelsians' and 'Aristotelians'

The appearance of *The Sceptical Chymist* in the form of two separate dialogues has been noted and discussed in the literature (see, for example Literature Review: Clericuzio and Principe), and in which the Paracelsian and Aristotelian dialogists have departed the scene by the end of the first dialogue. It could be argued that the reason why Boyle chose to exclude Philoponus and Themistius from the second and much longer dialogue is that he was simply unwilling to give the adherents of the two rival doctrines to his own any continued opportunity to further express and debate their beliefs. It may well be that he understood that these rival systems had already received enough exposure through the writings of their proponents and that he felt no need to accord them even more publicity. Neither does he seem willing to identify specific upholders of these dogmas by name, outside of those referred to in relation to particular points or comments he wishes to make in the dialogue, preferably of Paracelsians or Aristotelians either discrediting their own or each other's doctrine.

For example, he refers to Quercetanus, or Joseph du Chesne (1521/44-1609) as 'the grand stickler for the *Tria Prima*' (179.2-3) only to add that this Paracelsian expresses his belief in the inability of diamond to be separated into the *tria prima*. Boyle is pleased to report disagreement among the Paracelsians, as when Carneades complains that Sennert (1572-1637) attributes colours to sulphur, the common chemists to mercury, and '*Paracelsus* in divers places attributes them to Salt' (328.6-7). Similarly, in relation to the Aristotelians, Carneades is quick to point up the differences between them and the Paracelsians, as when 'that fierce Champion of the *Aristotelians* against the Chymists, *Anthonius Guntherus Billichius*' (315.19-21) asserts that the *tria prima* are themselves composed of the four Aristotelian elements.

When Carneades discusses at length the question of mixing he refers to the Aristotelian doctrine on the subject and contrasts it with those of other ancient philosophers. He makes no mention of any contemporary or near-contemporary philosophers, with the exception of the respected Sennert. Instead, he speaks of 'divers Modern Naturalists and Physitians' (137.4-5), 'Spagyrists' (137.6), the 'Schools' (137.8) and the 'Interpreters' (137.22) of Aristotle. He makes no effort to name any of these philosophers, despite the detail he goes into on the subject of mixing. Boyle obviously knew whom he was referring to among those modern naturalist and physitians, but makes no effort to identify them, perhaps believing that it was the Aristotelian doctrine itself, rather than those who promoted it, that required his consideration.

There is no mention in *The Sceptical Chymist* of the most famous English Paracelsian of the seventeenth century, Robert Fludd (1574-1637) whose works Boyle must have read, but his reason for not engaging with his writings may be that Boyle did not regard himself as a polemicist and only reacted to those who directly refuted his experimental findings, as when Hobbes and Linus (*qq.v.*) challenged the reality of the vacuum produced in Boyle's air pump.

When Boyle wished to criticise the doctrines of the Paracelsians or Aristotelians his approach was generally to disparage the teachings themselves, without naming those who held them. A good example is provided early on in the dialogue, when in the *Physiological Considerations*, Carneades declares that his present purpose is not to ascertain the truth either of the Paracelsian or Peripatetic doctrine in relation to the number of the elements 'but only to shew you that neither of these Doctrines hath been satisfactorily proved by the arguments commonly alledged on its behalfe' (12.6-9). Carneades makes no mention as to who is promoting these doctrines, as though only the arguments themselves counted.

Soon afterwards Carneades is even more explicit as to the groups of writers to which he is opposed, when he speaks of the 'assertors' (16.21) of the four-element or three-principle systems, without examining 'either *Aristotle* or *Paracelsus*, or this or that Interpreter, or follower' (16.25-27). The words 'assertors', 'Interpreters' and 'follower' are offered as indicated that the adherents of the two doctrines in question are categorised by role though not named as individuals. It is the elemental doctrines rather than those who profess them that count, indicating that these men have no great importance for Boyle as individual philosophers.

Carneades is willing to invite Themistius to name an Aristotelian who can demonstrate just one of their elements 'extracted out of Gold by any degree of Fire whatsoever' (33.13-15), knowing full well that he can issue this invitation without fear of a positive reply from his interlocutor. Yet when Boyle wishes to emphasise some consideration as important, as when towards the end of *The First Part* he wishes to demonstrate that not only fire, but cold as well, is capable of causing compound bodies to separate into distinct components, he takes great care to specify who the witnesses were, where they give the account in question, supply detailed information on the circumstances surrounding the relation, and give relevant quotations from the narrative.

For example, when Carneades wishes to discuss the freezing of wine and beer as described by some sailors who travelled from Amsterdam to Novaya Zemlya, he takes pains to name these as '*Gerard de Veer, John Cornelyson* and Others' (99.11-12), and to note that they left port in 1596, before proceeding to give a detailed account of how their wine and beer froze once they reached their destination. In this instance he adopts a positive attitude towards the claims made by the navigators, and adds to them his own experiences, and those of a friend in Holland, on the freezing of similar liquors. Another example is that provided by van Helmont, whom Boyle greatly admired, thought not uncritical of his doctrines. He states that van Helmont 'in several places affirms, That a Coal kept in a Glass exactly clos'd will never be calcin'd to Ashes, though kept never so long in a strong Fire' (62.17-21). Carneades goes on to bear out this claim by relating a similar observation of his own on the distillation of wood. In similar fashion he relates in detail van Helmont's famous tree growing experiment (113-114), and offers his own accounts on the growing of various plants in his house and garden.

Carneades does relate a claim made by Paracelsus, in book six of his *Archidoxis*, on the freezing of wine, of which a detailed account is provided. Yet he immediately registers a disclaimer, saying that he dare not 'lay much Weight upon this Process' (96.15-16), as he has not been in a position to verify this experiment, despite the coldness of 'this present Winter' (96.19-20). In addition, Carneades willingly relates an account of the Paracelsian Angelus Sala (1576?–1637) in which he avers that he has never seen the mercury of gold, then goes on to quote him as saying '*that he had often seen Detected many tricks and Impostures of Cheating* Alchymists' (181.5-7). Here Carneades is accepting the veracity of a claim made against the Paracelsians by a witness strongly influenced by Paracelsian doctrines. A good summation of how Boyle regards the Paracelsians and Aristotelians comes close to the end of

The Sceptical Chymist when Carneades observes that his objections are not directed at the Aristotelian or Paracelsian doctrines themselves but rather 'against the unaccurateness and the unconcludingness of the *Analytical* Experiments vulgarly Relyed On to Demonstrate them' (436.2-6).

Boyle's Philosophy of Matter

Boyle's account of matter is given its most comprehensive treatment in *The First Part*, where he offers four propositions on the subject, in which the '*Universal Matter*' (37.3) of creation was corpuscularised, had motion superadded to it by its Divine Creator, and could aggregate into larger assemblages of these primary corpuscles. He hypothesises that the various materials of which different bodies are composed, '*may without very much Inconvenience be call'd the Elements or Principles of them*' (46.3-5).

Boyle offers a succinct understanding of the production of the materials which he, and other chemical experimenters, manipulate in the laboratory by positing that if the corpuscles comprising each element be accorded 'a peculiar size and shape' (42.14) when mixed in various proportions and connected in a wide variety of ways, this may allow a huge number of differing material entities to be produced. Throughout the text Carneades refers to the twin principles of matter and motion, sometimes including the notion of rest in addition to motion.

Early in the text he offers a sharp contrast between his own understanding of the principles which underlie the natural world and those of the Paracelsians, berating them for not 'taking much more Notice than they are wont to do, of the Motions and Figures, of the small Parts of Matter, and the other more Catholick and Fruitful affections of Bodies' (A2*v*.6-9). Matter, differentiated both by morphology and movement, in addition to other unspecified qualities, informs the production of natural bodies and their physical properties.

Somewhat later Carneades gives a more specific account as to how different materials may be differentiated from one another by 'the Various Textures Resulting from the Bigness, Shape, Motion, and contrivance of their smal parts' (106.9-12). Now he is explaining that bodies are distinguished by corpuscular variation and motion, and the structure and texture of their agglomerations.

Boyle states that he can deduce a wider range of qualities from matter, motion and rest including: ‘Colours, Odors, Tasts, Fluidness and Solidity, and those other qualities that Diversifie and Denominate Bodies’ (376.27-29), whilst admitting that he can only do so ‘in general (for I pretend not to be able to do it otherwise)’ (376.24-26). In this way he argues that he can extend the explanatory power of his principles to encompass both primary and secondary qualities.

Transmutation

Boyle’s preoccupation with transmutation as an explanation for material change is well covered in *The Sixth Part* and he quotes examples from two sources: the growth of metals and minerals, explained by the transmutation of earth or water, as detailed by a wide variety of authors, and the growth of living things. The growth of a vine-slip provided him with the source of a range of differing materials resulting from the natural transformation of water, as well as some products synthesised in the laboratory. In this way Boyle could posit a step-by-step account which convincingly explained both transmutation and chemical change.

He begins with the *Aqua Vitis* or vine water which drips out of a cut vine, explaining that it is little different from water, yet goes on to be converted ‘into the Wood, Bark, Pith, Leaves, &c. of the Vine’ (413.11-13). The sap of the vine is converted into sour grapes, which if pressed yield an acidic juice or ‘Verjuice’ (413.17). If left intact on the vine the sour grapes ripen into mature grapes. These when sun-dried and then distilled, give an offensive smelling oil and a pungent burnt liquor. Alternatively, dried grapes when boiled in an appropriate amount of water produce a ‘sweet Liquor’ (413.28), which if distilled in good time, yields an ‘Oyle and Spirit’ (413.29), rather like those of the raisins or dried grapes.

If the grapes are pressed and the must fermented, an inflammable, spirit, miscible with water – alcohol – is produced, if the wine is distilled. The noblest wines may produce a crystalline substance, and a sweet liquor. Wine may also deposit tartar which will yield five different materials on heating. Wine, when left in the open, turns into vinegar, or a solution of acetic acid, which may be concentrated through distillation, and if this is added to ‘Salt of Tartar’ (415.7) or potassium carbonate, the solution boils up violently. Sometimes vinegar eels develop in vinegar. In addition, if the grape husks are reacted with copper, ‘Verdigrease’ (420.23) or basic copper acetate, which is greenish in colour, is produced. All of these changes are brought about ‘partly by the formative power of the plant, and partly by supervenient Agents or Causes, without the visible concurrence of any extraneous Ingredient’ (415.23-27). Boyle makes the rational argument that each one of the stages of development just described, from the *Aqua Vitis* of the growing vine to the vinegar eels found swimming in vinegar, can be accounted for by the transmutation of water abstracted from the soil by the growing vine, acted upon by the appropriate agents of formation.

A subject of ongoing fascination to Boyle was that, in the case of certain materials, corpuscular rearrangement could result in the formation of products radically different in properties from the reactants from which they were derived. A favourite example is provided by the reaction of concentrated vinegar with ‘Calcin’d Lead’ (421.25), lead oxide or litharge, to form the very sweet-tasting lead acetate. When this chemical compound is distilled at high temperature it decomposes to give the strong, yet somewhat pleasant smelling, acetone, along with an oily red residue – fixed oil of lead.

PRELUDE TO COMMENTARY

The Extent and Limits of Boyle's Corpuscular Philosophy[1]

Boyle displays a well-defined hypothesis on the origin, nature and agglomerations of the corpuscles. His explanation of their origins as the subdivided prime matter of creation means that he places them securely as the building blocks from which the material entities of the physical world are constructed. Corporeal change is routinely explained in terms of corpuscular motion and rearrangement into new structures and textures. The corpuscles may associate, dissociate, change configuration, come to rest or otherwise vary their motion, and move closer together or further apart. So much for material entities, but how does the Corpuscular Philosophy account for phenomena which are not obviously physical in nature?

Boyle well understands that every explanatory system – including his own – must account for the mundane operations of natural processes. He realises that not only the Paracelsian and Aristotelian, but other doctrines as well, and which claim to account for a host of natural phenomena but employ only a small number of primary material ingredients, are unlikely to possess sufficient explanatory capacity to satisfy 'an intelligent Inquirer after Truth' (303.24-25). Boyle recognises that not just material principles, but immaterial ones as well, are required if natural phenomena are to be comprehensively explained. He refers to 'the Architect of all this Elaborate structure' (302.22-23), 'this *Architectonick* Spirit' (302.26), which he views as informing the appropriate 'Seminal Principles' (301.25-26) acting on matter to constitute the bodies of plant and animal nature. He also acknowledges that the Architectonic Principle does have wider applications than the growth of specific plants and

[1] The notion of matter as subsisting as corpuscles, *prima naturalia* and *minima*, going back to medieval times is given detailed expression in: Christoph Lüthy, John E. Murdoch and William R. Newman, eds. *Late Medieval and Early Modern Corpuscular Matter Theories* (Leiden : Brill, 2001).
See also: Conleth Loonan. "Some Aspects of Robert Boyle's Corpuscular Hypothesis". *Maynooth Philosophical Papers* 7, (2013):.46-58.
A description of Newton's atomism and some comparisons between it and Boyle's corpuscular theory are given in: Alan Chalmers. *The Scientist's Atom and the Philosopher's Stone* (Dordrecht: Springer, 2011), Chap. 7.

animals. Its initial purpose, soon after creation, was ‘to turn that confus’d *Chaos* into this Orderly and beautifull World’ (375.27-28).

In considering the growth of metals and minerals, Boyle explains the production of iron by positing that it comes about through the transmutation of earth into the metal. The mechanism he proposes is ‘that earth, by a Metalline plastick principle latent in it, may be in processe of time chang’d into a metal’ (158 [358].27-29). In a more general sense he hypothesises that the earth from which metals are produced contains ‘some seminal Rudiment’ (364.7-8), or equivalent, the ‘plastick power’ (364.9-10) of which acts on the earth to form a metallic ore. Here, corporeal seeds of some kind are acted upon by an immaterial transformative power, which over time causes them to form a metallic product. In this case, Boyle’s thinking is reminiscent of the doctrine of ‘Plastick Natures’ of the Cambridge Platonist Ralph Cudworth (1617-88) (*q.v.*). Similarly, the mineral saltpetre, nitre, or potassium nitrate is produced by ‘the Seminal Principle of Nitre latent in the Earth’ (365.2-3) acting on the nearby earth, rich in organic matter, gradually converting it into saltpetre. In this example, there is no mention of any immaterial principle at work, merely a seminal principle acting on receptive earth to convert it into the mineral.

Corpuscles and *Effluviums*

Three phenomena not strictly material in nature and brought within the scope of Boyle’s explanatory system are: fire, static electricity and magnetism. Fire received much attention from him, in part due to its centrality in the manipulation of material bodies in the laboratory, but also due to Boyle’s strenuous assertion that fire is not a neutral or inert agent serving to decompose compound bodies neatly into their primary constituents. He offers some interesting insights into his thinking on fire, although attributing their origin to the ancient atomists. On this view 'the little nimble Atoms of Fire' (90.13) are sufficiently tiny and fast moving to be 'able to permeate the sollidest and Compactest Bodies, and even Glass it Self' (211.26-28).

Taking this notion of fire as his starting point, he constructs a fascinating model of the interaction of fire with some familiar materials. He posits that fire may be bonded to harder, more dense matter, citing as examples flints and some other compound bodies, where 'the Fiery part is Incorporated with the Grosser' (212.1-2). What he seems to mean is that, because flint produces sparks when struck a hard, glancing blow, fire must be a constituent of it, which harks back to the Aristotelian belief of fire as an elemental ingredient of natural bodies, but also is consonant with Boyle's understanding of fire as subsisting in corpuscular form as a component part of certain materials. Given the validity of the example just quoted, Boyle argues that large quantities of 'Fiery Corpuscles' (212.3-4) pass through the pores of glass and combine with whatever compound body they encounter to form new compounds, in accordance with the physical attributes of that body. He notes the possibility that 'the Corpuscles of the Fire' (212.15), though all of them are still minute and fast moving 'are not all of the same bigness, nor Figure' (212.17-18), that is to say, they share in the general corpuscular distinctions of size and shape, and just as non-fiery corpuscles can combine with others to form new compound bodies, so too fiery corpuscles from 'an open Fire' (212.24) can combine with non-fiery ones 'and add to the Quantity' (212.26). Fiery corpuscles may add to the bulk and weight of the material undergoing thermal processing, by which he seems to mean that some metals, on heating in air, react with oxygen to form a calx or oxide, which adds to the weight of the original metal.

Despite what he said earlier on the interaction of fire and glass, Boyle is not sure that when fire acts upon 'Bodies included in Glasses' (212.28-29) it does so by a mechanism of true

'Trajection of the Fiery Corpuscles themselves' (212.29 – 213.1-2) through the glass. This is possibly a reference to earlier experiments in which he attempted to incinerate some organic samples through glassware associated with his air-pump, by focusing the rays of the sun on the samples by means of a magnifying glass.[2] Boyle also postulates that when fire acts directly on a material, 'some of its Corpuscles may stick to those of the burnt Body, as they seem to do in Quicklime, but in greater numbers, and more permanently' (213.9-12). Quicklime or calcium oxide, produced by burning limestone, reacts violently with water to form calcium hydroxide or lime, leading Boyle to believe that the heat released in this chemical reaction is due to the presence of fire as an ingredient of the quicklime.

Boyle's explanation for the phenomenon of magnetism is that it is corpuscular in nature. For him, magnetic fields are due to the emission of small-sized corpuscles from the magnetic material. He notes that 'the *Epicureans*, *Cartesians*, and almost all other Corpuscularian Philosophers agree in , that Magnetism is performed by corporeal Emissions'.[3] He goes on to opine that these particular corpuscles are so fine as to pass through 'the pores of all solid Bodies, and even Glass it selfe, which neither the subtilest Odours nor Electrical Exhalations are observ'd to do'.[4]As a magnetic field permanently surrounds the body giving rise to it, he obviously views the emanation of corpuscles from the 'Loadstone' (187.8), a magnetic iron oxide, as a perpetual stream of 'little Corpuscles' (187.7-8). He remains silent as to the mechanism by which the flow of emitted corpuscles is either initiated or maintained, nor does he mention any experiment made to test whether a magnetic material loses weight over time as the magnetic corpuscles are continuously expelled from its bulk. He does, however, note

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[2] These experiments are reported in his *New Experiments Physico-Mechanical, Touching the Spring of the Air and its Effects*. See: Hunter and Davis, eds. *The Works of Robert Boyle*, 1:191.
[3] In: *Of the Strange Subtility of Effluviums*. See: *Works*, 7:266.
[4] Ibid., 266.

that these magnetic corpuscles are so miniscule as not to be 'Immediate Objects of any one of our senses' (187.5-6).

Boyle has quite a different explanation for the nature of static electricity. This phenomenon, he maintains, is caused by '*Effluviums*' (187.10), and again as is the case with the magnetic corpuscles, these *Effluviums* 'seem to fall under the Cognizance of our Sight' (187.14-15). Yet his notion of these entities does place them as a fundamental subdivision of matter when he states that ' the *Effluvia* of Bodies may consist of Particles *extremely small*.[5] Neither do they register on any of the other senses. These electrical *Effluviums* emanate from the electrostatically charged material, whether it be 'Amber, Jet, and other Electricall Concretes' (187.11-12).

[5] Ibid.,7: 233.

Influences on Boyle

Earlier Influences

One of the earliest to influence Boyle was the medic, experimental scientist and civil servant Benjamin Worsley (1618-77), with correspondence going back as early as 1646, when he was not yet twenty years old, and Worsley apparently acted as his mentor in chemical experimentation.[6] The medic Nathaniel Highmore (1613-85) gave Boyle some crucial advice when he seems 'to have interested the younger man in the idea that matter was made up of finite particles, which is in evidence in Boyle's writings from the mid-1650s onwards'.[7]

The Bermuda-born medic, chemist and alchemist George Starkey (1628-65) first met Boyle early in 1651 and 'it is clear that they almost immediately began to have a profuse and productive relationship. Starkey is already much in evidence in the second of the workdiaries which reveal Boyle's new-found enthusiasm for empirical science, and he seems rapidly to have ousted such members of the Hartlib circle as Worsley, becoming Boyle's chief mentor in such matters.'[8] Boyle's pursuit of alchemy was facilitated and developed through his contact with Starkey, who is identified with the alchemical master Eirenaeus Philalethes.[9]

Boyle first came into contact with the aforementioned Samuel Hartlib (*c*. 1600-62) the Prussian intelligencer, early in his scientific career, with correspondence between the two dating as far back as 1647.[10] Hartlib's circle included a wide variety of individuals, many of

[6] Michael Hunter, *Boyle Between God and Science* (New Haven: Yale University Press, 2009), 70.
[7] Ibid., 75.
[8] Ibid., 75.
[9] Boyle's alchemical interests are treated of in: William R. Newman and Lawrence M. Principe, *Alchemy Tried in the Fire* (Chicago: University of Chicago Press, 2005) and Lawrence M. Principe, *The Aspiring Adept* (Princeton: Princeton University Press, 2000).
[10] Michael Hunter, Antonio Clericuzio and Lawrence M. Principe, eds., *The Correspondence of Robert Boyle*, 6 vols. (London: Pickering & Chatto, 2001), 1:51.

them interested in natural philosophy.[11] Early in his time in Oxford Boyle came into contact with a group of academics and others, centred on the university. The importance of this circle in the advancement of science is detailed by Frank,[12] including such names as Robert Hooke (1635-1703), later to become assistant to Boyle, and John Locke (1632-1704). Hunter notes that 'practical classes in chemistry were laid on by the Alsatian chemist Peter Stahl, whom Boyle brought to Oxford and whose classes were attended by Locke and others.'[13] Boyle was a founder member of the Royal Society, which first met in 1660 at Gresham College, London, although still resident in Oxford.

The influence of various writers on Boyle is well known, both from his own writings and from the secondary literature. Three writers of especial importance to his development were Bacon, Gassendi and Descartes. None of these figures is mentioned in *The Sceptical Chymist*, but his indebtedness to them is mentioned in other works dating from approximately the same time as this book. The most relevant of these is *Certain Physiological Essays*, published in 1661, though written several years previously,[14] and *The Origin of Forms and Qualities*, published in 1666. Mentions of some of these authors come even earlier, as when the 15 year old Boyle, having learned Italian from his tutor Marcombes, while travelling in Italy, remarked that much of his spare time was 'spent in reading the Modern history in Italian & the New Paradoxes of the Greate star-gazer Galileo.'[15] Later, as a 20 year old, in a letter to Hartlib, he referred to Gassendi as 'a great favourite of mine' praising his ability as astronomer and mathematician.[16]

[11] Dobbs says of Hartlib that 'on his own initiative he undertook to be a sort or communications centre for the collection and dissemination of information of all sorts.'
In: Betty Jo Teeter Dobbs, *The Foundations of Newton's Alchemy* (Cambridge: Cambridge University Press, 1975), 62.
[12] Robert G. Frank, *Harvey and the Oxford Physiologists* (Berkeley: University of California Press, 1980).
[13] Hunter, *Boyle*, 95.
[14] Hunter and Davis, *Works of Boyle*, 5:xvii.
[15] Michael Hunter, ed., *Robert Boyle by Himself and his Friends* (London: William Pickering, 1994), 19.
[16] Hunter *et al*. *Correspondence of Boyle*, 1:59.

PRELUDE TO COMMENTARY

Aristotle

In the *Origin of Forms and Qualities* Boyle voices one of his key objections to Aristotle:

> For I have observed Aristotle in his physics to write very often in so dark and ambiguous a way, that it is far more difficult than one would think to be sure what his opinion was,[17]

he is careful to add that he would not condemn all of Aristotle's philosophy, nor speak ill of Aristotle himself:

> whose own writings give me sometimes cause a little to wonder, to find some absurdities so confidently fathered upon him by his scholastic interpreters.[18]

He goes on to explain that:

> For I look upon Aristotle as *one* (though but as *one amongst many*) of those famed ancients whose learning about Alexander's time ennobled Greece; and I readily allow him most of the praises due to great wits, excepting those which belong to clear-headed naturalists.[19]

He judiciously acknowledges his nuanced attitude towards Aristotle's writings:

> And I here declare, once for all, that where in the following tract, or any other of my writings, I do *indefinitely* depreciate Aristotle's doctrine, I would be understood to speak of *his physics,* or rather of the speculative part of them (for his historical writings concerning animals I much esteem);[20]

more specifically, when speaking of forms in the same work, Boyle asserts that, to him, forms as accidents are acceptable, but forms as substances he rejects. He absolves Aristotle of the latter interpretations on the subject, saying that he is, either 'irresolved' or is speaking 'ambiguously and obscurely enough' of forms to make his thinking clear.[21]

In the text of *The Sceptical Chymist* Carneades states that the principles of particular bodies may be reduced to two: matter and 'either *Structure* or Texture' (379.11-12). He elaborates on this:

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[17] M.A. Stewart, ed., *Selected Philosophical Papers of Robert Boyle* (Indianapolis: Hackett, 1991), 6.
[18] Ibid., 10.
[19] Ibid., 10.
[20] Ibid., 10.
[21] Ibid., 53.

> Or if, retaining the Vulgar Terme, You will call it the *Forme* of the thing it denominates, I shall not much oppose it; Provided the word be interpreted to mean but what I have express'd, and not a Scholastick *Substantial Forme*, which so many intelligent men profess to be to them altogether Un-intelligible (379.17-26).

Boyle is in partial agreement with Aristotle on the existence of a primal matter:

> Next, I consider, that there being but one Universal matter of things, as 'tis known that the *Aristotelians* themselves acknowledge, who call it *Materia Prima* (about which nevertheless I like not all their Opinions) (151.14-20).

Boyle is not willing to add to the number of his principles:

> Nor did I add to our Principles the *Aristotelian Privation*, partly for other Reasons, which I must not now stay to insist on; and partly because it seems to be rather an Antecedent, or a *Terminus a quo*, then a True Principle, as the starting Post is none of the Horses Legs or Limbs (377.12-20).

Further evidence of Boyle's indebtedness to Aristotle is indicated in *The Sixth Part* of *The Sceptical Chymist* when the question of mineral production is discussed, in particular the production of calcite in *Les Caves Goutieres*, when Carneades describes that water 'falling from the upper Parts of the cave to the ground does presently there condense into little stones, of such figures as the drops' (356.21-24). This explanation seems to be based on Aristotle's account in his *Meteorology* of the formation of hailstones, amber and calcite, as detailed in *Mete*. 1.348^{a} 15-36.

Yet Boyle's attitude towards Aristotle's understanding of the elements, as expressed throughout *The Sceptical Chymist*, is generally negative, as is his critique of the Stagyrite's doctrine on mixing, as discussed by Carneades in *The Second Part* of the book.

Hobbes and Linus

Hobbes was well-disposed towards the youthful Boyle as a letter from Hartlib to Boyle indicates.[22] Osler makes the point that 'Boyle was familiar with the physical thought of Thomas Hobbes (1588-1679), and Boyle's description of the "endeavours" of the spring of the air resonates with Hobbes' discussion of endeavour.'[23] Controversy between the two emerged following the publication of Boyle's work *New Experiments Physico-Mechanical Touching the Spring of the Air and its Effects* of 1660, a work which for the most part was well received, but he was forced to defend the findings he had published on his experiments he had performed with the air pump when it came under attack from Hobbes' *Dialogus Physicus De Natura Aeris*, and against the objections of the English Aristotelian and Jesuit Franciscus Linus. The former's case is sympathetically explained by Shapin and Schaffer.[24] Hunter gives the sub-title of Linus's *Treatise on the Inseparable Nature of Bodies*, published in 1661, as:

> The Vacuum experiments of Torricelli, von Guericke and Boyle are examined, their true explanations given, and consequently it is shown that a vacuum cannot be produced naturally, and so Aristotle's teaching on rarefaction is upheld.[25]

Boyle's position in relation to the existence of a vacuum in the air pump is well expressed by Chalmers:

> He refrained from taking a stand on the possibility of a vacuum and on whether his evacuated receiver or the space above the mercury in the barometer constituted one. He regarded such an issue as 'metaphysical' because not susceptible to experimental investigation. He did claim that his evacuated receiver was relatively free of air and was able to give a range of experimental evidence for this claim.[26]

[22] Hunter *et al.*, *Correspondence*, 1:66.
[23] Margaret J. Osler, 'Whose Ends? Teleology in Early Modern Natural Philosophy', *Osiris* 16, *Science in Theistic Contexts: Cognitive Dimensions* (2001): 151-168, 167.
[24] Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump* (Princeton: Princeton University Press, 1985).
[25] Hunter, *Boyle*, 132.
[26] Alan Chalmers, *The Scientist's Atom and the Philosopher's Stone* (Dordrecht: Springer, 2011), 109.

MacIntosh notes Boyle's antagonism towards Hobbes, believing him not only to be an atheist but also a poor natural philosopher and mathematician.[27] He goes on to explain that:

> Hobbes was, from Boyle's point of view, a survivor from a past age, both chronologically and intellectually, a person who was willing to make *a priori* pronouncements about matters of fact with the confidence as large as it was unjustified. Finally, in Boyle's view, Hobbes had not got the hang of what had come to count as an acceptable explanation.[28]

A further opinion on Boyle's attitude towards Hobbes is offered by Stewart, who notes that Boyle wrote widely to counter Hobbes', and his circle's, assertion that the doctrine of atomism tended towards atheism:

> It is significant that Hobbes was never quoted by Boyle as an ally, but was always quoted in contexts where he could be opposed.[29]

[27] J.J. MacIntosh, ed., *The Excellencies of Robert Boyle* (Peterborough: Broadview Press, 2008), 72.
[28] Ibid., 72.
[29] M.A. Stewart, ed., *Selected Philosophical Papers of Robert Boyle*, xv.

A Commentary on
The Sceptical Chymist
of Robert Boyle:
A PRAEFACE INTRODUCTORY

Introductory Remarks

In this short preface Boyle himself addresses the reader. He explains why he has allowed this work to be published in its imperfect form, and introduces his spokesman Carneades, the Sceptic, then Themistius and Philoponus who represent the Aristotelian and Paracelsian positions, respectively (A4*r*). He explains that Carneades' role is that of doubting the arguments of his adversaries, without having to propose arguments any more conclusive than theirs. He assures his readers that both arguments and details of experiments will be delivered clearly and unambiguously by him so reliably as to satisfy the most wary reader (A2*v*-A3*r*). Boyle notes that some educated men have undergone a change of heart and have begun to study chemistry (A2*r*), and offers the reassurance that he has conscientiously striven to deliver factual information in the accounts of his experiments (A8*r*).

A PRAEFACE INTRODUCTORY

To the following Treatise.

Returning to Boyle's Preface to *The Sceptical Chymist*, he calls attention to his hesitancy in publishing his 'Discourses' (A1v. 23) on 'matters Philosophical' (A1v. 25) by saying that he 'had reason to desire with the Painter, to *latere pone tabulam* [lie concealed behind the painting], and hear what men would say of them, before I own'd myself to be their Author' (A1v. 25-29). In making known his identity, and wishing to reveal himself as 'a person not altogether a stranger to Chymical Affairs' (A2r. 3-4), and in publishing the dialogues he is not doing so in order to enhance his own reputation 'yet for other purposes' (A2r. 11-12).

Boyle makes an argument in which he identifies both the study of chemistry and the results of chemical experimentation as a means by which one might arrive at an understanding of the fundamental constitution of matter. However, in order for this to happen the right people must study chemistry, and indeed it is beginning to be studied by 'Learned Men who before despis'd it' (A2r. 14), but it is also 'pretended to by many who never cultivated it' (A2r. 15-16), just so that they might be seen to have studied it. This state of affairs, according to Boyle, leads to a situation where 'Divers Chymical Notions about Matters Philosophical are taken for granted and employ'd, and so adopted by very eminent Writers both Naturalists [natural scientists; here: probably biologists] and Physitians [physicists]' (A2r. 17-21).

The trouble is, when two quite distinct groups of people claim to have knowledge of a subject, when only one of the groups is actually conversant with it, both parties believe, or at least pretend, that they possess knowledge about the subject. In turn, the two groups go on to claim knowledge of subjects related to, or having a dependency on, their chosen subject. In the case of the linkage between chemistry and the fundamental state of matter, unjustified assumptions are made about the latter. The result, Boyle fears, 'may prove somewhat prejudicial to the Advancement of solid Philosophy' (A2r. 21-23). It is the making of imagined connections between materials as they are observed in the laboratory and things more fundamental that Boyle objects to, arguing that although he is 'a great Lover of Chymical Experiments' (A2r. 23-24), nevertheless, irrespective of how highly one regards the value of manipulating matter and of benefitting from any products which may result from such work, any inferences drawn from these efforts must be treated with caution and not be applied beyond the strict bounds of matter itself and its effects. Boyle says that 'I distinguish these from their Notions about the causes of things, and their manner of Generation' (A2r. 26-27).

What Boyle is really against is the linking of 'a thousand Phaenomena in Nature' (A2r. 29), in addition to a 'Multitude of Accidents relating to the humane Body' (A2v. 1-2) which are unlikely to be 'clearly & satisfactorily made out' (A2v. 2-3) by those who do not go beyond the 'Salt, Sulphur and Mercury and other Notions peculiar to the Chymists [Paracelsians]' (A2v. 4-5). They would, Boyle argues, be well advised to consider the fundamentals of his own understanding of matter, the 'Motions and Figures, of the small Parts of Matter, and the other more Catholick and Fruitful affections of Bodies' (A2v. 7-9). Boyle believes that the objections to the 'three Hypostatical Principles' (A2v. 13) of salt, sulphur and mercury, which will be made by Carneades, will warn men off adopting these principles until they have been carefully examined, since his objections carry weight by having been made by a chemist, as only a chemist can.

Boyle goes on to present his reason for including 'several Experiments of my own' (A2v. 25), as well as others 'Scatter'd among many Chymical Books' (A2v. 26-27). He would like to help 'Ingeneous Persons' (A2v. 19) wishing to consider both sides of a disputed question, and are willing to 'understand Chymical Matters' (A2v. 23) but are not in a position to study them. Interestingly, Boyle's experiments have been 'purposely made to Illustrate the Doctrine of the Elements' (A2v. 26-27).

Boyle then draws a distinction between his use of chemical experiments and those of the Paracelsians. His experiments are delivered in such a way as 'an Ordinary Reader, if he be but Acquainted with the usual Chymical Termes may easily enough understand them' (A3r. 1-4). Not alone are they comprehensible but are of such a trustworthy nature that a 'wary One may safely rely on Them' (A3r. 5). This he contrasts with the work of his Paracelsian adversaries, whose efforts 'a Person any Thing vers'd in the writings of Chymists cannot but Discern by their obscure, ambiguous, and almost Aenigmatical way of expressing what they pretend to Teach' (A3r. 6-10), that they have, in fact, 'no Mind to be understood at all but by the Sons of Art (as they call them)' (A3r. 10-12) but even *they* cannot understand them ‘without Difficulty and Hazardous Tryals’ (A3r. 13-14).

Not only this, but some of them speak most ‘candidly, as when they make use of that known Chymical Sentence; *Ubi palam locuti sumus, ibi nihil diximus* [where we have clearly spoken, there we say nothing]’ (A3r. 15-18), and here Boyle seems to be pointing up the distinction to be made between the Paracelsians and himself: their clearest expression is to be had from observing the smoke given off in chemical reactions, which to him would reveal little, if anything, of what was happening at a fundamental level in the materials under examination.

For Boyle, not only does the ‘obscurity’ (A3r. 18) of what some of the authors he has in mind write, but also the ‘unfaithfulness [untrustworthiness]’ (A3r. 20) of others, means that their writings are ‘unfit to be reli’d on’ (A3r. 21). Reluctantly, for the sake of both the reader and of ‘the truths’ (A3r. 22) he warns the reader ‘not to be forward [inclined] to believe Chymical Experiments’ (A3r. 23-24) when they are presented in the form ‘of Prescriptions, and not of Relations (A3r. 24-25). Boyle is setting down a standard or set of conditions by which one may obtain reliable information on chemical change. Acceptable sources are: when such information comes from the body of knowledge he has built up on the subject *i.e.* ‘his own particular knowledge’ (A3r. 27-28), or ‘relations [accounts]’ (A3r. 28) obtained from others who have won his confidence through the credibility and reliability of their work.

COMMENTARY: A PRAEFACE INTRODUCTORY

Boyle berates ‘even Eminent Writers, both Physitians [physicists] and Philosophers’ (A3v. 1-2) who have recently allowed themselves ‘to be so far impos’d upon, as to Publish and Build upon Chemical Experiments’ (A3v. 4-6) which ‘questionless [unquestionably]’ (A3v. 6) they themselves have not carried out, for if they had done so, they would, as well as Boyle, have ‘found them not to be true’ (A3v. 8). Boyle believes that this matter can be put right by naming the experimenters and allowing the readers to form their own judgements on the likely value of the work, based on the credence they place in the author. He then goes on to say ‘something for Carneades’ (A4r. 2) and something for himself. Carneades, he says, is to play ‘the Antagonist and the Sceptick’ (A4r. 6-7) in a debate which is to be adversarial in nature, then explains how Carneades will behave in the discussion.

Boyle says that it may be that Carneades’ arguments may not be considered as ‘of the most Cogent sort’ (A4r. 14), nor should they be considered so, but that his role is ‘chiefly but to propose Doubts and Scruples’ (A4r. 18-19). It is, however, sufficient that he does so without having to prove that ‘his Adversaries Arguments are not strongly Concluding’ (A4r. 20-21), even though ‘his own be not so neither [either]’ (A4r. 21). Boyle argues that neither is it necessary that ‘all the things a Sceptick Proposes, should be consonant’ (A4r. 25-26), as his function is not to present a set of coherent objections to the opinions being advanced by his adversaries, but only to raise doubt about them. The result is that he may ‘propose two or more severall Hypotheses about the same thing’ (A4r. 28-29), all of which may serve individually to question the validity of these hypotheses without necessarily having to agree with one another.

He justifies this by stating that it is enough for Carneades 'if either of the proposed Hypotheses be but as probable as that [which] he calls a[1] question' (A4v. 4-6). Then, finally, he makes the point that by proposing several hypotheses that are 'Each of them probable, he does the more satisfie his doubts, by making it appear the more difficult to be sure, that that which they always differ from is the true' (A4v. 6-10). Boyle seems to mean by this that when considering a number of equally probable hypotheses, in stressing his doubts about them individually, he is calling attention to all of them being at variance from the true explanation.

Boyle then goes on to make the argument that Carneades, 'by holding the Negative' (A4v. 2) has the advantage that by proposing just one counter-example which proves to be 'Irrefragable [indisputable]' (A4v. 13-14), this alone 'is sufficient to overthrow a Doctrine which Universally asserts what he opposes' (A4v. 14-16). He quotes as example all bodies of whatever kind 'that are reckon'd among the Perfectly mixt Ones' (A4v. 17-18), which are composed of a fixed number of pre-defined ingredients, that this doctrine 'cannot be true' (A4v. 16) if any body can be produced 'that is not so compounded' (A4v. 20-21). Boyle goes on to make another point regarding the 'very [true] Principles of the Chymists' (A4v. 26) *i.e.* salt, sulphur and mercury, which as putative elements subsist as mass substances rather than as a set of strictly quantifiable entities, and that because of this 'Accurateness [careful exactness] will be the less expected from him [Carneades]' (A4v. 21-22), as any opinions or 'Chymical Arguments' (A4v. 25) which he may propose will also refer to the elements in a general

[11] 'in' in the 1680 edition.

sense, as they will be presented as 'Contrary to the very [true] Principles of the Chymists' (A4v. 25-26).

However, Carneades is not to receive any 'intentionall Assistance, except from some Passages of the Bold and Ingenious Helmont'[2] (A4v. 28-29), which statement he quickly qualifies by saying that he 'disagreed in many things' ([A5r.] 1-2) with van Helmont, including the ways in which he explains 'Divers Chymical Phaenomena' ([A5r.] 2-3), and ratiocinations [the action or process of reasoning], some of which 'seem very Extravagant [that wanders as out of bounds]' ([A5r.] 5). It is 'his Experiments' ([A5r.] 6-7) which Boyle esteems more highly than his explanations.

Boyle is willing to concede that 'some Aristotelians have occasionally written against the Chemical Doctrine he Oppugnes' ([A5r.] 7-9) meaning against the Paracelsian *tria prima*, which he opposes, and since he opposes the doctrines of both the Aristotelians and the 'Spagyrists' ([A5r.] 12) or Paracelsians, 'he was fain [gladly willing] to fight his Adversaries with their own weapons' ([A5r.] 12-14). He cites two objections against the Aristotelians or Peripatetics: the first is that their weapons are 'Improper, if not hurtfull for a person of his tenents [tenets]' ([A5r.] 14-16), perhaps meaning that the Aristotelian tenets do not sit comfortably with Carneades' sceptical approach; his second objection refers to the little use Aristotelians he has encountered have for experimentation, and their scant understanding of it.

[2] Jan Baptista van Helmont (1579/80-1644) Flemish medic and chemist, who recognised the existence of discrete gases and identified carbon dioxide.

COMMENTARY: A PRAEFACE INTRODUCTORY

Boyle hopes that Carneades will be able to expose the 'Chymical Doctrine' ([A5r.] 27) to critical analysis. The 'weakness of their Proofs' ([A5r.] 29 – [A5v.] 1) may be disbelieved by 'Judicious Men' ([A5v.] 2) following due information and consideration. In addition the 'abler Chymists' ([A5v.] 5) will be forced 'to speak plainer' ([A5v.] 6) of their doctrine, and 'maintain it by better Experiments and Arguments' ([A5v.] 7-8) than those Carneades has hitherto 'examin'd' ([A5v.] 9). His hope being that his efforts will impart 'either satisfaction or instruction' ([A5v.] 10-11) to those wishing to know.

Boyle goes on to speak of Carneades' openness to truths hitherto unknown to him, but only from 'any Truly knowing Chymists' ([A5v.] 16) who see fit 'in the civil and rational way to shew [show] him any truth touching the matter in Dispute' ([A5v.] 17-18). He gives a list of rules which Carneades will observe during the debate. He 'will not refuse either to admit [to allow] or to own [to adopt as one's own] a Conviction' ([A5v.] 18-19) – an expression of Carneades' honesty in the face of addressing beliefs, his own or another's – which he is willing to allow when presented as part of a calm, rationally conducted debate.

He then warns against 'any impertinent person' ([A5v.] 20-21) taking advantage of the discussion to 'get Himself a Name' ([A5v.] 21-22) or for any other purpose, who should 'wilfully or carelessly mistake the State of the Controversie, or the sence of his Arguments' ([A5v.] 22-24). This seems to be a cautioning of those who may be tempted to take advantage of the controversial nature of the debate to enhance their own reputations. Boyle goes on to name another category of opponent: those who 'rail [utter abusive language] instead of Arguing' ([A5v.] 24-25), and he gives in the margin the initials of three authors who, among others, have been conducting the obviously acrimonious debate engaged in 'by divers Chymists' ([A5v.] 26) in print.

Boyle's final objection concerns those who seem to write against Carneades' arguments 'in a canting [using unreal or affected language] way; I mean, shall express himself in ambiguous or obscure termes' ([A5v.] 27-28). A lack of clarity of expression, or a terminology which cannot be clearly explained, is unacceptable to Carneades. Not only this but attempting to 'argue from experiments not intelligibly enough deliver'd' ([A5v.] 29 – [A6r.] 1) will simply not be countenanced by Carneades. Boyle then goes on to 'say something too for my self' ([A6r.] 6).

He expresses the rationale behind his presenting the discussion in the manner which he does. He is at pains to eschew any connection which might be made between civility in the manner of presenting one's argument and weakness or feebleness of its content. He says that 'perhaps some Readers will be assisted to discern a Difference betwixt Bluntness of speech and Strength of reason, and find that a man may be a Champion of Truth, without being an Enemy to Civility' ([A6r.] 22-26). He argues that a man 'may confute [prove wrong] an Opinion without railing at them that hold it' ([A6r.] 26-27), and should make a conscious effort not to offend his adversaries 'when he says that they are in error' ([A6v.] 3).

Boyle draws on the debating style of the 'Prince of the Romane Orators himself'[3] ([A6v.] 13-14), and justifies how Carneades may 'speak sleightingly of the Opinions he opposes' ([A6v.] 9-10) by comparing this with what Cicero 'makes both great Persons and Friends say of one anothers Opinions, in his excellent Dialogues *De Natura Deorum* [On the Nature of the Gods]' ([A6v.] 14-16).

Boyle wishes the reader to understand that what follows is indeed a dialogue, and that Carneades is not simply a mouthpiece for him, saying that 'I make not all that he [Carneades] says, especially in the heat of Disputation, mine' ([A6v.] 29-30). He wishes to reassure the reader that he is not writing an anti-chemist polemic. He says that 'I hope the *Specimina* I have lately publish'd of an attempt to shew [show] the usefulness of Chymical Experiments to Contemplative Philosophers, will give those that shall read them other thoughts of me' ([A7r.] 6-9). In wishing to establish the value of practical chemistry to philosophers, he does not spare any of those who actually practice chemistry. He carefully distinguishes between 'those Chymists that are either Cheats, or but Laborants [practical chemists who have no real theoretical understanding of their subject], and the true *Adepti* [those who understand both the theory and practice of chemistry]' ([A7r.] 19-20). Yet Boyle, despite his admiration for the adepti, is quick to remind them that one of the principle aims of 'this Sceptical Discourse was, not so much to discredit Chymistry, as to give an occasion [an excuse] and a kind of necessity to the more knowing Artists to lay aside a little of their overgreat Reservedness' ([A7r.] 27-31). Their role is not simply to 'either explicate or prove the Chymical Theory better than ordinary Chymists have done' ([A7r.] 31-33), but also if their theoretical

[3] Marcus Tullius Cicero (106-43 BCE) Rome's greatest rhetorician.

understanding is inadequate can ‘by enriching us with some of their nobler secrets to evince that Their art is able to make amend’s even for the deficiencies of their Theory’ ([A7r.] 33 – [A7v.] 1-2).

Boyle shows his empathy towards, and high regard for, those who practice chemistry, and laments the failure of many, who devote so much time to laboratory work to consider the theoretical background to their art. He says that ‘we shall much undervalue Chymistry, if we imagine, that it cannot teach us things farr more useful, not only to Physick [medical chemistry] but to Philosophy, than those that are hitherto known to vulgar Chymists’ ([A7v.] 4-7). Even though the ‘Spagyrists [Paracelsians]’ ([A7v.] 8) through their efforts are deserving of the gratitude of the ‘Common-wealth of Learning’ ([A7v.] 9-10), Boyle is disappointed that ‘they should ever misse the Truth which they have so industriously sought’ ([A7v.] 11-12). He argues that however much practical work is carried out by the Paracelsians, their labours should be controlled or guided, so that they could be ‘cultivated’ ([A7v.] 15). And although Boyle is no admirer of the ‘theoretical Part of their Art’ ([A7v.] 12-13), if this were combined with a more disciplined approach to experiment, both sides could ‘employ Philosophy and Philosophers, and help to make men such’ ([A7v.] 16-18). Boyle is quick to dispel any belief that he might be, in fact, a ‘profound [deeply-buried] Spagyrist’ ([A7v.] 20) because he finds fault also ‘in the Doctrine wherein the Generality of Chymists scruples not to Acquiesce’ ([A7v.] 21-22), probably meaning the Aristotelian doctrine of the four elements. Boyle does, however, acknowledge that it is much easier to find fault with any given hypothesis than to posit one, and apart from this, as a young student of chemistry his teachers were 'illiterate persons' ([A8r.] 1-2).[4] The meant that he was not given a theoretical understanding of his subject. He was thereby free from the prejudices instilled in most students of chemistry, and was free to pick and choose in formulating his theoretical foundation.

Boyle, in approaching the study of chemistry in an open-minded way, started with 'a suspition that the Vulgar Principles [the *tria prima* of the Paracelsians] were lesse general and comprehensive or lesse considerately [with consideration] Deduc'd from Chymical Operations, than was believ'd' ([A8r.] 9-13). The doubt having been planted in his mind, it was easy for him to devise some experiments likely to 'Furnish Me with Objections against it' ([A8r.] 18), despite his relative inexperience as a practitioner of chemistry.

In rounding off his introduction, Boyle states that he is willing to leave others to judge the 'Experiments I have communicated' ([A8r.] 24-25). What he holds as important is that he has 'endeavour'd to deliver matters of Fact, so faithfully' ([A8r.] 27-28) as much to help 'the lesse skilful Readers' ([A8r.] 29) to examine the Paracelsian doctrine of the *tria prima* as to provoke the upholders of this doctrine to 'illustrate it' ([A8v.] 2), or equally the Aristotelian or any other theory, differing as they do from what he himself believes 'shall be intelligibly explicated, and duly prov'd to me' ([A8v.] 5-6), and that what he has discussed will help to convert those who can be so by 'any thing but Error' ([A8v.] 10-11).

[4] Boyle did not commence his formal studies in chemistry until 1659, when he was 32 years old, under Peter Stahl at Oxford.

A Commentary on *The Sceptical Chymist* of Robert Boyle: PHYSIOLOGICAL CONSIDERATIONS

Introductory Remarks

The dialogue begins in Carneades' garden, with Eleutherius acting as moderator (7-8), and Boyle's own participation limited to acting as mute recorder of the discussion (8-9). Only in this chapter do all four dialogists actually make a contribution to the unfolding debate, with Themistius delivering a lucid exposition of the Aristotelian doctrine on the elements, followed by a strong denunciation of the Paracelsian account of the elements (17-25). Philoponus' one contribution to the dialogue is not to explain his position on the elements, but rather to offer a conclusion to be drawn from an experiment on the separation of gold and lead, as related by Carneades (27-28).

PHYSIOLOGICAL CONSIDERATIONS.

Following on from the Preface, the first section proper of the work is called 'Physiological Considerations' [Physiological here meaning either 'relating to the material universe', or to 'natural science'] and straight away Boyle states the importance of a properly founded scientific methodology by giving the chapter's subheading as touching the 'experiments wont to be employed to evince [make evident or show clearly] either the four 'peripatetick [Aristotelian] Elements' of earth, air, fire and water, or the three 'Chymical [Paracelsian] Principles': sulphur, mercury and salt of compound bodies.

He introduces the text itself by noting his friends considering it 'very strange' (1.2-3) to hear him speak so 'irresolvedly [that is, without reaching a conclusion]' (1.4) on the elements or principles of 'Mixt Bodies' (1.8). He then makes an implied criticism of his adversaries – obviously the Aristotelians and Paracelsians – in which he admits his own willingness to doubt rather 'then [than] to profess that I know what I do not' (1.10-2.1). He argues that he would expect to see 'Philosophy solidly establish't' (2.4) if 'men would more carefully distinguish' (2.4-5) between those things which they 'know' (2.6) and those which they 'ignore [are ignorant of]' (2.7) or merely 'think' (2.7). By making a clear distinction between knowledge, ignorance and supposition Boyle is expressing the starting point of his understanding of how the investigation of the natural world should be pursued. Not only this, as well as acknowledging their level of understanding of a given thing, 'men' must also 'explicate clearly the things they conceive they understand' (2.8-9). In other words it is necessary to give as unambiguous an account as possible of what one thinks one knows – no loose accounts invoking obscure explanations of things, but a rigorous, rational, coherent description of whatever it is one is attempting to explain. One should 'acknowledge ingenuously [candidly, frankly, straightforwardly]' (2.9-10) what one does not know.

Another part of Boyle's methodology is revealed when he states that uncertainty is acceptable but investigators must express 'candidly their Doubts' (2.11), not as an admission of defeat or failure on their part, but with the intention of communicating the problem in hand to a wider circle of workers whose collective intelligence could be brought to bear on the issue with the prospect of a successful resolution. The 'intelligent persons might be set to work to make further enquiries' (2.12-13).[1] Not only would this comment apply to Robert Hooke but the Royal Society was coming into existence both as a forum for discussing, investigating and executing novel experiments and as a means of furthering knowledge of the natural world in a disciplined, rational way.

Boyle then acknowledges that, having said so much of his dissatisfaction with the doctrines on the elements of his adversaries, he will have to provide a detailed response to them. This entails giving a more 'particular accompt [an account providing specific details]' (2.16) of his objections to their doctrines on the 'Primitive Ingredients of Bodies' (2.19-20). The word 'primitive' here may refer to more than the elements into which materials can be ultimately resolved, for whatever about his thinking on the elements in themselves, Boyle held that matter and motion are the underlying principles

[1] Around the time of writing *The Sceptical Chymist* Boyle was employing Robert Hooke as his scientific assistant – himself a man of powerful intelligence and possessed of great ingenuity and dexterity as an experimenter.

of the created world; no occult or hidden forces, powers or states of matter will be accepted by him. In his opinion matter exists in a 'corpuscular' or atomic state. That a range of views is to be presented is announced by Boyle when he says that the discussion will involve 'persons of several opinions' (2.24).

Boyle begins the dialogue by introducing the reader to the chief protagonists: the 'inquisitive *Eleutherius*' (3.2-3) and his 'friend *Carneades*' (3.4). The latter gentleman is introduced as capable of being able to 'give our mindes at least a pleasing Exercise, and perhaps enrich them with some solid instruction' (3.17-19). This all sounds perfectly understandable, but what is curious is what is presented as his qualifications for so doing. He is 'so conversant with nature and with Furnaces' (3.13-14), without any mention of natural philosophy, of being a skilled investigator into the physical or mechanical properties of matter, of the physiological effects on living things of Boyle's air pump, or of his work in chemical experimentation, although his efforts on this last-named subject is hinted at by the mention of Carneades as being experienced with furnaces, which would form a central feature of Boyle's laboratory. Those other aspects of Carneades' interest, already referred to, Boyle seems content to summarise by stating that he (Carneades) is conversant with 'nature' as well as furnaces.

Another of Carneades' stated qualities is that he is so 'unconfin'd to vulgar [of or belonging to the multitude] Opinions' (3.14-15), meaning, it would seem, that he held his own private opinions on the matters about to be discussed in the dialogue. The probable means by which Carneades is to provide intellectual stimulation, and perhaps enlightenment, is by some ‘ingenious Paradox or other’ (3.16). Boyle’s use of the word ‘paradox’ – which he does repeatedly throughout the text – seems to mark a fundamental feature of his investigative methodology. The dictionary definition of the word ‘a statement or tenet contrary to received opinion or belief, especially one that is difficult to believe’[2] creates an expectation that Boyle’s investigations into the natural world and its functioning arrives at a set of results, insights and explanations which are contrary to those held by both the Aristotelians and the Paracelsians. His experimental programme would, he implies, generate a mode of explanation which would defy conventional wisdom, and would simply conflict with orthodox thinking on nature and its functioning.

Boyle then goes on to introduce the reader to the physical space in which the dialogue is to take place; ‘at the lodging of *Carneades*’ (3.22) in one of the ‘Arbours in His Garden’ (3.26-27), where, accompanied by Eleutherius, Boyle ‘found *Carneades*, *Philoponus* and *Themistius* sitting close about a little round Table’ (4.9-10). On the table, in addition to pen, paper and ink, lay ‘two or three open Books’ (4.13). He makes it known that all of the gentlemen who had just met were well acquainted with one another and were indeed friends. Nevertheless on the arrival of Eleutherius and Boyle the books that lay on the table were hastily closed, and the former guesses that this gesture and ‘much more by the posture [an attitude or pose] wherein I found Persons qualifi’d to discourse of serious matters’ (5.5-7), means that they were already engaged in a discussion, and he hopes that the newcomers may be allowed either to listen in on the ‘Philosophical conference’ (5.9-10) which their arrival had interrupted, or to participate

[2] OED online – consulted 31-5-11.

in it. Carneades invites Eleutherius to stay 'especially since you are pleas'd to desire to be present at what we shall say' (5.26-28), and introduces the subject under discussion as 'the number of the Elements, Principles, or Material Ingredients of Bodies' (6.1-3). The truth of this enquiry is of such 'Importance, and of that Difficulty' (6.4) as likely to merit investigation by 'such skilfull Indagators [investigators] of Nature as Your selves' (6.6-7).

Boyle goes on to say that they had sent someone to invite 'the bold and acute *Leucippus* to lend us some light by his Atomical Paradox' (6.8-10).[3] As it happens Leucippus could not participate in the dialogue as 'he was not to be found' (6.13-14), even though he had told Boyle 'but last night that he would be ready to give me a meeting where I pleased today' (6.22-24).

Boyle has obviously gone to some trouble in invoking the name of the originator of the doctrine of atomism as a suitable participant in the dialogue, then having to devise a strategy to explain why in the end he does not take part in it. The reason why he is not included may simply be that as Boyle himself professed a version of the atomic theory – his Corpuscularian Philosophy – he may have considered that, although atomism as a subject was of sufficient importance to warrant a mention in the preliminary stages of the dialogue, it was in no need of a second speaker.

[3] Leucippus was a fifth century BCE Greek philosopher, and originator of the atomic theory, the details of which have come down through his follower Democritus.

COMMENTARY: PHYSIOLOGICAL CONSIDERATIONS

That a discussion had already begun before the arrival of Boyle and Eleutherius is indicated by Carneades, although it was ‘so newly begun’ (6.26) that ‘we shall scarce need to repeat any thing’ (6.27-29) to apprise the newcomers of what had already passed between the speakers. And they are invited to be not just ‘hearers alone, but we hope Interlocutors at our conference’ (7.4-5). Carneades wishes to lay down some rules in relation to how the dialogue might proceed.

He says that ‘these learned Gentlemen’ (7.9), *i.e*. Philoponus and Themistius, ‘need not fear to discourse before any Auditors [audience]’ (7.11-12), which seems a straightforward statement of these speakers’ willingness to engage in debate before any given group of hearers, but Carneades qualifies this statement by saying of the audience ‘provided that it be intelligent enough to understand them’ (7.12-13). And, of course, this does put rather a different complexion on the matter as the implication is that they choose their audience carefully and are willing only to give an unguarded account of their beliefs and opinions before hearers of sufficient understanding to accord them a fair and open-minded hearing, rather than an audience whose preconceived opinions would not grant an unbiased reception to new or unconventional ones.

Continuing with the theme of the necessity for frank expression of opinions amongst the participants in the dialogue, Carneades says that for his part ‘I shall not dare to vent my unpremeditated thoughts before two such Criticks [*i.e.* before those who pass severe or unfavourable judgements] unless by promising to take your turnes of speaking, You will allow me mine of quarrelling [here: challenging or disagreeing with] with what has been said' (7.15-19). Each party to the debate is to be allowed to state their own opinions openly and candidly, but only on condition that the others have a right to pass judgement on any such opinions in an equally frank, uninhibited manner.

This understanding on the reciprocity of exchanges between the various speakers and hearers having been agreed upon, Eleutherius, after having 'fruitlessly endeavoured' (7.25-26) to be allowed remain silent, agreed not to do so on condition that he be allowed to act as an impartial moderator: able to side with one expressed opinion and then another as the discussion proceeded.

Boyle now makes a curious remark: 'But I conscious of my own Disability's told them resolutely that I was as much more willing as much more fit to be a hearer then [than] a speaker, among such knowing [learned, knowledgeable] persons, and on so abstruse [concealed, hidden, secret] a Subject' (8.8-12). What disabilities is Boyle referring to here – his lack of knowledge on the subject under consideration? Perhaps so, as he refers to the other participants in the dialogue as 'knowing' and the subject as 'abstruse'. But then, he allows Carneades as a kind of spokesman or *alter ego* for himself to more or less represent his opinion in the dialogue, as *he* is not one represented as lacking in either knowledge or self-confidence in the course of the discussion.

Another explanation presents itself: Boyle may in fact be speaking of himself. It is known that he was quite a shy person, who spoke with a stammer, and it may have been these personal qualities which he was referring to as disabilities.[4] That Boyle did not want his own voice to be heard in a dialogue may explain why he says that 'therefore I beseeched them without necessitating me to proclaim my weaknesses to allow me to lessen them by being a silent Auditor of their Discourses' (8.13-17). He goes on to say that he wished to be permitted to be 'at which I could present them no motive [here: asking a question requiring an answer]' (8.17-18). He then adds: 'save that their instructions would make them in me a more intelligent admirer' (8.18-20).[5]

However Boyle, in wishing to remain silent during the forthcoming discussion, does not want to stay inactive or otiose but instead wishes to take shorthand notes of the proceedings so that he may thereby 'preserve Discourses that I knew would merit to be lasting' (8.24-26). As this suggestion is rejected by '*Carneades* and his two friends' (8.26-27) the situation is saved by an intervention from Eleutherius who, cognisant of the fact that it was he who had brought Boyle along to the gathering, 'was content that I should register their Arguments, that I might be the better able after the conclusion to give them my sence upon the Subject of it, (the number of Elements or Principles:)' (9.6-11). Interestingly, this promise is not to be fulfilled, as at the end of the discussion it is Eleutherius and Carneades who speak on the subject on the names and number of the elements, with Boyle himself making no further intervention in the discussion. He does, however, allow himself a 'let-out clause', by stating that Eleutherius' promise was

[4] Walker and Fitzgerald believe that Boyle suffered from Asperger's Syndrome. See: A. Walker and M. Fitzgerald, *Unstoppable Brilliance*, (Dublin: Liberties Press, 2006), chap.4.
Hunter suggests that Boyle may have been mildly autistic. See: Michael Hunter, *Boyle between God and Science* (New Haven: Yale University Press, 2009), 35.

[5] What Boyle seems to mean here is that their instructions would make *me* (Boyle) a more intelligent admirer of *them*.

that Boyle should make the proposed intervention 'at the end of the present Debate, if time would permit, or else at our next meeting' (9.12-15). Boyle himself, though not altogether content at this turn of events, found the company 'would by no means receive my Protestation against it' (9.17-19). Turning their eyes on Carneades 'they did by that and their unanimous silence, invite him to begin' (9.20-21), and the dialogue is permitted to commence.

So with Boyle himself present only as a silent stenographer, Carneades immediately launches into querying 'the very [real or true] number of those material Ingredients of mixt bodies' (10.6-8) which are variously called 'Elements' (10.9) or 'Principles' (10.9). He distinguishes between the two sets of arguments or proofs which are meant to resolve the question, the first of which is the 'subtile reasoning' (9.25-26) which he has found in the 'books of the Peripateticks' (9.26-27), by which he means the doctrines of Aristotle and his followers, which are expounded in their various writings on the subject. These are, however skilfully they may be presented, still arrived at by purely rational means. The second process by which the matter is to be determined is by the 'pretty [elegant] experiments that have been shew'd [shown] me in the Laboratories of Chymists' (9.27-29). Here the proof of the number of the elements is arrived at by the direct experimentation of the Paracelsians, and Carneades praises the quality of the experiments, which have probably been carried out before his very eyes in their laboratories, in a practiced, well-rehearsed manner. However, he is of so 'diffident [distrustful], or dull [lacking in perception] a Nature' (10.6) as to think that if neither of these two groups can 'bring more cogent arguments to evince the truth of their assertion then [than] are wont [accustomed] to be brought' (10.2-5), it will be the case that it is perfectly reasonable for a person to retain 'some doubts' (10.6) regarding the number of the elements. Carneades contends that all of the arguments, both rational and experimental, advanced so far in relation to the number of the elements or principles are not powerful or convincing enough to win over one seeking an answer to this problem.

This response to the efforts of the Aristotelians and Paracelsians alike in failing to establish a secure bedrock on which to found their doctrine on the number of the elements, coming as it does at the inception of the dialogue, sets the tone for much of that which will recur throughout the work.

Carneades then makes a comparison between establishing the number of the elements in the created universe with that of securing their place in the teachings of the natural philosophers. He says that 'when I considered that the Tenents [tenets] concerning the Elements' (10.10-11) are as 'considerable' (10.12) among the 'Doctrines of natural philosophy' (10.12-13) as the 'Elements themselves are among the bodies of the Universe' (10.13-15). What Carneades seems to mean here is that just as the elements are of fundamental importance to the constitution of the material universe (and he may have in mind the Biblical water and earth of Creation) so too should their identity and number be firmly established by those who systematically study the fundamental constituents of natural bodies. For it is, he argues, upon these elemental materials that 'so many others are superstructed [built upon something else]' (10.17).

Yet when he went to the trouble of objectively examining those compound materials ‘said to result from the blended Elements’ (10.20-21) and ‘to torture them into a confession of their constituent Principles’ (10.21-22) he discovers that ‘Philosophers’ (10.25) had ‘contended [made vigorous efforts]’ (10.24-25) about the number of the elements, ‘with more earnestness than success’ (10.25-26). And here Carneades might have allowed himself a smile as he imagined how, when confronted with a hot furnace, compound materials ‘broke down’ and ‘admitted’ to him their primary constituents, but one can also interpret Carneades’ use of the word ‘torture’ as twisting and distorting materials by appropriate manipulation so as to dissociate them into their fundamental ingredients. Carneades’ mention of philosophers contending about the number of the elements, may mean that they are engaging in a debate on the subject instead of carrying out an experimental programme to decide the issue. And while praising of their efforts he is nonetheless dismissive of their inability to resolve the question.

Carneades says that his dissatisfaction has been ‘much wondered at’ (10.27-28) by Themistius and Philoponus, who differ ‘almost as much betwixt themselves’ (11.2-3) about the question of the elements as he does from either of them, yet he acknowledges that ‘both agree very well’ (11.5) that there is a ‘determinate number’ (11.6) of elements or principles. Then Carneades adds, intriguingly, ‘and that what that number is, I say not, may be, (for what may not such as they perswade?) but is wont [in the habit of] to be clearly enough demonstrated both by Reason and Experience’ (11.8-12).[6] What Carneades seems to mean here is that he is indifferent to any assertions as to the number

[6] What Carneades may mean here is: ‘and that, what that [they say the] number is, I say not [I am not denying], may be, (for what may not [be] such as they perswade?) but is, *etc*.

of the elements, for the matter will be decisively settled both rationally and experimentally. What any one party asserts to be the number of the elements may or may not be true, and hinges as much as anything else on the powers of persuasion of those promoting any particular argument on the matter. The question comes to be settled not verbally ‘but is wont to be clearly enough demonstrated both by Reason and Experience’ (11.10-12). Ultimately, the application of a scientific method employing both rational and experimental procedures will settle the issue.

Carneades, perhaps conscious of the apparently abrupt start to the dialogue, now reassures the reader that the ‘Discourse this afternoon’ (11.14) was actually in progress well before Eleutherius and Boyle arrived and that the participants ‘having fallen from one subject to another, and at length settl’d on this’ (11.14-16). That is to say they agreed to speak on the elements ‘out of both the Topics’ (11.18-19), the first of which being ‘Reason’ (11.20), which they decide to exclude on grounds of time, as it would not be possible for them ‘before supper to go through the Reasons and Experiments too’ (11.23-24). The reader is left wondering whether this is a convenient excuse on Carneades’ part not to give a proper airing to one half of the debate – that concerning the rational, as opposed to the experimental, justification for the elements. That this does indeed seem to be the case is reinforced by Carneades’ saying that it was the experimental side of the debate which they ‘unanimously thought the most requisite to be seriously examin’d’ (11.25-27), even though Themistius the Aristotelian and Philoponus the Paracelsian would surely have been more secure in arguing a rational basis to their understanding of the elements.

Carneades then issues a kind of warning or declaration to the company by stating that he is not present at the discussion in the capacity of one who wishes to add his opinion on the question of the elements to those of his fellow interlocutors. He is not constrained to 'declare my own opinion' (12.1-2) so as to 'assert or deny' (12.2-3) the 'Truth either of the Peripatetick [Aristotelian], or the Chymical [Paracelsian] Doctrine' (12.3-4) regarding the number of the elements, 'but only to shew [show] you that neither of these Doctrines hath been satisfactorily proved by the Arguments alledged on its behalfe' (12.6-9). The arguments referred to here are probably those presented by various writers and debators on the subject, and not just those who are now discussing the issue.

He further declares his acceptance of reason in determining the issue by stating that if one of the opinions presented at the debate should be 'a more rational account then [than] ordinary' (12.11-12), he may be swayed by 'it being obvious to all your observation, that a solid truth may be maintained by no other then [than] incompetent Arguments' (12.15-18). What Carneades seems to mean is that a truth on the question of the elements may be arrived at rationally, and that this truth stands regardless of the quality of the arguments adduced in support of it.

Carneades then goes on to state that it is not necessary for him to 'answer the Arguments' (12.21) advanced for either Themistius' or Philoponus' 'Opinion from the Topick of reason, as opposed to experiments' (12.23-24) since he is to examine solely these and 'not all these neither [either]' (12.26), but only those that they consider worthy to 'insist on' (12.28) and which have been habitually postulated as proof that all compound materials consist of either the 'four Peripatetick Elements' (13.1) or the 'three Chymical Principles' (13.2) *i.e.* the Aristotelian elements or Paracelsian principles, respectively.

Carneades now embarks upon what might be called a 'ground-clearing' exercise. He offers an examination of the respective positions of himself, Themistius and Philoponus in relation to the subject of the debate. He states that 'you' (13.5), Eleutherius, or perhaps the reader, should not do Themistius and Philoponus 'the injury of measuring their parts [roles] by the arguments they are ready to propose' (13.8-10). The reason why he wishes to allow this outcome is because the arguments accorded to his two opponents, in confining their discussion to experimental evidence in support of their position on the question of the elements, mean they will be forced to employ arguments of the 'vulgar of Philosophers' (13.12), the 'lawes of our Conference' (13.10) having dictated that this should be so. Neither should 'you not condemn me of presumption [bold or insolent behaviour or manners] for disputing against persons over whom I can hope for no [any] advantage, that I must not [might] derive from the nature, or rules of our controversy, wherein I had but a negative to defend' (13.15-20). Carneades acknowledges the different tasks facing himself and his two adversaries in the debate: they have to argue for the presence of three or four elements or principles in all material bodies, whereas his argument is that this is not the case. And if all of the arguments presented centre on experimental evidence, as the debators have already agreed should be the case, Carneades in denying the validity of any such evidence in support of a given position in relation to the elements, will invariably enjoy an advantage, for the simple reason that whatever four products from the thermal decomposition of any material are identified as constituting the four Aristotelian elements can have their elemental status denied by him. Carneades realises too that his task is made even easier because he will frequently have 'the Assistance of one of my disagreeing adversaries against the other' (13.21-23). One can see how this might play out in practice as the Aristotelian's four element analysis of any compound body can be immediately challenged by the Paracelsians who are able always to oppose this understanding and will attempt instead to identify their three principles in the decomposition products.

Eleutherius on hearing Philoponus and Themistius return 'civilities of like nature' (13.25-26), 'minded [reminded]' (14.1) them that they were meant 'not to exchange compliments, but arguments' (14.2-3). And he is as good as his word in that he expresses his good fortune in arriving at the gathering 'so luckily this Evening' (14.6), he immediately says that he 'has been long disquieted with Doubts' (14.7) relating to the subject about to be discussed. He declares himself pleased that Carneades has decided 'to insist rather on Experiments then [than] syllogisms' (14.23-24). This approach to the conducting of the debate he avers will, at the end of the dialogue, lead to his 'either los[ing] my Doubts or the hopes of ever finding them resolved' (14.17-19). The reason why he believes his doubts will be addressed is because the question about to be discussed – that of the elements or principles – will be tackled 'by persons that maintain such variety of opinions concerning it' (14.11-12) with the ability not only to 'enquire after truth' (14.13) but also 'to embrace it' (14.14) by whatever means it should come to them.

This means of conducting the debate he contrasts with that of the 'Schoolmen' (14.27)[7] and their 'Dialectical [addicted to or practicing logical disputation] subtleties' (14.26) which they 'too often employ about Physiological [relating to the physical universe or to natural science] Mysteries' (14.27-28). This practice is more likely to display the 'wit [intellect]'(14.29) of those employing this form of argumentation 'then [than] increase the knowledge or remove the doubts of sober lovers of truth' (15.1-3). Continuing with his tirade against the Schoolmen, Eleutherius says that 'such captious [alluring, taking, plausible] subtleties' (15.3-4) may frequently 'puzzle' (15.4), even 'silence' (15.5) men, 'but rarely satisfy them' (15.5). This he likens to the feelings 'men' (15.7) experience when they know they have been 'cheated' (15.7) by 'the tricks of Jugglers'(15.6) but cannot say exactly how. Then, by contrast, Eleutherius praises Carneades for making it his business to 'consider the *Phaenomena* [things which are perceived or observed]' (15.12) relating to the topic under discussion, which had been 'afforded by experiments, especially since it might seem injurious to our senses' (15.13-15) … 'to have recourse to far-fetched and abstracted Ratiocination[8] [the actions or processes of reasoning, *esp*. deductively or by using syllogisms; a conclusion arrived at by reasoning]' (15.18-19).

[7] A succession of writers, from about the ninth to the fourteenth century, who treat of logic, metaphysics and theology as taught in the 'schools' or universities of Italy, France, Germany and England. Later, the 'Schoolmen'came under increasing challenge as the New Science gained influence.
[8] Corrected to 'Ratiocinations' in the *Errata*.

Eleutherius then makes a statement which is important to the understanding of Boyle's empiricist philosophy, as well as that of his slightly younger contemporary John Locke.[9] He gives a good account of what the empiricist approach to philosophy is when he speaks of 'our senses, by whose mediation we acquire so much of the knowledge we have of things corporal' (15.15-18), and by which we 'know what are the sensible [perceptible by the senses] ingredients of those sensible things that we daily see and handle' (15.19-22) and which we are 'supposed to have the liberty to untwist … into the primitive bodies they consist of' (15.22-24).

Carneades then allays Eleutherius' fears that 'they had forgotten something preparatory to their debate' (15.28-29) namely, their adoption of an agreed definition of the word 'Principle or Element' (16.2-3). He replies to Eleutherius that they had not forgotten 'so requisite a thing' (16.5): on the contrary, 'being Gentlemen and very far from the litigious humour [*i.e.* having the character of those fond of debates] of loving to wrangle about words or terms or notions as empty' (16.6-9) – a further side-swipe at his philosophical adversaries – they had already agreed promiscuously [undiscriminatingly] both that elements and principles are 'terms equivalent' (16.12) and on a common definition of them.

Carneades goes on to speak of the subject matter in relation to the elements that is to be treated of in the discussion. The 'opinions to be debated' (16.19) would be as they 'have found them maintained by the Generality of the assertors' (16.20-21) of either the

[9] The classical empiricist view is associated with John Locke (1632-1704), the first of the so-called British Empiricists, though elements of it go back much earlier. The mind can be pictured as a *tabula rasa* or blank tablet on which information is imprinted by the senses in the form of sense-data.

four elements or three principles, rather than 'trying our selves to enquire scrupulously' (16.24-25) what 'either of those great persons' (16.27) – Aristotle or Paracelsus – or any one of their 'Interpreter[s]' (16.26) understood on the matter. Their intention is not the examination of the doctrines or thinking of any of these writers 'but what we find to be the most obvious and most general opinion of those' (17.1-3) who favour either of the two doctrines on the subject.

Clearly Carneades is an admirer of both Aristotle and Paracelsus, yet their opinions and those of their followers on the elements or principles is not to be the subject of the debate – probably because he does not wish to confine the discussion to the narrow subject of the definition of the elements, their naming, and accounting for their behaviour either as simple bodies or in combination. What Carneades seems to have wanted from the discussion was for those who followed either doctrine to give their account of what they understood by the elements, and his use of the words 'obvious and most general opinion' (17.2-3) would seem to suggest that the substances identified by them as elemental were derived from their chemical manipulation of materials. That the debate is to be conducted in an amiable manner is reiterated by Eleutherius' saying that it would have to be 'agreed which of your two friendly Adversaries' (17.9-10) would be the first to speak. It was quickly agreed that it should be Themistius (the Aristotelian) because his doctrine was the 'antienter [more ancient]' (17.14) [Aristotle lived in the fourth century BCE, whereas Paracelsus wrote in the sixteenth century CE] and the 'more general' (17.15), by which he probably means that the writings on the elements of Aristotle are much better known and popular than those of Paracelsus. Themistius addresses himself to Eleutherius, as the one ‘least interessed [personally involved or implicated] in the dispute’ (17.18).

He begins his narration by referring to his ‘great and peculiar Disadvantages’ (17.16-17) with which he engages in the debate, of which his interlocutors will be ‘made sensible [aware]’ (17.25) if they had paid attention to Carneades’ ‘late Confession [acknowledgement or declaration]’ (17.20), which was presented by him in ‘complementall [in a way that gives completeness] Expressions’ (17.22-23) which was ‘exacted [called for or required]’ (17.23) ‘by his Justice [principle of fairness]’ (17.23-24). He qualifies his disadvantages already spoken of as ‘besides those which his parts [interest, concern] and my Personal Disabilities [perhaps: instances of lack of ability to deploy all means open to him in the debate]’ (17.27-28). What Themistius seems to be referring to here is Carneades’ statement that the debate should concentrate on the experimental evidence for the elements which would put Themistius at an obvious disadvantage as his proofs for the elements were derived rationally. He complains that Carneades – although no better a speaker then himself – has made it the ‘chief condition of our Duell [contest]’ (18.4-5) that he must do without the ‘best Weapons’ (18.6) he has at his disposal to demonstrate the existence of the four Aristotelian elements, namely ‘the Arguments suggested to me by Reason’ (18.10). He believes that if he were allowed to employ these arguments drawn from reason, that he would make ‘You a Proselyte [convert to a point of view] to those unsever’d Teachers, Truth and *Aristotle*’ (18.12-14). He goes on to extol the philosophy of Aristotle, who ‘as his *Organum*[10]

[10] *Organum* or Organon [instrument] resulted from a grouping together of several of Aristotle’s treatises by the ancient commentators and regarding them as comprising his logical works.

witnesses' (18.18-19) was the greatest logician ever. This same philosopher 'disclaim'd the course taken by other petty Philosophers (Antient [ancient] and Modern)' (18.20-22), who fail to construct a coherent philosophy in which the parts are 'not only to be consistent together' (18.28), but also 'support each other' (18.29). Themistius here makes a direct and comprehensive criticism of lesser philosophers, and not just those of the nascent Scientific Revolution, but those of the classical era as well, for their lack of a rationally-based, self-consistent understanding of nature. And this may also represent a veiled criticism of Carneades both in his actual existence as the Greek sceptic and scholarch or head of Plato's Academy in the third and second centuries BCE, and in his present reincarnation as Boyle's *alter ego* in the debate now in progress.

Continuing with his Aristotelian theme, Themistius likens the philosophical system constructed by Aristotle with that of an arch, the individual stones of which would be 'perhaps defenceless [affording no defence or protection]' (19.9), if they were not 'sufficiently secur'd' (19.9-10), by the structure of which they form an integral part. He goes on to state how 'harmonius' (19.15) Aristotle's doctrine of the elements is in relation to the other parts of his philosophy and 'how rationally he has deduc'd their number'[11] (19.18) from the 'combinations of the four first Qualities'[12] (19.19-20). Not only these but many other 'Principles and *Phaenomena* of Nature' (19.23-24) which 'so conspire [act in purposive combination] with his Doctrine of the Elements' (19.24-25) that they reinforce each other.

[11] In logic, deduction is a rigorous proof or derivation of one statement (the conclusion) from one or more statements (the premisses).

[12] The four qualities Themistius seems to have in mind are the opposing pairs of wet/dry and hot/cold which in various combinations constitute the four Aristotelian elements.

Themistius goes on to say that those who believe in the four-element system 'value Reason so highly' (20.1-2) and are possessed of sufficient rational arguments 'to be satisfi'd' (20.4) that there are indeed four elements, even though no one has ever made any 'sensible [easy to perceive, evident] tryal' (20.6) to find out just how many there are. Even so, they are 'not destitute [completely lacking] of Experience' (20.7-8) in convincing others more influenced by 'their senses then [than] by Reason' (20.10).

Continuing with his argument in favour of reason over experiment he makes a somewhat ironic statement by citing the 'testimony of Experience when I shall have first advertis'd [advised] You' (20.11-13) that if men were as 'perfectly rational' (20.14) as their self-image might expect, then the 'sensible [of or pertaining to the senses or sensation] way of Probation [the act of proving or testing]' (20.15-16) would be as unnecessary as it is flawed. And further extolling the superiority of the rational over the experimental approach to the investigation of nature, he says that it 'is much more high and Philosophical to discover [show, reveal] things *a priore*, then [than] *a posteriore*' (20.17-19).[13]

However, it might be objected against Themistius' argument that if things are to be known *a priori*, or prior to experience, then knowledge of them does not depend for its authority upon the evidence of experience, but such knowledge is not intrinsically superior to that obtained by experience, rather that the two forms of knowledge are

[13] Knowledge is said to be *a priori* (literally: prior to experience) when it does not depend for its authority upon the evidence of experience, and *a posteriori* when it does so depend.

complementary with knowledge of things obtained by experience following on from, and in part at least derived from, certain things which are taken for granted, accepted as given, or understood as axiomatic, that is to say, things prior to experience.

Yet Themistius is not committed to accepting knowledge of certain things, such as the existence of four elements, as capable of being known *a priori*, defending his position in the face of any objection by those insisting on an experimental approach to the acquisition of knowledge about the natural world, although he is willing to acknowledge that the 'Peripateticks [Aristotelians] have not been sollicitous [eager] to gather Experiments to Prove their Doctrines' (20.21-22). Nevertheless he admits that a few such demonstrations have been made – not in an effort to reinforce their beliefs – but rather 'to satisfie those not capable of a Nobler [surpassingly better] Conviction' (20.24-25). He makes a clever, if unkind, implied comparison between the slower-witted students of astronomy and his philosophical adversaries. Astronomers (and by implication non-Peripatetic philosophers) must 'descend to the capacities of such as must be taught by their senses' (20.29-21.1-2). In the case of astronomers they do so by using 'Sphaeres of pasteboard'[14] (20.28-29) which are employed as a teaching aid to assist those who are incapable of 'being arrived to a clear apprehension of purely Mathematical Notions and Truths' (21.2-4).

Themistius says that he is speaking in this way 'only to do right to Reason, and not out of Diffidence [distrust] of the Experimental proof I am to alledge [to cite or quote as to confirm]' (21.5-8), by which he seems to mean that although he is confident that reason

[14] Pasteboard is a stiff but pliable material made by pasting three or more sheets of paper together.

does supply all the proofs needed in relation to the matters under discussion, experimental evidence also can be confidently deployed to provide further proof in addition to that provided by reason alone. He goes on to offer his experimental proof for the four Aristotelian elements, which are as ‘Satisfactory’ (21.11) as others are ‘needless’ (21.10-11). The experiment comprises a piece of ‘green-Wood burning in a Chimney’ (21.12-13): the ‘fire discovers it self in the flame’ (21.17-18); the rising smoke vanishes ‘into air’ (21.20); water manifests itself ‘boyling and hissing’ (21.24) at the end of the burning stick; and the ashes by ‘their weight, their firiness, and their dryness’ (21.27-28) show that they constitute the ‘Element of Earth’ (21.29-22.1).

Themistius then resorts to flattering his fellow interlocutors, realising that they are not about to be satisfied or won over by the understanding of the elements which is based on a purely rational account, subsequently vindicated by the decomposition products of physical bodies. He says that if his hearers were ‘less knowing [knowledgeable]’ (22.2), he could make an excuse for producing his elemental theory on ‘such an obvious and easie *Analysis*’ (22.4-5). Fearing such an approach to be ‘injurious’ [detrimental, deleterious]’ (22.5) and ‘needless’ (22.6) to them because they are ‘too judicious [having sound judgement]’ (22.7) ‘to prove obvious truths should be farr fetch’d’ (22.8-10), or ‘to wonder [to doubt]’ (22.10) that a wide range of compound bodies can be constituted from four elements, and that some of these materials ‘should upon a slight *Analysis* manifestly exhibit the Ingredients they consist of’ (22.13-15). What Themistius seems to be admitting is that intelligent, thoughtful, cautious men, well versed in philosophy and, perhaps also, science, are unlikely to be readily convinced of the fundamental constituents of material bodies by the burning of a freshly cut stick in a fire and a facile description of its decomposition products. Themistius adds that a straightforward analysis into primary constituents 'is very agreeable to the Goodness of Nature' (22.15-16), by which he seems to mean that the possibility of an uncomplicated, almost effortless, analysis of compound bodies would lend weight to the understanding of nature as producing such materials directly from simple ingredients. He adds that 'A Truth so important' (22.18-19) should not be lost on them.

Building on the notion of the fundamental simplicity of nature being manifest in the analysis of compound bodies, Themistius says that the 'more obvious [plain and evident]' (22.21) an analysis is the more evident is the 'Nature of that Doctrine which 'tis alledged [cited or quoted as to confirm] to prove' (22.23-24). Which doctrine 'being as clear and intelligible to the Understanding as obvious to sense' (22.25-27), he says 'tis no marvail the learned part of Mankind should so long and so generally imbrace it' (22.27-29). Themistius seems to be arguing that if thermal analysis of a piece of wood (for example) reveals as decomposition products to the *eye* of the observer the starting materials of which the wood is constituted, then this fact is equally obvious to the *mind* of the observer. And when both senses and intellect are as one in accepting this analysis, it represents an understanding of nature which is so manifestly evident as to be accepted as true by most, if not all, educated people.

Themistius goes on to draw a curious comparison between the Aristotelian doctrine of the four elements and those of the Paracelsians, and others. He says that the former 'is very different from the whimseys [whims] of *Chymists* [Paracelsians]' (23.1-2), and, not sparing any of the company, includes Carneades (though not mentioning him by name) referring instead to 'other Modern Innovators' (23.2). He compares the more recent hypotheses with the observations 'Naturalists do of less perfect Animals' (23.4-5) which being 'hastily form'd' (23.5) as a result 'are commonly short liv'd' (23.6). He argues that such doctrines 'are often fram'd in one week' (23.7-8), but may be considered a laughing stock the next, and 'being built perchance [perhaps] but upon two or three Experiments are destroyed by a third or fourth' (23.9-12). Themistius is here making a veiled criticism of the inductive method being developed in Boyle's scientific research in which general conclusions are drawn from a necessarily limited number of experiments. This process may lead to false conclusions, a situation Themistius contrasts with that of Aristotle, who had 'leasurely considered those Theories of former Philosophers' (23.14-15), which theories have now been 'with great applause [acclamation] revived' (23.16).

In fact Themistius presents Aristotle as a thinker whose careful evaluation of those theories on the elements in circulation in his own time caused them to be corrected by him and handed on to posterity. So much so that his doctrine on the elements has subsequently been 'embraced by the letter'd [learned or educated] part of Mankind' (23.22-23). Aristotle, in deliberating on the thinking on the elements of earlier philosophers, perfected a doctrine which, by virtue of its truth, stands for all time. Until, that is, '*Paracelsus* and some few other sooty Empiricks, rather then [than] (as they are fain [eager] to call themselves) Philosophers' (24.1-4) came along and 'began to rail [complain bitterly or vehemently]' (24.7) at Aristotle's doctrine which they were 'too illiterate [without book-learning or education] to understand' (24.8-9). The reason for their behaviour being because of their 'having their eyes darken'd, and their Brains troubl'd [agitated] with the smoke of their own furnaces' (24.4-6).

Themistius continues that the Paracelsians and other like-minded workers, possessed as they were of deficient intellectual capacities, began to tell 'the credulous World that they could see but three Ingredients in mixd Bodies' (24.9-11). And in order to claim the reputation of 'Inventors [discoverers] they endeavoured to disguise [transform] them by calling them, instead of Earth, and Fire, and Vapour, Salt, Sulphur, and Mercury' (24.12-15). They gave these the 'canting [here employed contemptuously to mean: using a secret language] title of Hypostatical Principles' (24.16-17).

Now comes the unkindest cut of all: in disagreeing with one another as to what these terms meant they disagreed equally 'from the truth they agreed in opposing' (24.21-22). Heaping scorn upon insult Themistius draws a comparison between the obscurity of their three principles and that of their 'Processes; and 'tis almost as impossible for any sober [having a serious mind or purpose] Man to find their meaning as 'tis for them to find their Elixir'[15] (24.23-26).

The vacuous nature of the Paracelsian doctrine is reiterated by Themistius' saying that it is disseminated only by 'their great Brags and undertakings [guarantees or sureties]'

[15] In alchemy, an elixir is a preparation by the use of which it was sought to change metals into gold. Sometimes identified with the philosophers' stone.

(24.28), and dismissing their efforts as having produced nothing ‘worth wondering at’ (25.2-3). They have, he concedes, managed ‘to draw *Philoponus* to their parts [interests or concerns]’ (25.3-4), and setting him a fool’s errand in causing him to defend an ‘unintelligible *Hypothesis*’ (25.5-6). Philoponus, he argues, knows full well ‘that Principles ought to be like Diamonds, as well very clear, as perfectly solid’ (25.7-9).

Themistius’ silence indicating that ‘He had finished his Discourse’ (25.12), Carneades addresses himself to Eleutherius, and without any delay delivers a withering opinion on the narrative he has just heard, saying that he had ‘hop’d for [a][16] Demonstration’ (25.15), only for Themistius to be put off ‘with a Harangue [a formal or pompous speech]’ (25.17), and adds that ‘he cannot have given me a greater Opinion of his Parts [involvement, interests, concerns] then [than] he has given me Distrust [lack of confidence] for his *Hypothesis*, since for it even a Man of such Learning can bring no better Arguments’ (25.17-22). It is as though the Aristotelian doctrine, no matter how adroitly it is presented or explained, will never be seen by Carneades as anything but an intrinsically unreliable and untrustworthy account of the elements.

Carneades now begins a more detailed response to what he has just heard by saying that he is ‘designing [contriving]’ (25.24-25) to examine only the ‘Argumentative [logical] part’ (25.25-26), leaving Philoponus to reply to the sections concerning ‘*Paracelsus* or *Chymists*’ (25.27-28). Carneades says he will ‘observe to You’ (25.29) the two things that Themistius is at pains to do: the first is to devise and explain ‘an Experiment’ (26.3) which will ‘demonstrate the common Opinion’ (26.3-4) concerning the four elements.

[16] Added in the *Errata*.

The second is ‘to insinuate [to introduce by subtle means] divers things which he thinks may repair the weakness of his Argument, from Experience’ (26.6-8), and by other means bring some credence to his ‘otherwise defenceless [indefensible] Doctrine’ (26.9-10).

Carneades begins by considering the experiment with the burning stick which seems to him ‘to be obnoxious [harmful] to not a few considerable Exceptions’ (26.13-15). His first objection is a favourite objection of Boyle’s – that it cannot be taken for granted that fire simply divides compound materials into their elemental ingredients, without in any way interacting with those same materials. He queries Themistius’, and others, method of ‘Probation [the act of proving of testing]’ (26.19) by which they, without the least scruple, ‘evince [make evident]’ (26.20) the four elements of earth, air, fire and water, and that ‘the former sort of *Concretes*’ (26.26), can be separated by fire into what they take to be ‘the Elements’ (26.28).

Carneades, in not wishing to ‘Anticipate’ (26.29) what he is to say later in relation to Philoponus’ opinion on fire as ‘the proper and Universal Instrument of Analysing mixt Bodies’ (27.4-5), if he were inclined to ‘wrangle [argue]’ (27.7) he might ‘alledge [cite of quote as to confirm]’ (27.7) that by Themistius’ experiment ‘it would appear rather that those he calls Elements, are made of those he calls mixt Bodies, then [than] mix’d Bodies of the Elements’ (27.8-12). What Carneades seems to mean here is that what Themistius identifies as elements in his burning-wood experiment are not in fact pure elements but compound bodies, and moreover Themistius cannot even be sure that these decomposition products are themselves comprised of the elements, but rather of materials more complex than these.

He goes on to explain it by saying that 'in *Themistius's* Analys'd Wood' (27.12-13) and in other bodies subjected to thermal decomposition 'it appears and he confesses [acknowledges]' (27.14-15) that what he understands to be fire and water 'are made out of the concrete [*i.e.* the wood] but it appears not that the Concrete was made up of Fire and Water' (27.16-19). Carneades says that it appears that neither Themistius, nor anybody else of 'his perswasion' (27.20-21) has ever been able to prove that anything can be obtained 'from a Body by the fire that was not *Pre-existent* in it' (27.22-23).

This 'unexpected objection' (27.24) 'surpriz'd' (27.26) all of the company, but Philoponus 'conceiving [taking into, or forming in, the mind] his opinion' (27.27-28) as well as that of Aristotle, 'concern'd in that Objection' (27.28-29) dismisses the opinion just presented as no more 'then [than] as an Exercise of wit [intellect]' (28.3), and places no 'weight upon it' (28.4). He then goes on to quote an experiment in support of his case, that of the separation of two metals, by which he wishes to demonstrate that a given material cannot be separated from a mixture in which it is not already present.

The example Philoponus gives involves the ancient process of cupellation, in this case, of lead and gold. The metals are placed in a bone-ash cup or cupel and subjected to 'the violence of the fire' (28.9) with a forced draught blown over the surface by means of a bellows. The lead is the first to melt (at 327^{o}C) with much stronger heating required to melt the gold (at 1064^{o}C) to form 'pure and refulgent [gleaming or lustrous] gold and lead' (28.10-11). The lead oxidises to form lead monoxide, which at lower temperature forms the yellow *massicot*, and this when heated above its melting point (886^{o}C) forms reddish-yellow scales of *litharge*, which floats on top of the molten gold, hence 'the Dross of the Gold is thence call'd *Lithargyrium Auri* [litharge of gold]' (28.12-13). The gold does not oxidise but forms a molten globule at the bottom of the cupel. Because two distinct substances, gold and litharge, results from this process, Philoponus asks how any man can question 'that they were existent in it before it was committed to the fire' (28.15-17).

Carneades adopts a rather mocking tone in his reply to Philoponus by saying that he would allow the latter's 'argument to prove something' (28.19) if lead and gold in 'mak[ing] the Mass you speak of' (28.21-22) we had seen 'Nature pull down a parcel of the Element of Fire, that is fancy'd to be plac'd I know not how many thousand Leagues off,[17] contiguous to the Orb of the Moon' (28.22-26). Carneades is here referring to the Aristotelian system of the elements in which the element fire exists as a layer between the top of the air and the orbit of the moon. So some fire, he argues, would have to come down from this firey layer and be blended with 'a quantity of each of the three other Elements' (28.27-28) out of which every 'mixt Body' (28.29) is produced. When such bodies are heated in the fire the four Aristotelian elements 'Fire, and Earth, and the rest' (29.1-2) are regenerated.

[17] A league is a distance of about three miles, or five km.

Continuing with his example of these four elements, Carneades returns to his objection that fire may itself interact with the materials it is supposed to be separating. He says to Philoponus that to make his ‘Reasoning cogent’ (29.3-4) he would have first to prove ‘that the fire do’s only take the Elementary Ingredients asunder, without otherwise altering them’ (29.4-7). He argues that if this were not the case then substances could be obtained from bodies which were not ‘pre-existent in them’ (29.9), ‘as flesh too long kept produces Magots, and old Cheese mites’ (29.9-11).

Carneades makes a second objection to Philoponus’ account of the separation of bodies by the fire by arguing that in the cupellation of gold and lead the ‘fire do’s not always barely [merely] separate the Elementary parts, but sometimes at least alter also the Ingredients of Bodies’ (29.13-16). There is ‘nothing Elementary’ (29.19-20) separated, in the example given by Philoponus, as the Gold and Lead resulting from his analysis are ‘confessedly yet perfectly mixt Bodies’[18] (29.23-24). Carneades does recognise that the cupellated lead is no longer the familiar dense grey metal, but that ‘the Litharge being Lead indeed’ (29.24-25) it differs ‘in consistence and other Qualities from what it was before’ (29.26-27). However, rather than pursue the matter further, he goes on to say how he has sometimes seen and ‘so questionlesse [without question]’ (29.29), even more frequently had Philoponus, ‘some parcells of Glasse adhering to the Test or Cuppel’ (30.1-2), and that this glass, even though it seems to emerge as an ingredient of

[18] Boyle did not recognise either gold or lead as elements – they do so appear in Lavoisier’s Table of the Elements of 1789.

the analysis will, Carneades holds, not be taken by Philoponus as a 'third Ingredient of the Mass out of which the fire produc'd it'[19] (30.6-7).

Just as we are about to witness a full-scale acrimonious debate on the connection between Aristotle's cosmology, his four elements and material bodies, Eleutherius as moderator of the discussion adroitly defuses the situation by reminding Carneades that when he 'first propos'd this Objection' (30.15) he at least half-promised that he would not, at this time, 'insist [make his stand] on it' (30.16-17), and that it is not necessary for his position that he should do so. Eleutherius then makes the point that even if Carneades accepts that there are elements, it does not automatically follow that 'there must be precisely four' (30.21).

Eleutherius invites Carneades to continue with his objections against the Aristotelian system of the elements as expounded by Themistius, and suggests an objection he might raise against it. He says that such an objection might stand given that there is 'so great a Disproportion in Bulke betwixt the Earth, Water and Air' (30.26-27), on the one hand, 'and those little parcells of resembling substances, that the fire separates from *Concretes*' (30.28-31.1), on the other. What Eleutherius seems to be referring to here is the considerable gap between the elements assigned to the decomposition products of organic materials and their putative exemplars. He then says that he finds it hard to believe that Carneades 'when to lose no [any] advantage against your Adversary' (31.3-4) seems to deny it to be rational, 'to conclude these great simple Bodies to be Elements,

[19] It is not clear how this glass comes to be in the cupel. Two possible explanations are that it was: (i) flakes of litharge fused together to give a glass-like mass, or (ii) some sand in the cupel which fused at high temperature to form beads of silica.

and not the Products of compounded ones' (31.5-7), by which Eleutherius seems to mean that Carneades could logically reject the four Aristotelian elements as true elements and simply dismiss them as the decomposition products of compound bodies.

Carneades takes Eleutherius up on one of the questions on the elements just posed by him: that 'the Vastness of the Earth and Water' (31.9-10) has led him to accept these as constituting 'the greatest and chief Masses of Matter to be met with here below' (31.11-13). However, this does not prove that they are 'such Ingredients as every mixt body must consist of' (31.18-20), but rather proves only that the elements (*i.e.* earth and water) as Eleutherius calls them, are no more than what they appear to be – large bodies of matter. Carneades reverts to the half-promise already mentioned by Eleutherius and says that he now will 'willingly perform it' (31.22-23), although he did not initially intend 'to insist on it at present against *Themistius*' (31.25-26), his reason for this being, that although he could understand his advantages, he did not see the need to appear as 'a rigid Adversary of a Cause so weak' (32.2-3) which will 'safely be favourably dealt with' (32.3-4). He does 'profess' (32.5) that although willing to move on to another argument 'it is not because I think this first invalid' (32.7-8). Carneades says that Eleutherius will find that he has 'reason to question the very way of probation [testing]' (32.10-11) employed by both Peripatetics and Chymists to 'evince [make evident] the being and number of the Elements' (32.13-14). That there are elements and that they can be 'separated' (32.15) by thermal analysis Carneades says is accepted by both parties. However, the reality of the elements has not 'been so much as plausibly attempted to be proved by either' (32.18-20).

Before moving on to debate a further point, an exchange occurs in which Carneades requests that Eleutherius 'will remember what I have now said' (32.24) in which he will 'rather for a while suppose, then [than] absolutely grant the truth of what I have question'd' (32.25-27). Eleutherius assures him that he will keep in mind what his fellow-interlocutor has just stated 'when time should serve [be favourable or suitable]' (33.1-2).

Reverting to his objections to the Aristotelian doctrine of the elements, Carneades says that there are 'divers Bodies' (33.5-6) from which Themistius, using fire, will be able to 'prove in haste' (33.7) the presence of four elements. He then adds that he 'should perchance [perhaps] trouble him'[20] (33.9-10) were he to ask him what Aristotelian can produce, not his four elements, for that would be 'too rigid [harsh or exacting] a Question' (33.12-13), but even to extract 'any one of them' (33.13) out of gold using 'any degree of Fire whatsoever' (33.14-15).

Pressing home his advantage Carneades lists some other 'Concretes' (33.21) such as 'both Silver and calcin'd *Venetian* Talck'[21] (33.20) not only would metals and minerals fail to separate into their four elements by the 'Disciples of *Aristotle*' (33.26), but also 'those of *Vulcan* [the Roman god of fire and metalworking]' (33.26-27) who using fire, have been unable 'to make the *Analysis*' (33.28).

[20] Here 'trouble' may have both the polite sense as an apology for asking that something be done on his behalf, and also the meaning of to cause discomfort or disturbance to him for asking him to perform an impossible task.

[21] Talc is a white or pale green form of magnesium silicate. Calcination is a process in which metals are heated to high temperatures and oxidised. Here, Boyle probably means that the talc was heated strongly.

Carneades' final, and perhaps, clinching argument is that, on the one hand some substances, and he probably has in mind here metals and minerals, will not separate into four elements, whereas on the other hand some materials – and he refers here to organic substances, that is those obtained from living things – can be divided into five. These organic substances he lists as 'the Blood (and divers other parts) of Men and other Animals' (34.8-9), and the decomposition products of these materials he names as 'five distinct Substances, Phlegme [an aqueous liquor] Spirit, Oyle, Salt and Earth' (34.10-11). Not only this but certain organic materials such as 'Mans Blood, Harts-Horns' (34.13) cannot readily yield a solid fraction separated from them – they 'abound with not uneasily sequesterable [separable] Salt [here: a solid fraction]' (34.15-16).

A Commentary on
The Sceptical Chymist
of Robert Boyle:
The First Part

Introductory Remarks

The dialogists have been reduced to two: Carneades and Eleutherius. Carneades presents four propositions on the production of the corpuscles from the primal matter of creation and their acquisition of motion through divine agency, their agglomeration, with the possibility of decomposing compound bodies composed of the corpuscles into distinct elemental substances (37-46).

Quoting Boas (*q.v.*), this first part of the book 'argues that fire is not the genuine universal analyzing agent.' Carneades offers convincing proof in favour of this assertion by quoting experimental evidence, both his own and from others, that cold can act to separate alcoholic beverages into alcohol-rich and water-rich fractions (93-101), and in so doing calls into question the Aristotelian dictum on cold (93). He quotes the Aristotelian definition of heat (85), only immediately to propose a counter-definition based on his own Corpuscular Hypothesis, offering some actual examples to substantiate his assertion (85-93).

The Sceptical Chymist.

The First Part.

Boyle sets out on the chapter's title page the title of the work – 'The Sceptical Chymist:' – followed by the sub-title. In so doing he may simply be expanding on what he means by his chosen title, for straight away he makes it clear to the reader that his 'Doubts & Paradoxes' are of a 'chemico-physical' nature, thereby setting out the context or framework in which the book is to be written, and that is, in the context of the new scientific outlook, which Boyle espoused, rather than that of a more traditional one. He makes no mention of attacking or even doubting any doctrine which would probably necessitate some kind of a verbal assault on the despised belief system of his adversaries. Instead, he intends to subject their 'experiments' to the scrutiny befitting one who is committed to utilising experiment, in combination with reason, in attempting to understand the workings of the created world. And the system he intends to contest is that based on Paracelsus' three principles of 'salt, sulphur and mercury' and which the 'vulgar spagyrists' have adopted in their understanding of the constitution of matter and its functioning.

Curiously, there is no mention of the other system of the elements then widely accepted: that of the earth, air, fire and water championed by Aristotle and his medieval followers, even though it too is to be scrutinised in the discussion to come.

Finally, Boyle gives a quotation from Seneca which may be translated as follows: 'If only all things were already comprehended and not secret but undoubted truth! Let us change nothing by decree. We now search for truth with those who teach.'

Carneades begins the dialogue proper by stating that although he is 'resolv'd to make good the part I have undertaken of a Sceptick;' (35.4-5) he will temporarily lay aside 'the Person of an Adversary to the Peripateticks and Chymists' (35.7-9). He wishes to acknowledge to the reader what may be 'tollerably enough' (35.12) added 'in favour of a certain number of Principles of mixt [compound] Bodies' (35.13-14) to what he calls 'that grand and known Argument' (35.14-15) resulting from the analysis of compound materials, and which he may possibly 'confute [disprove]' (35.2).

He states that he will present what he has to say in the form of 'a pretty [appropriate] number of distinct Propositions' (36.5-6). He takes it for granted that Eleutherius (or the reader) 'need not be advertis'd [notified]' (36.9) that what he has to say, 'whether for or against a determinate number of Ingredients of mix'd Bodies' (36.10-12) may be 'indifferently [equally] applied to the four Peripatetick Elements [the earth, air, fire and water of Aristotle], and the three Chymical Principles [the salt, sulphur and mercury of Paracelsus]' (36.13-15). Carneades adds that 'Divers [various]' (36.15) of his objections will 'more peculiarly [specifically]' (36.16) be applied against the Paracelsian elements, because these are 'seeming to be more countenanc'd by Experience than the other' (36.18-19), and he will 'insist [take his stand on]' (36.20) mainly on the disproving of this one. He adds that most of the arguments applied against it may, with little change, 'be made to conclude [convince] at least as strongly against the less plausible, *Aristotelian* Doctrine' (36.24-26).

Carneades then gives the first of four propositions on the nature of matter, from its first production as Universal Matter (at Creation), to its initial subdivision into corpuscles, and the subsequent agglomerating of these into the material entities which participate in the production of material things.

In his first proposition Carneades says that the 'Universal Matter' (37.3) was 'divided into little particles of several sizes and shapes variously mov'd' (37.5-7). And here he introduces the two fundamental qualities which underlie the Boylean scheme of things, namely matter and motion, with matter, produced at the time of Creation, itself being subdivided into corpuscles of different sizes and shapes, and with motion imparted to them through divine agency.

Carneades believes that his account of the first production of matter as we know it is uncontroversial. Matter as 'parts very minute and of differing Figures' (37.20-21) is supplied by natural processes, microscopic examination of 'Concretes [compound bodies]' (37.15), by 'Chymical Resolutions of mixt [compound] Bodies' (37.16-17) and through other 'Operations of Spagyrical Fires [thermal analysis] upon them' (37.17-18).

He now discusses the question of motion, which quality he wishes to assert was imparted to matter by Divine intervention, in contradistinction to Epicurus who held that random motion was inherent to atoms, thereby denying a role to the Creator in the origin of motion, and allowing critics to ascribe a secular starting point to his account of the twin principles of matter and motion. Carneades attributes the 'Origine of Concretions' to either Epicurus or to Moses.[1]

Carneades goes on to speak of the 'inspir'd Historian [author of the Old Testament of the Bible]' (38.6) and how 'the great and Wise Author of Things' (38.7-8) produced plants and animals from 'pre-existent, though created, matter, that he calls water and earth' (38.11-12), thereby showing his own belief in the Biblical earth and water as the Primal Elements. He underscores his belief that motion was introduced into matter through Divine action, and Carneades, happy now that his first proposition need no longer be 'insisted [maintained persistently] on' (38.21) moves on to state his second one.

In his second proposition he describes the aggregation of the primary particles 'into minute Masses or Clusters' (38.26) which cannot easily be decomposed into their constituent particles. Carneades, quick to assert that this preposition on matter is 'deduc'd'[2] (39.4) 'from the Nature of the Thing it self' (39.5-6), meaning that it was arrived at by rational means, then goes on to relate some of the information obtained about the behaviour of metals by experimental means. And although he acknowledges that such information has not been so employed heretofore, nevertheless to him it

[1] Moschus or Moschus of Sidon who lived about 1200 BCE and to whom some trace the origin of ancient atomism. He came to be identified with the Biblical Moses by some seventeenth-century authors.

[2] Deduction is a species of argument or inference where from a given set of premises the conclusion must follow.

'seems to me more fairly [clear, positive] to make out that there May be Elementary Bodies, then [than] the more questionable [of doubtful quality] Experiments of Peripateticks [Aristotelians] and Chymists [Paracelsians] prove that there Are such' (39.9-13).

He goes on to detail some experimental evidence drawn from the manipulation of metals. He speaks first of how gold may be 'colliquated [melted or fused together] not only with Silver, Copper, Tin and Lead, but with Antimony, *Regulus Martis* [iron as produced in the smelter] and many other Minerals' (39.14-17). The combination of gold with these materials will result in a mixture or alloy, quite distinct from both gold and the other ingredient in question. Carneades then goes on to describe 'knowingly [referring to personal experience]' (39.22) how gold may undergo dissolution with '*Aqua Regis* [a mixture of hydrochloric and nitric acids]' (39.21) and various other '*Menstruums* [solvents]' (39.23) which solutions can pass through 'Cap-paper [filter paper]' (39.26) and 'with them also coagulate into a Crystalline Salt' (39.26-28).[3]

Carneades goes on to state that he has managed to prepare a gold compound. He says that 'with a small quantity of a certain Saline Substance I prepar'd, I can easily enough sublime Gold into the form of red Crystals of a considerable length' (40.1-4).[4] He then

[3] The other *Menstruums* or solvents Carneades has in mind here is not clear, as very few materials react with gold, and reactants such as selenic acid were unknown in Boyle's day. Gold does, however, react with fused alkalis, so perhaps he reacted it with fused sodium hydroxide. It also reacts with chlorine water (for which see below).

[4] Boyle may have prepared the deep-red crystalline auric chloride by evaporating a solution of gold in chlorine water, and heating at 150^{o}C. He could have prepared chlorine by reacting nitric acid with ammonium chloride in the cold, when a mixture of nitrosyl chloride and chlorine gas is evolved. The chlorine readily dissolves to form chlorine water, and the nitrosyl chloride is decomposed by water.

refers to the fact that it is possible to produce a variety of different compounds of gold through chemical reaction. Carneades understands that gold is present in all of the products derived from it as he refers to the gold's being 'disguis'd' (40.5) in these materials. That gold compounds are easily reduced to the metal by heating, is referred to by him when he says that the gold can be regenerated as the 'self-same Numerical, Yellow, Fixt, Ponderous and Malleable Gold' (40.9-11).

Carneades describes gold as the 'Fixedst [most unreactive]' (40.12) and 'Quicksilver [mercury]' (40.14) as the 'most fugitive [here: reactive]' (40.13) metal, and then lists many of the ways in which mercury can combine with several other materials. It will with 'divers [various] Metals compose an *Amalgam* [alloy or mixture of metals]' (40.15-16); 'with divers *Menstruums* [solvents] it seems to be turned into a Liquor' (40.16-17) whereby Carneades seems to be referring to the fact that in certain acids, such as concentrated sulphuric acid and in *aqua regia* (a mixture of hydrochloric and nitric acids) it dissolves, as well as in dilute nitric acid. He states that mercury with '*Aqua fortis* [nitric acid] will be brought into either a red or white Powder or precipitate'[5] (40.17-19).

Of course auric chloride can also be prepared by reacting gold with a mixture of hydrochloric and nitric acids to form the yellow crystalline chlorauric acid, which decomposes at 120°C to give the deep-red auric chloride.
The latter reaction would have been common knowledge in Boyle's day, whereas Carneades seems to be referring to a process known only to himself.
[5] Carneades here seems to be referring to the reaction of cold dilute nitric acid on excess of mercury to form colourless crystals of mercurous nitrate. When this material is added to water it gives a white precipitate of basic mercurous nitrate. This solution then oxidises, by excess of water, into the red crystalline mercuric oxide.

He continues that with 'Oyl of Vitriol [sulphuric acid]' (40.20) mercury is converted into a 'A Pale Yellow' (40.20) precipitate,[6] Carneades says that mercury with sulphur 'will compose a blood-red and volatile Cinaber' (40.21-22), a reference to the reaction of sulphur and mercury to form mercuric sulphide, and with 'some Saline Bodies it will ascend to form a Salt which will be dissoluble in water'[7] (40.22-24).

Carneades then says that 'with *Regulus* of Antimony [antimony metal] and Silver I have seen it [mercury] sublim'd into a kinde of Crystals' (40.25-27), which may somehow refer to the formation of volatile amalgams with these metals. He goes on to relate that 'with another Mixture I reduc'd it into a malleable Body, into a hard and brittle Substance by another' (40.27-29). Again these may be references to the formation of amalgams of differing hardness depending on the metal with which it amalgamates, as mercury penetrates copper sheet, for example, rendering it brittle.

Carneades goes on to give second-hand accounts of the reduction of mercury 'into Oyl, nay into Glass, to mention no more' (41.3-4), which may also be references to the production of physical mixtures formed by the mixing of mercury with, for example, fats or sugar. His point being, that despite the range of products obtained by reacting or

[6] This is probably a reference to the formation of the white crystalline mercuric sulphate, prepared by boiling mercury with concentrated sulphuric acid. Mercuric sulphate with a small amount of water gives colourless crystals, which with more water hydrolyses at 25^{o}C to form a yellow crystalline, sparingly soluble powder of the basic sulphate, formerly called *turpeth mineral*.

[7] What Carneades is referring to here is unclear, but he may be referring to the formation of, for example, the almost insoluble mercurous chloride (*calomel*), formed as a white precipitate on adding mercurous nitrate solution to excess of hot sodium chloride (common salt) solution, or by subliming a mixture of mercuric chloride and metallic mercury (prepared by grinding the substances together in a mortar) in an iron pot.

mixing mercury with other materials, the ‘running Mercury’ (41.6) was ‘disguis’d’ (41.8) in these products, and could be recovered from them.

He then explains that in giving an account of the various material combinations which gold and mercury entered into and yet were retrieved, his purpose was to illustrate his understanding of how bodies such as these two metals may be composed fundamentally of assemblages of smaller particles, yet during chemical and physical transformations these agglomerations of particles remain as particulate assemblages and do not break down into their primary corpuscles. Carneades says that ‘such little primary Masses or Clusters, as our Preposition mentions, may remain undissipated’ (41.12-15), even though they form ‘various Concretions’ (41.16-17), and despite not consisting of ‘primary Concretions of the most minute Particles of matter, but confessedly Mixt Bodies’ (41.18-21), may form a multitude of mixtures and reaction products without ‘losing their own Nature or Texture, or having their cohaesion violated by the divorce of their associated parts or Ingredients’ (41.23-26).

Eleutherius, as if to reinforce Carneades’ argument, makes an interjection in which he berates the Aristotelians for not exploiting the possibilities offered by their four-element system, for no other reason than for their unwillingness to carry out a greater number of experiments designed to vindicate it. He argues that from four elements a large number of compound bodies could be produced, then goes on to connect this with the huge variety of material types which are possible from the basic variations in corpuscular types and in the differing proportions in which the corpuscles can be combined.

Eleutherius maintains that the claim which some ‘Chymists, and other modern Innovators’ (42.1) are inclined to make against the four-element system of the ‘Peripateticks’ (42.3), that is, of earth, air, fire and water, and which could form ‘but an inconsiderable [not considerable] variety of compound Bodies’ (42.5-6), could readily be shown to be mistaken but ‘for want of Experiments they are fain [glad] to suffer [allow] it to do’ (42.10-12). Of course Eleutherius, not content merely to point up the shortcomings of the Aristotelians in relation to their unwillingness to incorporate an adequate experimental programme into their philosophical outlook, chides them also for not being ‘half as well vers’d in the works of Nature as they are in the Writings of their Master’ (42.7-9).

In considering the various combinations capable of being entered into by the corpuscles – which themselves vary in ‘size and shape’ (42.14) – he says that they ‘may be mingled in such various Proportions’ (42.16-17), and then adds another variable factor by saying that they ‘may be connected so many several wayes’ (42.18). The result being that ‘an almost incredible number of variously qualified [imparting various qualities to] Concretes [compound bodies] may be compos’d of them’ (42.19-21). Further distinctions may be introduced by variations in the ways in which the corpuscles may be agglomerated, in that the ‘Corpuscles of one Element may barely [merely] by being associated among themselves, make up little Masses of differing size and figure from their constituent parts’ (42.21-25).

Eleutherius then seems to state that a further variation between compound bodies may be effected simply by bonding the minute masses of corpuscles in different ways, when he states that 'to the strict [tight, close] union of such minute Bodies there seems oftentimes nothing requisite [necessary] besides the bare [mere] Contact of a great part of their Surfaces' (42.26-29). And returning to his discussion of the four Aristotelian elements, he makes the argument that a single material can be manipulated in such a manner as to make possible a great variety of objects simply by altering the shape or spatial arrangement of bodies made from this one material. The example he offers is that of iron, and Eleutherius remarks 'how great a variety of *Phaenomena* [appearances] the same matter' (43.1-2) can show when 'only several ways dispos'd or contexed [formed or constructed]' (43.3-4) 'may partly appear by the multitude of differing Engines' (43.4-6). Instead of just one material, 'four very differently qualified [imparted with a certain quality] sorts of matter' (43.10-12) if one considers what Carneades 'freshly [recently] took notice of concerning the new Concretes [made up of various ingredients] resulting from the mixture of incorporated Minerals [a reference to the list of reaction products, from gold and mercury, just given by Carneades]' (43.13-15), one will hardly doubt what a large number of different materials may be produced from 'the four Elements mannag'd by Natures Skill' (43.16-17).

Carneades then speaks, launching another criticism of the Aristotelian scheme of the elements by arguing that if they considered their four elements as strictly material entities, then they could reasonably account for the existence of a large number of compound bodies simply by the admixture of these four elements. He argues that the

Aristotelians 'might with probability deduce a much greater number of compound bodies from the mixture of their four Elements' (43.20-23) than with their 'present *Hypothesis*' (43.24), 'if instead of vainly attempting to deduce the variety and properties of all mixt Bodies from the Combinations and Temperaments'[8] of the four Elements, as they are (among them) endowed with the four first Qualities' (43.25-44.1), they had instead 'endeavoured to do it by the Bulk and Figure of the smallest parts of those supposed Elements' (44.2-4). Carneades avers that from 'these more Catholick [universally prevalent] and Fruitfull Accidents[9] of the Elementary matter may spring a great variety of Textures, upon whose Account a multitude of compound Bodies may very much differ from one another' (44.4-10). And he adds that what he has said of the 'four Peripatetick [Aristotelian] Elements' (44.11) may be applied '*mutatis mutandis* [with the necessary changes having been made]' (44.12) to the 'Chymical [Paracelsian] Principles' (44.13-14).

He then goes on to say that more is required of the Aristotelians and Paracelsians than an account of material elements acting 'to excite [bring about] or regulate the motion of the parts of the matter' (44.17-19) and dispose them as necessary to the making up of compound bodies. He then continues to express his dissatisfaction with the Aristotelian understanding of the constitution of material bodies which they are 'wont [in the habit

[8] In the natural philosophy of the Middle Ages the combination of supposed qualities (hot or cold, moist or dry) in a certain proportion.
The four Aristotelian elements were each considered to result from the combination of a contrasting pair of qualities: earth – dry and cold; air – hot and moist; fire – hot and dry; water – moist and cold.

[9] In Aristotelian thought an accident is a quality which is not essential to the kind of thing in question.

of] to alledge' (44.28) from a 'certain substantial Form,[10] whose Origination they leave more obscure that what it is assum'd to explicate' (45.1-3).

Carneades moves on to state his third proposition on the elements, this time considering the elements as decomposition products of naturally occurring materials rather than as the building blocks from which they are composed. He acknowledges the possibility of the thermal decomposition of compound materials of 'Animal or Vegetable Nature' (45.7) into 'a determinate [definite, fixed] number' (45.9) 'of Substances, worthy of differing Denominations' (45.11-12). However, Carneades is careful to state that he is only willing not to 'peremptorily [emphatically] deny' (45.5) the separation of certain bodies into simpler substances, he does not say that he will not deny the proposition, following further analysis or consideration. And he goes on to say that he is likely to mention, later on, many of those 'Experiments that induce me to make this Concession' (45.13-14), and asks 'You [either his hearers or readers]' (45.18) to keep any such experiments in mind.

Carneades goes on to give his fourth proposition, in which he concedes that 'those distinct substances' (46.1-2) from which mixed bodies either consist of or are decomposed into, may 'without very much Inconvenience be call'd the Elements or Principles of them' (46.4-5). He explains why he employs the qualification '*without very much Inconvenience* [impropriety]' (46.6-7) by referring to 'the Admonition of

[10] In Aristotelian thought the substantial form is the structure or nature that is imposed upon undifferentiated prime matter to make the different kinds of substance in the world.

Galen,[11] *Cum de re constat, de verbis non est Litigandum* [with the matter agreed, it is not to be disputed verbally]' (46.8-9). He continues that 'I scruple [question the propriety of] not to say *Elements* or *Principles*' (46.10-11) in part because the 'Chymists [Paracelsians]' (46.12) call them '*Principles*' (46.13), whereas the Aristotelians call them '*Elements*' (46.14), both terms being acceptable to Carneades, and in part because both names refer to the fundamental constituents of material bodies, but viewed from different perspectives. 'Principles' as the simplest bodies possible, and 'elements' as the entities from which all compound bodies are composed.

He goes on to further explain that in 'Premising [mentioning or setting forth before something else] the words, *very much* to the word *Inconvenience* [impropriety]' (46.22-24) of calling these words '*Elements* or *Principles* be not very great' (46.27), still he considers it 'an *Impropriety* of Speech' (47.1) and as a result in a 'matter of this moment [significance]' (47.2-3) not to be completely overlooked. He adds that by 'that [the] time you shall have heard the following part of my Discourse' (47.5-6) one will be in a good position to judge 'the former Propositions' (47.8) and tell which of them are true, and which Carneades represents 'as specious [plausible, but in reality fallacious] enough to be fit to be consider'd' (47.11-12).

Carneades advises Eleutherius that he is about to 'resume the person of a Sceptick' (47.14-15), and if one takes this word to mean 'a seeker after truth, an enquirer who has

[11] Galen (129-199/200 CE) of Pergamum in modern Turkey, physician, biologist, philosopher and philologist, chiefly remembered for his contribution to medicine.

not yet arrived at definite conclusions',[12] one might well understand what Carneades next proposes, which is that he is willing to examine what may be 'either dislik'd, or at least doubted of' (47.16-17) in the *tria prima* – salt, sulphur and mercury – of the 'Chymist' (47.18) or Paracelsians. This, he assures Eleutherius, he is doing as a consequence of the 'Employment' (47.23) to which the company has 'for this Meeting, doom'd [condemned] me; then [than] either to my Humour [habitual state of mind] or my Custom [habitual or usual practice]' (47.24-26).

Carneades continues that of all the arguments he could offer against the 'three Principles' (47.29) and of the 'Experiments wont [accustomed, in the habit of] to be alledg'd as Demonstrations of it' (48.1-2) may be understood 'in four Capital Considerations' (48.4-5). He advises that he does not consider it necessary to 'assert an *Hypothesis* of my own, as to give an Account wherefore [because of which] I suspect the Truth of that of the Chymists' (48.8-10). He adds that his 'Objections' (48.12) may not be of the 'most cogent sort' (48.12-13) because he argues that 'it is reason enough to Doubt of a propos'd Opinion, that there appears no cogent Reason for it' (48.13-15).

Carneades' first objection is a favourite one of Boyle: that of his doubt that 'Fire ought to be esteem'd [considered] the general and universal Instrument of analysing mixt bodies' (48.21-23). He acknowledges that he has already made reference to this doubt, but says that it was 'so transiently [briefly] discours'd of, that it will now be fit to insist [persevere] upon it; And manifest [disclose, reveal] that it was not so inconsiderately [rashly] propos'd as our Adversaries then imagin'd' (48.25-29).

[12] OED online – consulted 02-08-2011.

Carneades notes that before proceeding further ‘into this Disquisition [investigation]’ (49.1-2) he says that it is to be wished that ‘our Chymists [Paracelsians] had clearly inform’d us what kinde of Division of bodies by Fire must determine the number of the Elements’ (49.3-6). The effect of fire on Bodies depends on the nature of the fire itself and how it is applied to the task in hand, Carneades sensibly points out. He says that determining how heat affects bodies ‘is nothing near so easy as many seem to think’ (49.7-8). The effects of heat he argues, he ‘could easily manifest [disclose, reveal]’ (49.9-10) if he had but ‘leasure to shew [show] you how much the Operations of Fire may be diversify’d [varied, modified] by Circumstances’ (49.10-12).

Carneades gives as an example the burning of ‘*Guajacum*’[13] (49.15) which when ‘burnt with an open Fire in a Chimney, is sequestered [separated] into Ashes and Soot’ (49.16-17), whereas when the same wood is ‘distill’d in a retort [closed container]’ (49.18) it yields ‘far other Heterogeneities [multifarious components]’ (49.19), being ‘resolv’d into Oyl, Spirit, Vinegar, Water and Charcoal’ (49.20-22). He goes on to say that if the charcoal is to be ‘reduc’d into Ashes, requires the being farther calcin’d then [than] it can be in a close [closed] Vessel’[14] (49.22-25).

[13] The hard and heavy, brownish-green wood of *Guajacum Officinale* and *Guajacum Sanctum*, used in medicine. Also called: *Lignum vitae* = wood of life.

[14] The distillation referred to here would involve heating the wood in a closed container, in a necessarily restricted supply of air. Consequently after losing its volatile components the wood would char rather than burn outright. Complete combustion, or calcination, would require heating the charred residue in an open container when it would eventually be reduced to ashes.

Carneades goes on to list some other observations made with bodies subjected to combustion in both open and closed containers. Over an open flame he 'kindled Amber [a yellowish, translucent fossil resin]' (49.25) and using 'a clean Silver Spoon' (49.26) or a different 'Concave and smooth Vessel over the Smoak of its [amber's] flame' (49.27-28) he observed the 'Soot into which that Fume condens'd' (49.29). He notes how much this differed from any of the decomposition products which the 'steam or Amber' (50.3) 'distilled *per se* [by itself] in close [closed] vessels' (50.4-5) yielded.

He goes on to give an account of the thermal decomposition of 'Camphire [camphor]'[15] which he 'kindled' (50.6), then 'catcht [caught] the Smoak that copiously ascended out of the Flame' (50.6-8). He found that it condensed into 'a Black and unctuous [oily, greasy] Soot' (50.8-9). That this was indeed a decomposition product from the combustion of the camphor, rather than a fraction simply separated from it through heating, is indicated by Carneades' saying that the 'unctuous Soot, which would not have been guess'd by the Smell or other Properties to have proceeded from Camphire [camphor]' (50.9-12). He then details how he heated the same 'Fugitive [volatile] Concrete' (50.14) only now 'to a gentle heat in a close [closed] Glass-Vessel' (50.14-15). This time he found that the camphor 'sublim'd[16] up without seeming to have lost any thing of its nature' (50.16-17), meaning that the heating did not cause it to undergo any thermal decomposition. Later, he increased the heat 'so as to bring it to Fusion' (50.19-20), that is, to melt it.

[15] A product obtained from various plants, including the camphor laurel (*Cinnamomum camphora*).
[16] To sublime a substance is to subject it to heat in a vessel so as to convert it into a vapour, which is carried off or up, and on cooling is deposited in solid form.

Carneades goes on to speak of 'Divers [various] other Bodies' (50.21) which, when heated in closed vessels, the heat would not usually make 'any separation of Heterogeneities, but only a comminution [reduction or breaking up into small fragments] of Parts' (50.23-25), the first fraction of volatiles to separate off 'Being Homogeneal [homogeneous] with the others, though subdivided into smaller Particles' (50.26-27). From this fact Carneades remarks that 'Sublimations have been stiled, *The Pestles of the Chymists*'[17] (50.28-29).

He then describes how sulphur may be treated by exposure to fire. He says that 'common Brimstone [sulphur] once or twice sublim'd, that expos'd to a moderate Fire in Subliming-pots, it rises all into a dry, and almost tasteless, Flowers'[18] (51.2-6). He goes on to say 'Whereas being expos'd to a naked Fire it affords store of a Saline and Fretting [corrosive] Liquor' (51.6-8).

Carneades next relates how fire affects the decomposition products of compound materials. The variable factors at play here being exposure to the air, and temperature. If they are 'expos'd to the open Air' (51.12-13) or 'shut up in close [closed] Vessels' (51.13), a different outcome is to be expected, and in addition the temperature or 'degree of Fire by which the *Analysis* is attempted [is] of no small moment [significance]' (51.14-15). Continuing with the effect of heat on the outcome of chemical procedures

[17] A pestle is a club-shaped instrument with a rounded head, used to crush or pound substances in a round dish or mortar.

[18] It is interesting to compare Boyle's description of the refining of sulphur with that of Partington: 'The sulphur fused in an iron pot flows into an iron retort. It boils, and the vapour enters a large brickwork chamber, where it condenses on the cold walls as a light yellow powder called *flowers of sulphur*. As the walls become hot this melts (unless removed) and liquid collects at the bottom, whence it is tapped into cylindrical moulds to form *roll sulphur* or *brimstone*' in: J.R. Partington, *General and Inorganic Chemistry*, 3rd ed. (London: Macmillan, 1958), 688.

he says that ‘a milde *Balneum* [bath] will sever unfermented blood (for Instance) but [no more than] into Phlegme and *Caput Mortuum* [inert residue]’ (51.15-18). This ‘later [latter]’ (51.18) which Carneades sometimes obtained, is ‘hard, brittle, and of divers [various] Colours’ (51.19-20) when ‘press’d [advanced with force] by a good Fire in a retort yields a Spirit, an Oyl or two, and a volatile Salt, besides a[19] *Caput Mortuum* [insert residue]’ (51.21-24).

He then goes on to discuss the production of soap, and says that it may be ‘pertinent to our present Designe [purpose]’ (51.25) to note what happens in the ‘making and distilling of Sope [soap]’ (51.26-27). He relates that by the action of ‘one degree of Fire the Salt, the Water and the Oyl or Grease, whereof that factitious [artificial] Concrete is made up’[20] (51.27-29 – 52.1) are ‘boyl’d up together’ (52.1-2) and ‘are easily brought to mingle and incorporate into one Mass’ (52.2-3). The addition of water to the soap left in the retort now causes a reversal of the initial saponification reaction: ‘but by another and further degree of heat the same mass may be again divided into an ‘oleagenous [oily, greasy], an aqueous, a Saline [here: the sodium or potassium hydroxide] and an Earthy part’ (52.3-7). The ‘earthy’ part probably being the result of some impurities present in the original reactants.

Carneades next moves on to describe the heating, or cupellation, of a mixture of metals. He says that when ‘impure Silver and Lead being expos’d together to a moderate Fire’ (52.8-9) they will be ‘colliquated [fused together] into one Mass, and mingle *per minima*

[19] Corrected to ‘another’ in Errata.

[20] This is a description of the so-called ‘saponification reaction’, in which an animal fat or vegetable oil is reacted with sodium or potassium hydroxide to yield a soap.

[at the most intimate level]' (52.10-11), that is to say, the different metals will melt and flow together to form a homogeneous, molten mass. However, a 'much vehementer Fire will drive off the baser Metals' (52.12-13) by which he means the lead, copper 'or other Alloy' (52.14-15) from the silver. What Carneades is describing here is the process of cupellation by which a mixture of metals when heated to a high temperature, the more reactive metals, such as lead and copper, will oxidise, and float on top of the molten silver. What remains as a molten metal is the silver alone, hence Carneades' saying 'though not for ought [aught] appears, separate them from one another' (52.15-17).

He then goes on to describe the case of how 'a Vegetable abounding in fixt [not volatile] Salt is analyz'd [resolved into its components] by a naked Fire' (52.17-19) and 'how one degree of heat will reduce it into Ashes' (52.19-20). Carneades then adds '(as the Chymists themselves teach us)' (52.20-21) then goes on to say 'so, by only a further degree of Fire, those Ashes may be vitrified [rendered glassy] and turn'd into Glass' (52.21-23). It is not obvious how ashes produced by the combustion of plant tissue can, by further heating, be turned into a glassy solid. Carneades seems to be thinking along these lines too for he adds mischievously that he will not 'stay [stop] to examine how far a mere Chymist might on this occasion demand, If it be lawful [justifiable] for an *Aristotelian* to make Ashes, (which he mistakes for meere [pure] Earth) pass for an Element' (52.24-28) simply because it may be produced 'by one degree of Fire' (52.29). By the same reasoning he questions why 'Glass is one of the Elements of many Bodies, because that also may be obtain'd from them, barely [simply] by the Fire' (53.2-5).

Carneades, not willing to dwell on the issue, really wishes to make the point that the nature of the thermal decomposition products obtained by burning compound bodies is dependent on the temperature of the fire in which they are burned. He says that 'By a Method of Applying the Fire, such similar Bodies may be obtain'd from a Concrete, as Chymists have not been able to separate; either by barely [simply] burning it in an open fire, or by barely [simply] distilling it in close [closed] Vessels' (53.7-12).

He says that it seems 'very considerable [important]' (53.13) to him that he has not 'by any of the common wayes of Distillation in close [closed] Vessels, seen any separation made of such a volatile Salt as is afforded us by Wood' (53.15-18) when the wood is decomposed first by an open fire into 'Ashes and Soot' (53.20), with the soot then placed in a 'Strong Retort' (53.21) and 'compell'd by an urgent [severe] Fire to part with its Spirit, Oyl and Salt' (53.22-23). Carneades is careful not to 'peremptorily [emphatically] deny' (53.24) that in the 'Liquors [distillates] of *Guajacum* [a hard, dense wood]' (53.25) and other woods 'distill'd in Retorts' (53.26) in the usual way, 'which by reason of the Analogy may pretend [have a pretension] to the name of some kinde of volatile Salts' (53.28-29 – 54.1). He concedes that it is not always the 'First, or even second Rectification [distillation]' (54.6-7) which causes such salts to separate, but the third.

What Carneades seems to be referring to here are the different fractions which distil over in the distillation of wood, with the lower boiling point chemical compounds distilling over during the first distillation, and the progressively higher boiling point products boiling and distilling over as the temperature is increased in the second and subsequent distillations.

Carneades goes on to contrast the distillation products of wood with those of soot, saying that ‘we could never yet see separated from Woods analys’d [resolved into its components] only the vulgar [customary] way in close [closed] vessels any volatile Salt in a dry and Saline form’ (54.8-11), presumably because the distillation products from wood are in liquid form. By contrast, soot whose volatile distillation products ‘we have often had very Crystalline and Geometrically figur’d’ (54.12-13), possibly because some of the distillation products from the soot sublimed and solidified as crystalline materials. He continues with this contrast in volatility between wood and soot by saying that ‘whereas the Saline parts of the Spirits of *Guajacum*, &c. appear upon distillation sluggish enough, the Salt of Soot seems to be one of the most volatile Bodies in all Nature’ (54.14-18), which he says rather enigmatically, ‘if it be well made’ (54.18-19) will volatilise with ‘the milde heat of a Furnace’ (54.19-20), probably because these are chemical species which are being sublimed at a low temperature, and once vapourised will remain in that state until they come in contact with a surface cool enough to cause them to solidify. On the other hand, high boiling point liquids require a considerable amount of thermal energy to vapourise them, and such vapours condense at a relatively higher temperature.

Apart from ease of distillation, Carneades says ‘the taste and smell of the Salt of Soot are exceedingly different from those of the Spirits of *Guajacum*, &c.’ (54.24-27). He expands on this by saying that the salt of soot ‘not only smells and tastes much less like a vegetable Salt, than like that of Harts-horn[21] [antler from a hart or stag]’ (54.27-29) and in ‘divers [various] other Properties seems more of Kinne to the family of Animals, than to that of vegetable Salts’ (55.1-4).

Following on from his examples involving the distillation of organic materials, and of his showing that the products obtained depend on the temperature at which the distillation is carried out, Carneades says that ‘the Chymists [Paracelsians], to have dealt clearly, ought to have declar’d by what Degree of Fire, and in what manner of Application of it’ (55.7-11), they would have us ‘Judge a Division made by the Fire to be a true *Analysis* into their Principles’ (55.12-14) and for the resulting products to ‘deserve the name of Elementary Bodies’ (55.15).

Having set his adversaries the difficult task or replying to this criticism of their theory on the elements, Carneades says that he will ‘proceed to mention the particular Reasons that incline me to Doubt, whether the Fire be the true and universal Analyser of mixt Bodies’ (55.16-19), and says that what he has just been saying about the analysis of wood and soot, ‘may pass for one’ (55.21) such objection.

Carneades goes on to discuss a favourite topic of his: the inability of the Paracelsians to produce any or all of their *tria prima* of salt, sulphur and mercury from certain materials. He argues that ‘the most obvious Instance of this Truth is Gold, which is a

[21] Carneades is probably referring to ammonium carbonate, which would have a pungent, ammoniacal odour; so much so that it has been used as ‘Smelling Salts’.

Body so fix'd [unreactive]', and wherein the Elementary Ingredients (if it have any) are so firmly united to each other' (55.27-29 – 56.1-2) that no fire, however hot, can cause any loss of 'its fixednesse or weight' (56.6), as it is not to be 'dissipated [dispersed]' (56.7) into its principles 'whereof one at least is acknowledged to be Fugitive [volatile] enough' (56.8-9), by which he seems to mean mercury, the principle of volatility in the Paracelsian scheme of things. Carneades goes on to quote from a 'Spagyrical Poet' (56.10), '*Cuncta adeo miris illic compagibus harent*' (56.12), which may be translated as: 'you know, they adhere all together in wonderful structures.'

He then goes on to mention an experiment he has come across from '*Gasto Claveus*'[22] (56.16) which illustrates the relative volatility of gold and silver. Carneades relates Gasto Claveus's account of heating an ounce of gold in one 'small Earthen Vessel' (56.20-21) and the same amount of silver in another, then keeping them both in a 'Glass-house Furnace' (56.24) in the molten state for 'two Moneths together' (57.1-2). On reweighing them he found 'that the Silver had not lost above a 12*th* part of its weight, but the Gold had not of his lost any thing at all' (57.5-7). Carneades is dismissive of Claveus's attempt at giving 'a Scholastick Reason' (57.9) for this. Yet Claveus seems content to accept the veracity of the experimental evidence presented by this test, with Carneades saying of him 'that though it be strange, yet experience it self taught it him to be most true'[23] (57.13-15).

[22] Gaston de Claves, or Gaston Duclo, or Le Doux, born *c*. 1530, was a French lawyer and chemist.

[23] Although it is unclear as to how much an ounce of gold or silver actually converts into in our contemporary units of weight, one might take an ounce to be equivalent to approximately 30 grams. Neither do we know exactly how hot the glass-blowers' furnace was, but it would have had to be above the melting point of both silver (962^{o}C) and gold (1064^{o}C), perhaps 1100-1200^{o}C. At these temperatures molten gold would be far less volatile than molten silver, more than one-hundred times less volatile, in fact.

This experiment on the volatility of gold and silver introduces Carneades' argument that there may not be any other material 'to be found so perfectly fix'd [non-volatile] as Gold' (57.17-18). Not only gold but 'divers [various] others so fix'd or compos'd, or at least of so strictly [tightly, closely] united parts' (57.18-20) that he had never seen fire separating any one of the 'Chymists Principles [salt, sulphur and mercury]' (57.22) from them. Rather jocosely, he goes on to speak of the complaints of the more 'Candid [fair, impartial] and Judicious of the Chymists' (57.24) directed at the 'Boasters that confidently pretend, that they have extracted the Salt or Sulphur of Quicksilver [mercury]' (57.26-28) which they have disguised by means of 'Additaments [things added], wherewith [whereby] it resembles the Concretes [compound bodies] whose Names are given it' (57.29 – 58.1-2). Of course when this material is subjected to a 'skilfull and rigid *Examen* [examination]' (58.2-3) it may be released from its 'Disguises' (58.4) and returned to its original 'pristine form of running Mercury' (58.5). And the material thus removed from the pure mercury, the 'pretended Salts and Sulphurs' (58.6) are not at all elementary in nature but rather are 'De-compounded [made up of compound ingredients] Bodies' (58.10-11) comprising of 'the whole Metal and the *Menstruum* [solvent], or other Additaments [things added] imploy'd to disguise it' (58.11-13).

So Claveus, in recording a weight reduction in the silver of one-twelfth, would have seen a diminution in weight of about 30/12 or 2.5 grams, which weight loss he could easily enough have detected using the weighing equipment available in his day. However, gold in being less volatile than silver by a factor of 100 or more would have lost not more than 2.5/100 = 0.025 grams, or 25 milligrams, which weight loss is so slight as to be difficult to detect with anything but very sensitive weighing equipment, and the likelihood is that such equipment was not available in Claveus's time.
It does seem, therefore, that Claveus's account is quite credible.

Carneades goes on to discuss the case of silver, and he begins by saying that he had never seen a fire of any heat to cause even one of 'its three Principles' (58.15-16) to separate from it. He then considers the experiment just quoted from Claveus on the weight loss incurred by silver when held at high temperature for a long period of time. He makes the point that this experiment may be interpreted to demonstrate the 'Suspition that Silver may be dissipated [dispersed]' (58.18-19) by a very hot fire of long duration. Carneades argues that 'it will not necessarily follow' (58.20-21) that because fire could cause the silver to 'lose a little of its weight, it was therefore able to dissipate [disperse] it into its Principles' (58.23-24).

He continues that he 'might alledge [affirm]' (58.25) that he had observed 'little grains of Silver to lie hid in the small Cavities (perhaps glas'd over by a vitrifying heat) in Crucibles' (58.26-28). Goldsmiths are able to recover these 'latent [lying] particles of Silver' (59.4) by grinding the crucibles to powder. From this he makes the argument that 'perhaps *Claveus* was mistaken' (59.5-6) in thinking that the silver had been driven off by the heat of the furnace, but that it actually 'lay in minute parts hid in his Crucible' (59.8-9), in whose pores a small amount by volume of 'so ponderous a Bodie might very well lie conceal'd' (59.10-12). Of course one of his adversaries might well ask of Carneades how, if silver could come to be trapped in the pores of the crucible, the same effect did not occur in gold, (which in Claveus's experiment lost no measurable weight on prolonged heating at high temperature).

Carneades goes on to consider that even if one accepts that the observed weight loss of silver did actually occur through ‘the violence of the Fire’ (59.15), he asks ‘what proof is there’ (59.15-16) that it was either the salt, sulphur or mercury ‘of the Metal, and not rather a part of it homogeneous [alike, similar] to what remain’d?’ (59.17-19). He very sensibly makes the point that if the silver had ‘any one of its Principles’ (59.22-23) separated from it, then the silver would have been altered in some way, but this was not the case. Carneades argues that ‘other Mineral Bodies of a less permanent nature than Silver (58.24-25) may be divided by the fire into ‘such minute parts’ (59.26) and carry them away ‘without at all destroying their Nature’ (59.28-29). He gives as an example of this the refining of silver, in which process there is ‘lead that is mix’d with it [the silver] (to carry away the Copper or other ignoble Mineral that embases the Silver)’ (60.1-4). This lead will ‘if it be let alone’ (60.4) over time ‘evaporate away upon the Test’ (60.5). What Carneades seems to be referring to here is the addition of lead to impure silver (that is, silver containing some copper as impurity). If the mixture of metals is simply heated to a temperature above the melting point of the lead (334^{o}C) the lead will eventually evaporate off.

However, the actual reason for adding the lead is probably to cause both it and any copper present as impurity to oxidise and form a slag or dross on top of the molten silver, which can then be skimmed off, leaving pure silver behind.

Carneades explains that it is more usual that the ‘Lead be blown off from the Silver by Bellows’ (60.8-9), leading to the oxidisation of the lead, with the formation of an oxide layer on top of the molten silver. If air were not blown over the surface of the molten silver the lead would simply evaporate off, or, in Carneades' own words 'would else have gone away in the Form of unheeded steams' (60.9-10). However, as air is continually blown over the molten silver, the lead 'will in great part be collected not far from the Silver, in the Form of a darkish Powder or Calx [metal oxide]' (60.11-13). This darkish powder is the reddish/yellow litharge or lead monoxide, which would float on top of the silver, along with any copper oxide formed by the oxidisation of any copper present in the silver as an impurity. Carneades says that 'because it [litharge] is blown off from Silver, they call [it] Litharge of Silver' (60.13-15).

Carneades goes on to describe how Agricola[24] recounts that when copper or 'the Oare [ore] of it is colliquated [melted or fused together] by the violence of the Fire with *Cadmia* [zinc oxide]' (60.17-18) a large number of sparks ascend, some of them 'stick to the vaulted roofs of the Furnace' (60.20-21) in the form of small, mainly 'White Bubbles' (60.23) which both the Greeks and 'our Drugsters [druggists] call *Pampholix* [bubbles or blisters]' (60.24-25), with some adhering to the sides of the furnace and others falling to the ground and which, because of 'their Ashy Colour as well as Weight' (60.29 – 61.1) were called by the same Greeks σποδος' (61.2) or 'Ashes' (61.4).

Carneades goes on to say that he has not found 'that' (61.5) 'those of my Acquaintance that have try'd have been able by the Fire to separate any one of the Hypostatical [elemental] Principles' (61.11-14) from a number of materials. He gives a list of these

[24] Georgius Agricola or Georg Baur, (1494-1555) German metallurgist and mining technologist, regarded as the Father of Mineralogy. His best known works are *De Re Metallica* and *De Natura Fossilium*.

materials, beginning with 'Venetian Talck'[25] (61.5), followed by '*Lapis Ossifragus*' (61.7-8) or '*Ostiocolla*'[26] (61.8-9), followed by '*Muscovia* Glass'[27] (61.9). Then 'Pure and Fusible [capable of being fused or melted] Sand, to mention now no other Concretes [compound bodies];[28]' (61.9-11).

The fact the no one with whom Carneades is acquainted has been able to separate any element from these materials, one will 'the less scruple [hesitate] to believe' (61.14-15) if one considers that glass may be made by the 'bare [simple] colliquation [melting down] of the Salt and Earth remaining in the Ashes of a burnt Plant'[29] (61.16-18).

Carneades says that 'common Glass, once made' (61.19) is so inert towards 'the violence of the Fire, that most Chymists think it a Body more undestroyable than Gold it self' (61.20-22). From this he reasons that if 'the Artificier [artisan]' (61.23) is able to combine 'such comparative [estimated by comparison] gross Particles' (61.24) as the earth and salt that constitute common ashes 'into a Body indissoluble by Fire' (61.26), why may not 'Nature associate in divers [various] Bodies the more minute Elementary Corpuscles' (61.27-29) she has at her disposal 'too firmly to let them be separable by the Fire?' (61.29 – 62.1).

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[25] Talc is a white or pale green form of magnesium silicate.

[26] Osteocolla is a calcareous deposit forming an incrustation on the roots and stems of plants in sandy ground, especially in some parts of Germany, formerly called glue-bone stone, from its supposed ability to help in the knitting of broken bones.

[27] Muscovy glass (from Muscovy, the principality of Moscow) which is the mineral muscovite, especially as used to make translucent windows.

[28] This semi-colon removed in the 1680 edition.

[29] This would apply if some sand were present in the ashes, along with some potash (potassium carbonate) resulting from the combustion of woody material.

Carneades now wishes to mention to Eleutherius ‘two or three sleight [artful, crafty] Experiments’ (62.3-4) which he hopes will be ‘more pertinent [appropriate] to our present Discourse’ (62.5-6) than might appear at first sight. The first of these experiments Carneades describes as putting a quantity of ‘that Fugitive [volatile] Concrete [compound body], Camphire [camphor]’[30] (62.8-9) into a glass vessel and placing it in a gentle heat. He found that it vapourised or sublimed, leaving no more by his estimate than ‘one Grain’[31] (62.12-13). The sublimed camphor condenses at ‘the Top of the Vessel into Flowers: which in Whiteness, Smell, &c. seem’d not to differ from the Camphire it self’ (62.13-16).

He next goes on to discuss an experiment ‘of *Helmont*’ (62.17) in which he stated that ‘A Coal kept in a glass exactly [perfectly, completely] clos’d will never be calcin’d [here: burned] to Ashes, though kept never so long [as long as could be] in a strong Fire’ (62.18-21). In order to ‘countenance [confirm]’ (62.21) this, Carneades gives an example of his own: that of the distillation of wood. He says that ‘some Woods, as particularly Box, whilst our *Caput mortuum* [inert residue] remain’d in the Retort, it continued black like Charcoal’ (62.24-26) even though kept red hot in an earthen vessel in a ‘vehement [intense] Fire’ (62.28). As soon as it was removed from the ‘candent [glowing with heat] Vessel’ (62.29 – 63.1) into the open air ‘the burning Coals did hastily degenerate or fall asunder, without the Assistance of any new Calcination [that is, burning or combustion] into pure White Ashes’ (63.1-4).

[30] Camphor is a terpenoid ketone, found in various plants, including the camphor laurel *Cinnamomum camphora*.

[31] One grain is one seven-thousandth part of a pound avoirdupois, or 65 milligrams.

These findings probably seemed surprising to both van Helmont and Boyle simply because they did not understand the nature of combustion. We now understand that as burning or combustion involves the combining of a carboniferous fuel (such as wood or coal) with oxygen from the air, a glowing fuel kept isolated from the air will simply glow for as long as it is maintained at high temperature. Once removed from its container into the open air, the oxygen in the air will combine with it, causing it to burn until there is no more carboniferous material left, and it is reduced to inert ashes.

This process did not come to be firmly understood until Antoine Lavoisier (1743-94) explained it.

Carneades then goes on to describe the combustion of 'Brimstone [sulphur]' (63.12-13) which if burnt in the open air gives 'a penetrating Fume [sulphur dioxide]' (63.14) which when 'caught in a Glass-Bell condenses into that acid liquor called Oyl of Sulphur *per Campanam*'[32] (63.15-17). He concludes this line of reasoning by saying that what he understands by these experiments 'collated [brought together]' (63.18) with Agricola's account is that, even with bodies that are not 'fixt [unreactive], these are divers [various] of such a Texture, that it will be hard to make it appear, how the Fire, as Chymists are wont [accustomed] to imploy it, can resolve them into Elementary Substances' (63.21-25).

[32] Presumably 'sulphurous acid' (H_2SO_3), more correctly, hydrated sulphur dioxide, formed by dissolving sulphur dioxide in water, although oxidisation of sulphur dioxide would lead to the formation of sulphur trioxide, which dissolves in water to form sulphuric acid.

He then makes an argument in which he states that, in any event, some bodies may be so readily volatilised that the energy required to evaporate them is less than that required to decompose them. He says that some 'Bodies being of such a Texture' (63.25-26) that the heat of the fire can drive them into the cooler part of the 'Vessel wherein they are included [confined]' (63.28), and cause them to 'fly [flee] the Greatest heat, more easily than it can divorce their Elements' (64.1-2), then adds immediately, '(especially without the Assistance of the Air)' (64.3-4). Clearly, Carneades is thinking here of the ability of the open air to cause a glowing coal or burning piece of wood to be reduced to ashes. He continues 'we see that our Chymists cannot Analyze [break down] them in close [closed] Vessels' (64.4-5), presumably because volatile materials cannot escape from the container and their presence there means that the interior of the container cannot reach a sufficiently high temperature for complete thermal decomposition of the test materials to occur. He adds that 'of other compound Bodies the open Fire can as little separate the Elements' (64.5-7).

Reiterating his argument that a volatile compound material will more easily escape the tendency of the heat of the fire to degrade it than to remain behind and be decomposed, this time he more explicitly states the argument by referring to the behaviour of materials at their most fundamental level of subdivision. He asks 'what can a naked Fire do to Analyse [break down] a mixt Bodie, if its component Principles be so minute, and so strictly [closely, tightly] united, that the Corpuscles of it need less heat to carry them up, than is requisite [required] to divide them into their Principles' (64.8-13). Carneades concludes that 'of some Bodies the Fire cannot in close [closed] Vessels make any

Analysis [resolution] at all' (64.13-15), and that other materials 'will in the open Air fly away in the Form of Flowers[33] or Liquors, before the Heat can prove able to divide them into their Principles' (64.16-18). Not only this, but the above will hold equally true for artificial as for naturally produced materials, and he gives as example 'factitious [artificially produced] *Sal Armoniack* [ammonium chloride]' (64.22) in which the 'common[34] and the Urinous Salts'[35] so well mingled, that both in the open Fire and in subliming Vessels they rise together as one Salt' (64.23-26) and 'which [the newly produced *Sal Armoniack*] seems in such Vessels irresoluble [incapable of being resolved into elements] by Fire alone' 64.26-27). So stable is Sal Ammoniac, Carneades adds, that 'I can shew [show] you *Sal Armoniack* which after the ninth Sublimation does still retain its compound Nature' (64.27-29 – 65.1). Continuing with this theme, Carneades says that 'I scarce know any one Mineral' (65.1-2) from which the Chymists [Paracelsians] are 'wont [accustomed] to sever any Substance' (65.3-4) which is simple enough to be called an element or principle. He goes on to consider two sulphur compounds: 'native Cinnaber [mercury sulphide]' from which 'they distill Quicksilver [mercury]' (65.6) and from '*Pyrites* [iron sulphide] they sublime Brimstone [sulphur]' (65.9), and adds 'that Quicksilver [mercury] and this Sulphur being very often the same with the common Minerals' (65.10-12) sold under these names in the shops. These two minerals, he argues, are 'themselves too much compounded Bodies to pass for the Elements of such' (65.13-15). And because he has stated his arguments at some length Carneades says that 'I shall the lesse insist [persevere] on' (65.18-19) the other ones.

[33] Formed by the condensation of some vapours, such as that of sulphur, onto cooler surfaces.
[34] Presumably the chlorine from common salt, sodium chloride.
[35] Presumably ammonia, which would be reacted with hydrochloric acid to form *Sal Armoniack* or ammonium chloride.

Carneades goes on to discuss how materials can be decomposed by non-thermal means. He says that 'there are divers [various] Separations' (65.22-23) which fire of itself is either unable to make or is not the only agent capable of so doing. The first example he gives is a simple mixture or alloy of gold and silver, which when 'melted into one Mass' (65.26-27) would 'lay a great Obligation [duty] upon Refiners and Goldsmiths to teach them [themselves] the Art of separating them by the Fire, without the trouble and charge [burden] they are Fain [inclined] to be at to sever them' (65.27-29 – 66.1-3). When gold and silver are melted together they form an alloy or intimate mixture which cannot be undone by any simple thermal process. However, silver is more chemically reactive than gold, allowing the two to be separated by chemical means. Carneades says that they 'may be very easily parted by the Affusion [pouring on or into] of Spirit or Nitre or *Aqua fortis* [nitric acid]' (66.3-5), meaning that in a mixture of gold and silver, the silver is dissolved by the acid, leaving the gold untouched, which falls to the bottom of the reaction vessel, and from which it can be retrieved. He says that the French call nitric acid '*Eau de Depart*'[36] (66.6).

Carneades' next example is that of the separation of copper from copper sulphate. He says that the 'Metalline part of Vitriol [here: copper sulphate]' (66.7) will not easily be separated from the 'Saline part even by a violent Fire' (66.9-10), but that by the 'Affusion [pouring on or into] of certain Alkalizate Salts [such as sodium or potassium hydroxide]' (66.10-11) in solution, when added to a solution of the 'Vitriol [copper

[36] 'depart' here means 'separation or distinction', presumably because of nitric acid's ability to separate materials such as gold and silver through dissolving out one of them.

sulphate]' (66.12). He describes how the 'acid Salt of the Vitriol [the sulphate radical]' (66.13-14) leaves the 'Copper it has corroded to joyn with the added Salts, the Metalline part will be precipitated like mud'[37] (66.14-17).

He next considers some reactions of antimony, and begins by remarking that 'Chymists [Paracelsians] have not been able (for ought [aught] is vulgarly known) by fire alone to separate true sulphur from Antimony' (66.21-23), which seems to be a reference to the fact that what Carneades calls antimony is actually antimony sulphide,[38] which when heated alone does not decompose to give sulphur.[39] Carneades adds that despite claims in their writings to the contrary, all such efforts prove as unsuccessful as the 'many fruitlesse Tryals' (66.26-27) he has performed to extract it. He says, with conviction, that the 'Productions of such Processes are Antimonial Sulphurs rather in Name than Nature' (66.29 – 67.1-2).

Carneades next says that when 'Antimony sublim'd by its self' (67.3), meaning when antimony sulphide or stibnine[40] is heated strongly in air, it is 'reduc'd but to a volatile Powder, or Antimonial Flowers' (67.3-5), by which he means it is oxidised to antimony

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[37] What Carneades is here describing is the addition of a solution of an alkali such as sodium or potassium hydroxide to a copper (II) sulphate solution, when a precipitate of copper (II) hydroxide is formed.

[38] 'Very confusing is the fact that antimony, a relative latecomer, was better known as the ore than as the metal, so that the name antimony meant to the seventeenth century not the metal, then called regulus of antimony, but the sulphide'. From: Marie Boas, *Robert Boyle and Seventeenth-Century Chemistry* (Cambridge: Cambridge University Press, 1958), 118-119.

[39] According to Partington, antimony sulphide or stibnite is reduced to the metal by heating with iron and a little salt in a plumbago crucible. From: Partington, *General and Inorganic Chemistry*, 630.
Otherwise, antimony can be produced by reducing the sulphide through roasting (to give the oxide) followed by reduction with carbon and sodium carbonate. From: John Daintith, ed. *Oxford Dictionary of Chemistry*, 6th ed. (Oxford: Oxford University Press, 2008), 41.

[40] This mineral, the most important antimony ore, has a lead-grey metallic lustre, hence the ease of confusing it with antimony itself, which is a semi-metal or metalloid.

trioxide or flowers of antimony, which he rightly identifies as being of a 'compounded Nature' (67.5) but goes on to say 'like the Mineral that affords them' (67.5-6), by which he seems to indicate his belief that antimony sulphide is a compound material.

He goes on to describe how he has 'sublim'd out of Antimony a Sulphur' (67.7-8), saying that he will 'acquaint you with' (67.11) his method, and explains why by stating that 'Chymists seem not to have taken notice of what Importance such Experiments may be in the Indagation [investigation] of the Nature, and especially of the Number of the Elements' (67.12-16). And, of course, we can understand what he means by recollecting that the 'antimony' he speaks of is actually antimony sulphide or stibnite, which itself is a compound of antimony and sulphur. So when Carneades goes on to describe in detail the process by which he obtained sulphur from his 'antimony', what he seems to have done is place powdered antimony sulphide in a glass vessel, the 'eight Ounces of good and well powder'd Antimony' (67.17-18) along with 'twelve Ounces of Oyl of Vitriol [sulphuric acid]' (67.19), stoppered the vessel, and left it at room temperature for 'about six or seven Weeks' (67.20-21). What seems to have happened next is that the powdered antimony sulphide reagglomerated to form a 'Mass (grown hard and brittle)' (67.22).

Carneades then seems to have removed this mass from the retort and placed it, perhaps along with whatever sulphuric acid adhered to it, and caused it 'to be distill'd in a Retort plac'd in Sand, with a strong Fire' (67.22-24). He continues that the 'Antimony [antimony sulphide] to be so opened, or alter'd by the *Menstruum* [the sulphuric acid] wherewith it had been digested' (67.24-26) that, instead of the 'Flowers [of antimony]' (67.28) given by 'crude Antimony [antimony sulphide]' (67.27), he obtained from 'our Antimony' (67.29) 'About an Ounce of Sulphur' (68.3) divided between 'the Receiver' (68.1) and the 'Neck and at the Top of the Retort' (68.2).

He then goes on to some lengths to demonstrate that this substance was indeed sulphur, saying that it was 'yellow and brittle like common Brimstone' (68.3-4), it had a strong 'Sulphureous' (68.5) odour, so much so that on 'unluting [removing the sealing from] the Vessel it infected the Room with a scarce supportable stink' (68.6-7). It also burned like 'common Brimstone' (68.10), and had the 'blew [blue]' (68.12) flame characteristic of sulphur.

Carneades believed that the 'long digestion wherein our Antimony and *Menstruum* were detain'd, did conduct to the better unlocking of the Mineral' (68.13-16), not realising that his 'antimony' was in fact a compound of antimony and sulphur, *i.e.* antimony sulphide, and that his *Menstruum*, which in this case was sulphuric acid, also contains sulphur, and that what seems to have occurred is the decomposition of the acidified antimony sulphide to yield sulphur and, perhaps, antimony itself, although Carneades is silent as to what was formed in addition to the sulphur.

He goes on to say that this experiment can be repeated, but without causing the ingredients to have 'so long a Digestion' (68.17), and again with 'powder'd Antimony [antimony sulphide]' (68.18-19) and 'Oyl of Vitriol [sulphuric acid]' (68.20), this time 'committing them immediately to Distillation' (68.20-21) and one will 'obtain a little Sulphur like unto the common one' (68.21-22). Carneades adds revealingly that this sulphur is 'more combustible than perhaps you will at first take notice of' (68.23-24). This seems to indicate that this particular product is not quite as inflammable as normal sulphur, and he adds that 'the Flame would sometimes go out too soon of its self' (68.26-27), and if it were kept in a candle flame would 'be rekindled and burn a pretty while' (68.29 – 69.1) even after the 'third or fourth accession [ignition]' (69.2-3).

All of this seems to indicate that the product in question does indeed contain sulphur, but also something else, less inflammable than sulphur, as well. It may be mixed with some of the 'flowers of antimony' or antimony trioxide, already referred to by Carneades, and which is formed by the decomposition of Carneades' 'antimony' (actually antimony sulphide). Antimony trioxide turns yellow, when heated in air, forming antimony dioxide. So what may have happened is that the product which he found burned with some difficulty, was a mixture of the yellow antimony dioxide mixed with sulphur (also yellow), but of the two materials only the sulphur actually burned.

Carneades next addresses the moderator of the discussion, Eleutherius, and seems to refer to a separate, earlier experiment by saying that 'I think I shewed [showed] my way of discovering something of sulphureous in Oyl or Vitriol' (69.3-5), which would of course be true, as sulphuric acid does contain sulphur. He then reverts to the present discussion by saying that Eleutherius 'may perchance [perhaps] suspect' (69.6) 'either that this Substance was some Venereal Sulphur [sulphur of copper] which lay hid in that

Liquor' (69.6-9) and in this experiment was 'reduc'd into a manifest [revealed] body' (69.9-10). Or, that it was a compound of 'the unctious [oily] parts of the Antimony, and the Saline [here: solid] ones of the Vitriol' (69.11-13). He goes on to explain '(as *Gunther*[41] informs us) divers [various] learned men' (69.13-14) believe that sulphur is no more than a 'mixture made in the Bowels of the Earth of Vitriolate [sulphureous] Spirits and a certain combustible Substance' (69.16-18).

Carneades then goes on to attempt an explanation as to what exactly may have produced the sulphur formed in his experiment. He simply says 'but the Quantity of Sulphur we obtain'd by Digestion was much too great to have been latent in the Oyl of Vitriol' (69.18-21). In so saying Carneades excludes the sulphuric acid as the origin of the sulphur in question, and this means that it must originate in the only other product – the 'antimony' (actually antimony sulphide). He says as much when he explains 'that Vitriolate [sulphate] Spirits are not necessary to such a Sulphur as ours, I could easily manifest [clearly reveal]' (69.21-24), by taking Eleutherius through the various experiments by which he has obtained 'though not in such plenty, a Sulphur of Antimony, colour'd and combustible like common Brimstone' (69.26-29).

Interestingly, Carneades in acknowledging that the sulphur he has obtained, (clearly from the decomposition of antimony sulphide), also remarks that the amount of sulphur thereby obtained is not in 'such plenty' (69.26-27) as that obtained in the lengthy experiment he has just detailed. This realisation, however, does not cause him to consider that some of the sulphur obtained earlier may have come from the oil of vitriol

[41] This may be Anton Guenther Billichius, active *c*. 1600, medic and chemist.

or sulphuric acid, and that this is why he obtained his sulphur from ‘antimony’ or antimony sulphide in a smaller amount when reacted without the presence of sulphuric acid.

He says that he is not now willing to ‘discover [reveal, show] them’ (70.1), yet relates ‘that to satisfie some Ingenious [highly intelligent] Men, that distill’d Vitriolate [sulphate] Spirits are not necessary to the obtaining of such a Sulphur as we have been considering’ (70.2-5), explaining that by ‘the bare [very, actual] distillation of only Spirit of Nitre [nitric acid] from its weight of crude Antimony [antimony sulphide]’ (70.5-7) he soon separated ‘a yellow and very inflammable Sulphur’ (70.8-9), then adds wryly, ‘which for ought [aught] I know, deserves as much the name of an Element’ (70.9-11) as any product separated by the chemists from ‘any Mineral by the Fire’(70.12-13) – a clear reference to the claim of the Paracelsians that bodies consist of the *tria prima* of salt, sulphur and mercury. And again, what Carneades has done is to decompose antimony sulphide, his ‘antimony’, to give sulphur and antimony trioxide.

Carneades advises the company that he could perhaps tell his hearers of other experiments on ‘antimony [antimony sulphide]’ (70.14-15) involving some process other than thermal decomposition, in which something may be ‘extracted from it’ (70.15-16), but will save these for another time, contenting himself for the moment to ‘annex [append] at present this sleight [artful, crafty], but not impertinent [inappropriate] Experiment’ (70.18-20). He goes on to explain that he has already pointed out that whereas ‘the Urinous and common Salts whereof *Sal Armoniack* [ammonium chloride] consists, remain unsever’d by the Fire in many successive

Sublimations [distillations]' (70.21-24) they can readily be separated, even without added heat, by finely powdering this 'Concrete [chemical compound]' (70.26-27) and pouring over it 'a Solution of Salt of Tartar [potassium carbonate], or of the Salt of Wood-Ashes [also potassium carbonate]' (70.27-29). Once these materials are mixed together there is a 'very strong smell of Urine' (71.2) given off, with perhaps also watering of the eyes, by the 'same subtle and piercing Body that produces the stink' (71.4-5). Carneades explains this reaction by saying that by the 'Alcalizate Salt (here: the potassium carbonate] the Sea Salt [sodium chloride] that enter'd the composition of the *Sal Armoniack* [ammonium chloride] is mortify'd [weakened in activity] and made more fixt [unreactive], and thereby a divorce is made between it and the volatile Urinous Salt [ammonia]' (71.7-11). What Carneades seems to have in mind is that when these materials are reacted together the *Sal Armoniack* or ammonium chloride is decomposed, liberating ammonia, the pungent nature of which serves to 'offend the Nostrils and Eyes it meets with' (71.13-14) as it escapes.

Carneades then goes on to say that if this experiment is carried out 'in convenient [appropriate] Glasses' (71.16) heated in a water bath, 'the ascending Steams may easily be caught and reduc'd into a penetrant Spirit, abounding with a Salt, which I have sometimes found to be separable in a Crystalline Form' (71.18-22). What Carneades may mean is that sometimes a solution of ammonia in water, as it is caused to vaporise and then condense, may have entrained in it some ammonium chloride, which during collecting and cooling can crystallise out.

He then changes topic to speak of 'Sublimate [corrosive sublimate or mercuric chloride] consisting' (71.23-24) 'of Salts & Quicksilver combin'd and carried up together by Heat' (71.24-26) may be repeatedly 'Sublim'd' (71.26) or distilled 'by a like degree of Fire, without suffering any divorce of the component Bodies' (71.27-29). However, 'the Mercury may be easily sever'd from the adhering Salts if the Sublimate [corrosive sublimate or mercuric chloride] be distill'd from Salt of Tartar [potassium carbonate], Quick Lime [calcium oxide], or such Alcalizate [alkaline] Bodies' (71.29 – 72.4). This seems to be a reference to the ability of alkalis to react with mercuric chloride to form yellowish-red mercuric oxide.

This observation is offered more as an offhand remark than anything else: what Carneades wishes to draw attention to is 'what divers [various] ingenious [highly intelligent] men have thought somewhat strange; that by such an Additament that seems but only to promote the Separation, there may be easily obtain'd from a Concrete [compound body] that [*sc*. that which] by the Fire alone is easily divisible into all the Elements that Vegetables are suppos'd to consist of' (72.5-12), and the product thereby obtained is 'such a similar Substance as differs in many respects from them all' (72.12-14). The conclusion of this is that many of the ablest chemists deny that this substance is contained in the 'mixt Body [compound]' (72.16-17).

What Carneades seems to mean is that when an unfamiliar decomposition product is separated off from a compound body, many of the best chemists still deny that it was contained in the original body.

Carneades then related how 'common Tartar'[42] (72.18) without the addition of any mineral except 'Saltpetre [potassium nitrate]' (72.20-21) may by a single distillation in an earthen retort 'be made to afford good store of real Salt' (72.22-23). This product, which is 'readily dissoluble in water' (72.23-24), is neither acid, nor smells like tartar, is almost as volatile as 'Spirit of Wine [alcohol]' (72.26) and is different from any of the distillation products of tartar. So much so that 'divers [various] Learned Men' (72.29 – 73.1) could hardly be convinced 'that so fugitive [volatile] a Salt could be afforded by Tartar' (73.3-4) until Carneades himself 'assur'd it them upon my own Knowledge' (72.4-5).

The chemical compound referred to here, being non-alcoholic, volatile, water soluble and distinct in odour from tartar and its decomposition products, may perhaps have been acetone, formed when tartar is dry-distilled with potassium nitrate.

Carneades proceeds to give a favourite argument of his – that of the inability of fire always to separate bodies into their component elements. He says that 'Fire even when it divides a Body into Substances of divers [various] Consistences [qualities]' (73.13-15) does not usually separate it into 'Hypostatical Principles [elements]' (73.16) but instead 'only disposes [arranges] its parts into new Textures [here: structures]' (73.16-17) and produce 'Concretes [compound Bodies]' (73.18) which although new are still of 'a compound Nature' (73.19). He goes on to add that it will be 'requisite [appropriate]' (73.20) for him to follow this argument so completely later that it is not for the lack of

[42] Tartar is a brownish-red substance consisting mainly of potassium hydrogen tartrate.

'good Proofs' (73.23) that he wishes to 'suspend my Proofs' (73.24) but rather until the full '*Series* of my Discourse' (73.24-25) makes it more appropriate for him to do so.

Carneades then reverts to his 'First Consideration' (73.28), *i.e*. his doubting that fire is a means of decomposing compound bodies into their elemental constituents, and adds that it may also be 'alledg'd [cited]' (73.27) in support of this doubt that some 'such distinct Substances may be obtain'd from some Concretes [compound bodies] without Fire' (73.29 – 74.2) equally deserve to be called elements as 'many that Chymists [Paracelsians] extort [extract forcibly] by the Violence of the Fire' (74.3-4). He gives as an example the 'Inflamable Spirit, or as the Chymists esteem [deem or think] it, the Sulphur of Wine [ether]' (74.5-7) 'may not only be separated from it [presumably the wine][43] by the gentle heat of a Bath [*sc*. water bath]' (74.7-8), but actually be distilled from it 'either by the help of the Sun-Beams, or even of a Dunghill' (74.9-10), the reason being that it is of so 'fugitive [volatile] a Nature' (74.11) that it does not require the addition of 'external heat' (74.11) to cause it to volatilise. The reason for this is that ether boils at 34.5^{o}C – even lower than body heat (37^{o}C).

Carneades then goes on to describe how 'a Vessel full of Urine being placed in a Dunghill [where it will undergo some, though not excessive, heating], and Putrefaction is wont [accustomed] after some weeks to open the Body' (74.15-17). He observes that 'the parts disbanding the Saline Spirit' (74.18-19) will, in a fairly short time 'fly away of it self' (74.20), if the vessel is left open. He adds that from the urine, thus aged, he has been able to distil little more 'than a nauseous Phlegme [aqueous product]' (74.23),

[43] Ether can be prepared by dehydrating alcohol or, in earlier times, wine, using sulphuric acid.

whereas if the vessel had been properly closed and heated in a fire he would have obtained an 'active and piercing Salt and Spirit' (74.24). What Carneades seems to be referring to here is the separation of ammonia solution (with its pungent tear-inducing vapour) by distilling fresh urine. When left for some time at lower temperature in an open container the ammonia escapes, leaving an unpleasant smelling, aqueous solution.

He states as his fifth consideration that it will be very difficult to prove 'that there can be no other Body or way be given which will as well as the Fire divide Concretes into several homogeneous Substances' (75.1-4) fit to be considered as the 'Elements or Principles' (75.5-6) of them 'as well as those separated or produc'd by the Fire' (75.5-6). Fire is simply not the only means by which bodies can be separated into their constituent elements, nature can do so too (as in the experiment just recounted). It may also be the case that 'Art may make, some such substance as may be a fit Instrument to Analyze [break down] mixt Bodies' (75.12-14). Not only this, but a means may be 'found by Humane Industry or Luck' (75.15-16) whereby compound materials may be decomposed into 'other Substances, than such as they are wont [habitually] to be divided into by the Fire' (75.17-19).

Carneades equates the justification for considering the decomposition products as 'component Principles of the Bodies that afford [supply, yield] them' (75.21-22) with the chemists' claim that they can obtain their *tria prima* of salt, sulphur and mercury from the analysis of compound bodies. This is all the more true given that 'I shall hereafter make it evident' (75.24) that 'the Salts, and Sulphurs, and Mercuries of

Bodies' (75.26-27) claimed to be such by the 'Chymists [Paracelsians]' (75.25) are not 'so pure and Elementary as they presume' (75.27-28), and as required by their hypothesis.

He continues that this realisation can be 'the more freely press'd [advanced despite opposition] upon the Chymists' (76.1-2) for the simple reason that they could not accept such an idea without compromising their doctrines, whether Paracelsian or Helmontian. He says that van Helmont has stated more than once that both '*Paracelsus* and himself were Possessors of the famous Liquor, *Alkahest* [universal solvent]' (76.7-8) which on account of its great ability in 'resolving [breaking down] Bodies irresoluble by Vulgar [common] Fires, he somewhere seems to call *Ignis Gehennae* [infernal fire or fire of hell]' (76.9-11).

Carneades, no longer able to keep a straight face, says that van Helmont, much of it from personal experience, accords to his *alkahest* 'such wonders' (76.14) which if true would make Carneades 'so much the more a Friend to knowledge than to Wealth' (76.15-16) so much so as to make it for him 'a nobler and more desireable Secret than the Philosophers Stone it self'[44] (76.17-19).

He goes on to recount an experiment in which van Helmont related how his 'Universal Dissolvent' (76.19-20) 'having digested with it for a competent [appropriate] time a piece of Oaken Charcoal' (76.20-22), the *Alkahest* had reduced the test sample into 'a

[44] Although there is no simple definition of the 'Philosophers' Stone' it might be regarded as a pure substance which could transform, transmute or perfect gross matter.

couple of new and distinct Liquors discriminated [differentiated] from each other by their Colour and Situation [location]' (76.23-25). He continues that the entire sample of 'Coal was reduc'd into those Liquors, both of them separable from his Immortal *Menstruum* [solvent]' (76.26-28), the latter remaining 'as fit for such Operations as before' (76.29 – 77.1).

Continuing with his account of the *alkahest*, Carneades says that van Helmont claims in 'divers [various] places of his Writings' (77.2) that by 'this powerful, and unwearied agent, he could dissolve Metals, Marchasites [iron sulphide in orthorhombic crystal system], Stones, Vegetables and Animal Bodies of what kinde soever' (77.2-6) and even powdered glass, in fact 'all kinds of mixt Bodies [compound bodies]' (77.8) 'into their several similar [of the same structure throughout] Substances' (77.8-10) leaving no 'Residence [residue] or *Caput mortuum* [inert residue]' (77.10-11).

A doctrine of particular interest to Carneades is van Helmont's claim that when compound bodies are decomposed by his *alkahest* or universal solvent they 'were oftentimes different enough both as to Number and as to Nature, from those into which the same bodies are wont [in the habit of] to be divided by the common Fire' (77.15-18). Carneades slyly draws a comparison between the usual experience of those who commonly decompose compound bodies in the laboratory and the claims of van Helmont on the subject. He says that he need not cite any proof 'then [than] that' (77.20) in the usual process of decomposing compound bodies. 'There remains a terrestrial [earthy] and very fixt [non-volatile] Substance' (77.22-23) often associated with a ‘Salt as fixt’ (77.24). He adds that van Helmont claims ‘that by his way he could Distill over all Concretes without any *Caput mortuum* [inert residue], and consequently could make those parts of the Concrete [compound body] volatile’ (77.25-28) which by the ‘Vulgar [that of the common chemists] *Analysis* would have been fixt [non-volatile]’ (77.29 – 78.1).

Continuing with his efforts to press home his own claims on the matter, Carneades argues that if ‘our Chymists’ (78.1) are not willing to reject the ‘solemn and repeated Testimony’ (78.2-3) of one of ‘the greatest Spagyrists [one who synthesises and decomposes compound bodies]’ (78.4-5), namely van Helmont, they ‘must not deny’ (78.6) that there exists in ‘Nature another Agent able to Analyse compound Bodies less violently, and both more genuinely and more universally than the Fire’ (78.7-10).

Carneades, in attempting to promote the value of the direct observation of an experiment, quotes ‘Our Friend *Mr. Boyle*’ (78.23-13) and his belief that the one with ‘*more Reason to beleeve it*’ (78.15-16) is the one who has seen it. He is not quite saying that ‘seeing is believing’ but rather than the very act of witnessing an experiment and its results provides greater cause for accepting it than one whose knowledge of the experience is second hand. He goes on to praise van Helmont as ‘a fruitful [trustworthy, veracious] writer’ (78.17), discounting his ‘Treatise *De Magnetica Vulnerum Curatione* [On the Magnetic Cure of Wounds]’ (78.20) as possibly spurious, and saying that ‘I think it somewhat harsh to give him the Lye, especially to what he delivers upon his own proper Tryal’ (78.23-25).

Carneades, not fully committed to the experimental findings of van Helmont, preserves a sceptical distance between himself and even apparently reliable reports, trying to give all sides careful consideration in the matter. He quotes both himself and 'very credible Eyewitnesses' (78.26-27) as arguing 'so strongly that a circulated [refluxed][45] Salt or a *Menstruum* [solvent] (such as it may be)' (78.28 – 79.1) removed from compound materials, whether animal, mineral or vegetable 'leave them more unlockt [separated or parted] than a wary [cautious, careful] Naturalist would easily believe' (79.4-5). This causes Carneades to be cautious about any assertations he might make regarding the exact effect of any analytical tools that might be brought to bear on the analysis of compound bodies. He says 'I dare not confidently measure the Power of Nature and Art by that of the *Menstruums* [solvents], and other Instruments that eminent Chymists themselves are as yet wont [accustomed] to Empoly[46] about the Analysing of Bodies' (79.5-11). Neither is he willing to 'Deny that a *Menstruum* may at least from this or that particular Concrete [compound material] obtain some apparently similar Substance' (79.11.14) differing from those which any form of thermal analysis can supply.

He is not willing 'to deny peremptorily [emphatically] that there may be such Openers of compound Bodies' (79.18-19), because among those experiments that make him 'speak thus warily [cautiously, carefully]' (79.21) 'there wanted [to be lacking in or missing] not some' (79.21-22) in which it did not appear 'that one of the Substances not

[45] Subjected to repeated distillation and condensation in a still.
[46] Corrected to 'employ' in the *Errata*.

separable by common Fires and *Menstruums* [solvents] could retain any thing of the Salt by which the separation was made' (79.23-26).

Carneades, realises that he should finish that part of his 'Discourse as belongs to the first consideration' (79.29), but acknowledges that 'two such specious [fair or attractive but wanting in genuineness or sincerity] Objections' (80.3) as may block his confident progression must first be 'examin'd' (80.5) by him.

The first objection that Carneades' 'Opposers will be forward [eager]' (80.7) to make to him is that they 'do not pretend by Fire alone to separate out of all compound bodies their *Hypostatical* [elemental] *Principles*' (80.7-10). They acknowledge that it is sufficient that the fire 'dividers them into such' (80.11) but some other agent may be employed to 'collect the similar (homogenous] parts of the Compound' (80.13-14). They understand that water, for example, may be used to dissolve out the 'Saline parts of Ashes' (80.15-16) from the 'terrestrial [earthy]' (80.16), and from which latter they may be recovered through crystallisation, leaving the earthy component behind in the ashy sludge. They do realise, Carneades concedes, that it is the fire which brings about the reduction of the 'fix'd [inert] part of them into the Salt and Earth, whereof Ashes are made up' (80.19-21).

Carneades has some sympathy with this objection, saying that it is not 'inconsiderable' (80.21-22), even to the point of accepting much of it 'without granting it to make [tell] against me' (80.23-24). He adds that the real target of his criticism is not those who hold this belief, but rather ‘those Vulgar Chymists, who themselves believe, and fain [gladly] make others do so, That the Fire is not only an universal, but an adequate and sufficient Instrument to analyse [break down] mixt [compound] Bodies with’ (80.27 – 81.3). Returning to his original ‘Opposers’ (80.6) he explains that the addition of water to the ashes of a thermally decomposed body serves only to dissolve the soluble component of ashes – it does not of itself act as an agent of decomposition. He continues that with their habit of ‘Extracting the fix’t [inert] Salt out of Ashes by Affusion [pouring on] of Water’ (81.3-5), it is ‘obvious to alleadge [affirm]’ (81.5-6) that the ‘Water does only assemble together the Salt the Fire had before divided from the Earth’ (81.6-8).

He gives as an analogy the sieving of ‘Corn’ (81.9) into ‘Flour’ (81.11) and ‘Bran’ (81.11) which before had been ‘promiscuously [randomly] blended together in the Meal’ (81.12-13). Carneades says that he might ‘alleadge [adduce or urge as reason]’ (81.14) the foregoing as an excuse for considering the objection no further. However, in order to take advantage of the ‘Rise [movement towards a position of greater power] it may afford me’ (81.17-18) he is happy to give it some further consideration, insofar as his ‘present Disquisition [investigation] may be concern’d in it’ (81.20-21).

Carneades, wishing to make as clear as possible his understanding of the effect of water or other liquids on the decomposition products of compound bodies burnt in the fire, says that he is willing to accept that, whereas water serves only to dissolve some of these bodies, other solvents may react with those same bodies to form new compounds.

That he is somewhat indulgent towards his adversaries he makes clear by saying that he is 'so civil [courteous] an Adversary' (81.24) as to grant it to the 'Chymists [Paracelsians]' (81.25) that after a compound body has been thermally decomposed, they may use 'fair [clean] Water' (81.26) to extract water soluble products from the burnt residue, but only when the 'Water does not cooperate with the Fire to make the *Analysis* [decomposition]' (81.28-29 – 82.1) and this because he supposes that the 'Water does only wash off the Saline Particles' (82.2-3) already 'Extricated in the Analys'd [broken down] Body' (82.4-5) by the fire. However, he makes it clear that he does not consider it 'Reasonable' (82.5-6) that this 'Concession should Extend to other Liquors that may add to what they Dissolve' (82.6-8), and he has in mind not 'other Cases' (82.8-9) but rather 'those Newly [very recently] Mentioned' (82.9).

This 'Limitation' (82.10) Carneades wishes his hearers to remember, as he will return to it 'Anon [in a short time]' (82.14) then goes on to 'Observe' (82.14) firstly, that the 'Objections we are Considering' (82.17-18) will not apply to many of the examples given earlier, simply because many substances are not inflammable, due to the fact that fire, with or without 'The Assistance of Water' (82.19-20) cannot 'Separate any of the Three Principles [salt, sulphur and mercury], either from Gold, Silver, Mercury or some Others of the Concretes named Above' (82.20-23). From this Carneades is able to 'Inferre That Fire is not an Universal Analyser [decomposer] of all Mixt [compound] Bodies' (82.24-26), as with metals and minerals 'wherein Chymists [Paracelsians] have most Exercis'd Themselves, there Appears scarce Any which they are able to Aanlyze[47] by Fire' (82.27-29). He then adds rather dismissively that the chemists cannot

[47] Corrected to 'Analyse' in the 1680 edition.

'Unquestionably Separate so much as any One of their Hypostatical [elemental] Principles' (83.1-3) by means of thermal analysis, which represents a considerable 'Disparagement as well to their *Hypothesis* as to their Pretensions [claims]' (83.4-6).

Carneades concedes that there may be means other than the 'wonted [customary] *Analysis* [decomposition] by Fire' (83.9-10) by which, from a compound material 'Substances as Homogeneous as those that Chymists [Paracelsians] Scruple [doubt] not to Reckon among their *Tria Prima* [three principles of salt, sulphur and mercury]' (83.11-13) may be separated. He then surmises that by the use of 'Convenient Additaments [additives] such Substances may be Separated by the Help of the Fire' (83.16-18) but could not be split off by fire alone, and adds 'Witness the Sulphur of Antimony'[48] (83.19-20).

Carneades' final consideration follows on from the acceptance that since fire is only one of the means that 'must be Employ'd in the Resolution of Bodies' (83.23-24) then one is justified in challenging 'the Liberty [permission] of doing Two Things' (83.25-26). His first consideration is the behaviour of 'any *Menstruum* [solvent] or other Additament [additive]' (83.27-28) when employed in conjunction with fire, with the objective of obtaining 'a Sulphur or a Salt from a Body' (83.29 – 84.1). He queries how the system behaves: does the '*Menstruum*' (84.3) 'barely [merely] Help to Separate the Principle Obtain'd by It' (84.3-4), that is to say, does the solvent simply act to dissolve the materials with which it comes into contact, or alternatively 'there Intervene not a

[48] What Carneades seems to be referring to here is his experiment involving 'antimony' (actually antimony sulphide) and sulphuric acid, discussed earlier.

Coalition of the Parts of the Body Wrought upon with those of the *Menstruum* [solvent]' (84.5-7). Carneades seems to mean by this that the solvent may react with any material dissolved in it, and if this latter condition obtains, then 'the Produc'd Concrete [compound body] may be Judg'd to Result from the Union of Both' (84.7-9).

He goes on to consider the influence of additives, present in the reaction mixture or the decomposition products, and how such additives alter the possibility of determining whether any of the three principles of the Paracelsians could thus be obtained. He argues that for 'the same Mixt [compound] Body' (84.14-15), depending on the 'Nature of the Additaments [additives]' (84.15-16) and the manipulation of the compound body, 'be made to Afford [supply, yield] differing Substances from those Obtainable from it by other Additaments, and another Method' (84.17-20).

Reverting to the reaction he described earlier 'about Tartar'[49] (84.21-22) Carneades says that the different substances obtained as decomposition products may also differ from those 'into which a Concrete is divisible by the Fire without Additaments [additives]' (84.23-24) even though such additives may not form any part of the decomposition product, but instead serve only to 'Diversity [modify] the Operation of the Fire upon the Concrete [compound body]' (84.28-29), and 'though that Concrete by the Fire alone' (84.29 – 85.1) may be separated into decomposition products as numerous as the elements, as taught by 'Any of the Chymists' (85.3) of Carneades' acquaintance.

[49] In which a solution of Salt of Tartar [potassium carbonate] was poured over *Sal Armoniack* [ammonium chloride] to give a strong urinous odour – actually ammonia.

Having dealt with the objections of some of the chemists, Carneades now turns his attention to those likely to be 'Confidently press'd [advanced insistently] By Divers [various] Peripateticks [Aristotelians]' (85.9-10) who in support of their belief in the power of fire to decompose compound bodies into their elements 'will Plead [contend]' (85.12) that Aristotle's is the 'very [true] Definition of Heat' (85.12-13), given as: '*Congregare Homogenea, & Heterogenea Segregare* [like things come together and unlike things separate]' (85.14-15). Carneades counters this definition by saying that 'it rather Seems that the True and Genuine Property of Heat is, to set a Moving, and thereby to Dissociate the parts of Bodies' (85.20-23) so reducing them into 'Minute Particles' (85.24). He gives as examples 'the Boyling of Water, the Distillation of Quicksilver' (85.27-28) or the heating of materials whose constituents at a given temperature, as not 'Dissimilar' (86.2). All that the heat can do in this case is to 'Divide the Body into very Minute parts which are of the same Nature' (86.3-5) both with one another and with their '*Totum* [the whole of a thing] as their reduction by Condensation Evinces [manifests, establishes]' (86.6-7).

Carneades goes on to say that when the 'fire seems most so *Congregare Homogenea, & Segregare Heterogenea* [like things come together, and unlike things separate]' (86.8-9), that this occurs 'but by Accident; for the Fire does not Dissolve the Cement, or rather Shatter the frame, or [s]tructure[50] that kept the Heterogeneous Parts of Bodies together' (86.10-14) and this 'under one Common Form'[51] (86.14-15). The compound body thus

[50] Given as 'structure' in the Errata.

[51] The use of the word 'form' here seems to be as the Aristotelians understood the term – either as the structural organisation of the different parts of physical entities, or as an organising principle applying to them.

decomposed means that the 'Component Particles of the Mixt [compound body]' (86.16-17) are free to separate or agglomerate, and 'oftentimes without any Operation of the Fire' (86.18-19) come together by type, or rather by their various 'Degrees of Gravity [heaviness] and Levity [lightness], Fixedness [inertness or non-volatility] or Volatility' (86.22-23) whether occurring naturally or due to the effects of the fire.

He then gives as examples the distillation 'of Man's Blood' (86.26-27) in which the first decomposition process is to 'Dissolve the *Nexus* or Cement of the Body' (86.27-28). The water 'being the most Volatile' (86.29 – 87.1) and extractable, distils over 'either by the Igneous Atomes, or the Agitation they are put into by the Fire' (87.2-3) then, as it is the heaviest product to separate, it occupies the bottom of the receiver. Once the aqueous fraction has distilled over, the less volatile fraction remains behind – 'the other Principles of the Concrete [compound body] remain Unsever'd' (87.6-8), and for the 'Separation of its more Fixt [non-volatile] Elements' (87.9-10) a higher temperature is required. A hotter fire 'Carries over the Volatile Salt and the Spirit' (87.11-12) which 'though Beleev'd to be Differing Principles' (87.13-14), when in fact they differ only in 'Consistency [solidity or viscosity]' (87.15), having 'an almost Equal Volatility' (87.15-18). The next fraction to distil over 'as less Fugitive [here: volatile]' (87.16-17) is the 'Oyl' (87.17) as these are of equal non-volatility or 'Fixednesse' (87.19) the 'Fire Severs them not, for all the Definition of the Schools'[52] (87.19-21).

[52] The 'Schools' were the universities of medieval Italy, France, Germany and England, and whose teachings, later, came under increasing challenge as the New Science gained influence.

Carneades then observes that if ‘into a Red-hot Earthen or Iron Retort you cast the Matter to be Distill’d’ (87.21-23) what probably will happen, as he himself testifies, is that ‘the predominant [prevailing] Fire will Carry up all the Volatile Elements Confusedly in one Fume’ (87.24-27). In other words, if a material containing volatile components is put into a very hot container, the volatile fractions will distil over together, and only in condensing the distillate will the various volatile products actually separate from one another as they ‘afterwards take their Places in the Receiver’ (87.27-28), finding their own levels ‘either according to the Degree of their Gravity [weight]’ (87.28-29) or to ‘the Exigency [requirements] of their respective Textures’ (88.1-2).

The high temperature at which the distillation process takes place means that the boiling occurs with such agitation that some of the solids carry over with the vapour, with ‘the Salt [solids] adhering for the most part, to the Sides and Top’ (88.2-3), with the ‘Phlegme Fastening it self there too in great Drops’ (88.4-5), and the ‘Oyle and Spirit’ (88.5) finding their place according to their ‘Ponderousness [weight]’ (88.7-8), causing them either to float or sink.

The way in which a compound body separates when heated is not invariable. Why this is so Carneades does not say; he does not attribute it to any difference in intensity of the applied heat. He says that though ‘Oyl or Liquid Sulphur be one of the Elements’ (88.9-10) separated during thermal decomposition, ‘yet the Heat which Accidently United the Particles of the other Volatile Principles, has not always the same Operation on this’ (88.11-15), with Carneades noting that ‘there being divers [various] Bodies which Yield

Two Oyls' (88.15-16), differing in density, or perhaps, miscibility, as 'One sinks to the Bottom of that Spirit on which the other Swims' (88.17-18).

Carneades quotes as examples 'some Oyls of the same Deers Blood' (88.19-20), and 'Two Oyls carefully made of the same Parcel of Humane Blood' (88.21-23), which differ 'extreamly in Colour' (88.23-24), but occupy two distinct layers 'as if by Agitation Confounded [disordered]' (88.25-26) and which will simply unmix of their own accord.

Continuing with his account of the various ways in which fire decomposes bodies, Carneades remarks that it may 'divide Bodies' (88.28-29) due to the fact that 'some of their Parts are more Fixt [non-volatile], and some more Volatile' (88.29 – 89.1-2). He then explains how far removed either fraction may be from a 'pure Elementary Nature is Obvious enough' (89.3-4) by noting that if 'Men' (89.4) would but simply observe the combustion of wood, which the 'Fire Dissipates into Smoake and Ashes' (89.6-7). He then goes on to detail the products actually contained in these two decomposition products. The ashes, he argues, are 'Confessedly [admittedly]' (89.8) composed of two distinct materials 'Earth and Salt' (89.9-10), but the earth is actually soot, which 'Discovers [reveals] it self to Contain both Salt and Oyl, and Spirit and Earth' (89.12-14) with some 'Phlegme [aqueous product]' (89.14).

All of these behave as though almost 'Equally Volatile to that Degree of Fire which Forces them up' (89.15-17), possibly with the more volatile components helping along with the 'Urgency of the Fire, to carry up the more Fixt [non-volatile] ones' (89.19-20). Carneades himself has tried to take advantage of the same effect with 'Dulcify'd [purified from acid] *Colcothar* [an anhydrous sulphate] sublim'd by *Sal Armoniack* [ammonium chloride] blended with it' (89.21-22), and which distil over together,[53] but later may be 'Separated by other Degrees of Fire whose orderly Gradation' (89.24-25) allows them to separate in accordance with the differences in their respective volatilities. This is perhaps a reference to the fact that when anhydrous iron sulphate is heated strongly it decomposes, giving off sulphur trioxide, which dissolves in water to give sulphuric acid.

Carneades goes on to give as example that when 'Differing Bodies United into one Mass be both sufficiently Fixt [non-volatile]' (89.27-29) that no one component of the mixture is sufficiently volatile to be 'Expell'd or carried up, makes no Separation at all' (90.1-2) and he cites 'a Mixture of Colliquated [melted or fused together] Silver and Gold' (90.3-4) from which the two metals may be separated by '*Aqua Fortis* [nitric acid], or *Aqua Regis* [a mixture of hydrochloric and nitric acids] (according to the predominancy of the Silver or the Gold)'[54] (90.5-7). Carneades continues that even a hot fire does not separate these two metals, adding that the 'Fire only dividing the Body into smaller Particles (whose littleness may be argu'd from their Fluidity)'[55] (90.9-10), and explains the action of the fire by saying that 'either the little nimble Atoms of Fire or its brisk and

[53] What Carneades seems to mean is that in heating together a mixture of ammonium chloride with an anhydrous sulphate, the ammonium chloride, which sublimes, in so doing tends to carry over the solid sulphate.
[54] Nitric acid dissolves silver, though not gold; *aqua regis* dissolves both silver and gold.
[55] What Carneades seems to mean is that the fire, in melting the mass of gold and silver, is reducing them into their constituent corpuscles.

numberless [innumerable] strokes upon the Vessels' (90.12-14) operating upon the mass of gold and silver, simply causes them to melt, 'hinder Rest and Continuity' (90.15) without diminishing or interfering with their metallic properties, *i.e*. 'without any Sequestration [separation or elimination] of Elementary Principles' (90.16-17).

He continues that sometimes fire functions not to separate but rather to 'Unite, Bodies of a differing Nature' (90.19) but only if they are of 'an almost resembling Fixedness [here: reactivity]' (90.20-21) and 'have in the Figure of their Parts an Aptness to Coalition' (90.21-22) as happens in the 'making of many Plaisters [plasters] Oyntments, &c' (90.23-24). Carneades goes on to speak of alloys, for example, that are made by 'melting together two parts of clean [unblemished] Brass[56] with one of pure Copper' (90.25-27) which could be cast into 'such curious [exquisite] Patterns' (90.28-29) as to please the eye.

Carneades then describes some chemical reactions, noting that the materials 'mingled by the Fire are Differing enough as to Fixidity [here: reactivity] and Volatility' (91.3-4) yet are caused to react together by the 'first Operation of the Fire, that it self does scarce afterwards Separate them' (91.5-7), serving only to 'Pulverize [reduce to a powder] them' (91.8). He may mean by this that once a chemical compound is formed by the action of the fire on the reactants the only change which takes place is that the liquor in which the reaction occurs is evaporated off, the solid reaction products left behind being in a finely divided, crystalline form.

[56] Brass is an alloy of copper and zinc.

He gives as examples the 'Common Preparation of *Mercurius Dulcis* [mercurous chloride or calomel]' (91.9-10), in which the 'Saline Particles of the Vitriol [ferrous sulphate], Sea Salt [sodium chloride], and sometimes Nitre [potassium nitrate]' (91.10-12), in reacting together, 'do so unite themselves with the Mercurial particles' (91.13-14) to make mercuric chloride, or '[corrosive] Sublimate' (91.15). This is heated with mercury to produce mercurous chloride or *Mercurius Dulcis*, which is what Carneades is referring to when he says that the heating process serves 'to Dulcifie it' (91.16). Liquid mercury, in reacting with mercuric chloride or corrosive sublimate, in the correct proportions, produces mercurous chloride, which vaporises or sublimes at 400^{o}C. This is what Carneades seems to be referring to when he says that 'the Saline and Metalline Parts arise together in many successive Sublimations, as if they all made but one Body' (91.16-19).

Carneades says that fire sometimes binds bodies so firmly together as to be incapable of separating them subsequently. This he explains by saying that the fire may combine the 'Differing Elements of a Body' (91.21) so strongly 'that Nature her self does very seldom, if ever, make Unions less Dissoluble' (91.22-24). He argues that fire, when applied to 'some Bodies exceedingly and almost equally Fixt [inert]' (91.25-26) does not separate them, but instead 'makes an Union so strict [tight, close], that it self alone, is unable to Dissolve it' (91.27-29).

The actual example of this which is given by Carneades is the production of glass, which is a material so stable as to resist thermal decomposition. In the production of glass an 'Alcalizate Salt [probably lime]' (91.29 – 92.1) along with 'the Terrestrial Residue of the Ashes [potash, or potassium carbonate]' (92.1-2), are blended with 'Pure Sand [silica]' (92.2-3) which are 'by Vitrification made one permanent Body' (92.3-4) by which he means 'the course or greenish sort of Glass' (92.4-5). Once made, the hottest fire 'though able to Marry the Ingredients' (92.7) is unable 'to Divorce them' (92.8).

Continuing with his theme of glass production, Carneades says that he 'can shew [show] you some pieces of Glass' (92.9) which he saw 'flow down from an Earthen Crucible' (92.10-11), which had 'Silver in it' (92.12), and which had been subjected for some time 'to a very Vehement Fire' (92.12-13). What may have happened here is that the silver oxidised, and with silica from the earthen crucible combined to form a glass (perhaps similar to the lead glass used for crystal production in later times).

A further example of minerals vitrifying, from the metallurgical industry, is given by Carneades. He states that some of those who are involved in 'the Fusion of Metals' (92.14) tell him 'that the melting of a great part of a Crucible into Glass is no great Wonder in their Furnaces' (92.15-17). What may simply be happening here is that the working temperatures are so high as to vitrify the silica, or related compounds, present in the earthen crucibles. That very high temperatures are indeed involved is indicated by Carneades' description which involves 'the Melting of great Quantities of Iron out of the Oar' (92.18-19) using 'Store [abundant supply] of Charcoal' (92.20) as 'Sea-Coal [ordinary coal] will not yield a Flame strong enough' (92.21-22). The fuel is caused to burn with ‘prodigious Vehemence’ (92.22-23), as the fire is ‘Exited by vast Bellows’ (92.23-24), which is water operated. The intense heat caused some of the material ‘instead of being Analyz’d [resolved into its components]’ (92.26-27) to be ‘Colliquated [fused together], and turn’d into a Dark, Solid and very Ponderous Glass’ (92.27-29) in great quantity. What seems to have occurred in this case is that the very hot burning charcoal caused some of the silica, present in earthen vessels, to vitrify into a very hard glass, suitable for use in repairing ‘High-wayes’ (93.2).

Carneades goes on to remark that ‘some kind of Fire-stone[57] it self’ (93.5-6) and ‘expos’d to very strong And lasting Fires’ (93.7-8) in furnaces, had ‘had all its Fixt Parts so Wrought [fashioned] by the Fire, as to be perfectly Vitrify’d’ (93.9-10), which he himself has ‘try’d [purified or refined] by Forcing from it Pretty large Pieces of Perfect and Transparent Glass’ (93.11-13).

Addressing Eleutherius, and anticipating that he may be about to propose that the action of heat in the combining of bodies may be the same as the ‘Definition which is wont [accustomed] to be given and Acquiesc’d in [tacitly agreed with], of its contrary Quality, Cold’ (93.16-18) as ‘*tam Homogenea, quam Heterogenea congregare* [so like things, as unlike things, come together]’ (93.19-20). Carneades says that this definition is not only ‘unquestionable [not liable to question]’ (93.22), and not without ‘Exception’ (93.23), but adds that the ‘Union of Heterogeneous Bodies’ (93.25-26) which cold is supposed to bring about, ‘is not Perform’d by every Degree of Cold’ (93.27-28). He goes on to give as example the ‘Urine of Healthy Men’ (93.29 – 94.1) which has been

[57] A stone that resists the action of fire, used in lining furnaces and ovens.

'Suffer'd [allowed] a while to stand' (94.2). The cold causes it to separate into two fractions: a 'Thinner Part from the Grosser [main]' (94.3-4), and the latter 'Subsides [sinks] to the Bottom' (94.4-5) of the container, and becomes 'Opacous [opaque]' (94.5-6). On the other hand, if 'the Urinal be Warme, these Parts readily Mingle again, and the whole Liquor becomes Transparent as before' (94.6-9).

Carneades goes on to speak of the freezing together of water with some solid material bodies, saying that 'the Cold does not Cause any Real Union or Adunation [combination]' (94.12-13) 'of these Bodies' (94.14) but merely their freezing together with the water into ice, the other bodies being only 'Accidently Present' (94.17) but not 'Really United' (94.19) in the frozen mass. A further illustration of the fact that cold does not cause dissimilar objects actually to combine is given by Carneades, and it is that if a 'Heap of Mony Consisting of Gold, Silver and Copper Coynes' (94.20-21) and other dissimilar bodies which are 'Destitute [devoid] of Aqueous Moisture, Capable of Congelation' (94.23-24) are exposed to 'never [ever] so intense a Cold' (94.25) one finds that the various bodies are not 'so much as Compacted, much less United together' (94.27-28).

He goes on to discuss Paracelsus' doctrine of the separation of alcohol, water and residue by the freezing of wine. He says, respectfully, that if '*Paracelsus* his Authority were to be look't upon as a Sufficient Proof in matters of this Nature' (95.3-5), Carneades might 'insist [assert or maintain persistently]' (95.5) on Paracelsus' procedure for the separation of wine whereby 'the Essence of Wine may be sever'd from the Phlegm [aqueous] and Ignoble [base] Part by the Assistance of Congelation [freezing]' (95.7-10). That this process has carried 'much Weight' (95.10), not only with Paracelsus but also other writers, who seem to have been convinced of its veracity, as 'Some of whom seem not to have perus'd it themselves' (95.13-14). Carneades then quotes a passage from 'the sixth Book of his *Archidoxis*' (95.16-17) in which the procedure is described. This passage may be translated as follows (95.19 – 96.14):

> 'It should be understood of wine that its lees and phlegm are minerals, and that its body is the substance in which the essence is preserved, inasmuch as in gold lies the essence of gold. Equally, that we commit our practical knowledge to memory, lest we forget it, in this way:
>
> Take the best and oldest wine which you can possibly have, with warmth and flavour to your liking, pour this into a glass vessel until it is one-third full, and, together with a statuette of Hermes,[58] place into a horse's stomach, and keep it there for four months, in constant heat, lest it should spoil. This done, it is subjected to the harshness of the winter cold for a month, so that the exposure will freeze it. By this means the cold forces the spirit of wine, as one with its substance, to the centre of the wine and is separated from the phlegm.[59] Remove the congealed fraction which is not entirely frozen, this spirit having been judged to be the substance of the wine. When this has been placed in a pelican[60] and arranged in sand it shall then be allowed to remain for some time at a moderate

[58] Hermes (in Latin *Mercurius*) is the messenger of the gods. Hermeticism is the outlook associated with the Hermetic writings, a literature in Greek which developed in the early centuries of the Christian era, under the name 'Hermes Trismegistus [Hermes the Thrice Great God]', much of it concerned with Astrology, Alchemy and other occult sciences, but there is also a philosophical Hermetic literature.
[59] The cold would cause the tartar to separate out from the wine as a white, probably crystalline, solid.
[60] A pelican is a type of still, consisting of a glass container, by which reflux distillation (*i.e*. boiling, with the vapour condensing and flowing back) is carried out.

temperature. Afterwards, recover the magistery[61] of the wine of which we have spoken'.[62]

Carneades immediately casts doubt upon the veracity of this description by recounting his own unsuccessful attempts at separating the alcohol from wine through freezing. He says that if the foregoing account 'were True, it would be but seldom Practicable in this Country upon the best Wine' (96.17-19), then states that although 'this present Winter hath been Extraordinary Cold' (96.19-21) he has not 'been able in any Measure to Freeze a thin Vial full of Sack [a Spanish white wine]' (96.23-24).

Carneades goes on to relate that even with 'Snow and Salt'[63] he could 'Freeze little more than the Surface of it' (96.25-26), but then concedes that it is not 'every degree of Cold that is Capable of Congealing Liquors' (96.27-28), and which can make 'such an *Analysis* [separation into component parts]' (96.29) of them by 'Separating their Aqueous and Spiritous [alcoholic] Parts' (97.1-2). He continues with the account of his own experiments in the matter by stating that he has 'sometimes, though not often, frozen severally [individually], Red-wine, Urine and Milk, but could not Observe the expected Separation' (97.3-6). Carneades then narrates the experiences of the

[61] The magistery is composed of the original elements of the body, freed from impurities. Here: the alcoholic fraction of the wine.

[62] '*De Vino sciendum est, faecem phlegmaque ejus esse Mineram, & Vini substantiam esse corpus in quo conservatur Essentia, prout auri in auro latet Essentia. Juxta quod Practicam nobis ad Memoriam ponimus, ut non obliviscamur, ad hunc modum: Recipe Vinum vetustissimum & optimum quod habere poteris, calore saporeque ad placitum, hoc in vas vitreum infundas ut tertiam ejus partem impleat, & sigillo Hermetis occlusum in equino ventre mensibus quatuor, & in continuato calore teneatur qui non deficiat. Quo peracto, Hyeme cum frigus & gelu maxime saeviunt, his per mensem exponatur ut congeletur. Ad hunc modum frigus vini spiritum una cum ejus substantia protrudit in vini centrum, ac separat a phlegmate: Congelatum abjice, quod vero congelatum non est, id Spiritum cum substantia esse judicato. Hunc in Pelicanum positum in arenae digestione non adeo calida per aliquod tempus manere sinito; Postmodum eximito vini Magisterium, de quo locuti sumus.*'

[63] A freezing mixture capable of reaching a temperature as low as - 21^{o} C, in the appropriate proportions.

Dutchmen who wintered in 'that Icie Region neer the Artick Circle, call'd *Nova* [Novaya] *Zembla* [Zemlya] (97.7-9), off the northern coast of Russia, who state that 'there was a Separation of Parts made in their frozen Beer about the middle of *November*' (97.10-12), and who for the following month speak of how their 'Back'[64] (97.13) behaved in the cold. By contrast with the beer, their '*Sack, which is so hot* [by which he seems to mean warming when consumed], *was Frozen very hard*' (97.15-16), necessitating that it be thawed in the fire prior to drinking. He states that the Dutchmen are not saying that their sack had been separated 'by the Frost into differing Substances, after such manner as their Beer had been' (97.22-24).

Both beer and wine do freeze, with the freezing point dependent upon the alcohol content, along with the presence of salts, sugars and other non-aqueous additives. The higher the content of alcohol, and other ingredients, the lower the freezing point. The freezing point of wine produced by modern wine producing methods would run at approximately -5 to -10^{o}C.

What probably happened to the Dutchmen's beer was that the first fraction to freeze out was a water-rich fraction containing little alcohol, but the November cold may not have been sufficiently intense to cause the remaining fraction to freeze, as this fraction would have contained more alcohol than the first. By contrast, in December their wine, as it froze would also have yielded a watery fraction containing some alcohol, but that the more intense cold caused the remaining alcohol-rich fraction to freeze as well, leading to the production of a solid frozen mass.

[64] Corrected to 'Sack' in the *Errata*.

Carneades seems to reserve his opinion as to the veracity of the account just given, for he says 'all of which notwithstanding, *Eleu.* [*therius*] suppose that it may be made to appear, that even Cold sometimes may *Congregare Homogenea*, *& Heterogenea Segregare* [bring like bodies together, and separate unlike ones]' (97.24-28). In order to 'Manifest this' (97.28-29) he relates how he had a 'Plant abounding with Sulphureous and Spirituous Parts'[65] (98.2-3) 'Decocted [boiled down] in fair [clean] Water' (98.1-2). Then, 'having expos'd the Decoction to a keen North-Wind in a very Frostly Night' (98.3-5) he observed on the following morning that the 'more Aqueous Parts' (98.6) of the mixture were turned into 'Ice' (98.7). Towards the centre of the frozen portion to which the 'more Agile and Spirituous Parts' (98.9) 'having Retreated' (98.10) had 'there preserv'd themselves unfrozen in the Form of a high colour'd Liquor' (98.12-14). The 'Aqueous and Spirituous parts having been so sleightly [subtly] (Blended rather than) United in the Decoction' (98.14-17), and having come together in a simple mixture rather than combining chemically, were 'easily Separable by such a Degree of Cold' (98.17-18) as would not cause the separation into their component parts of 'Urine or Wine' (98.20) which 'by Fermentation or Digestion are wont [habitually]' (98.20-21), as Carneades himself has found, 'to be more intimately associated each with other' (98.22-23).

He tells Eleutherius that he is not about to 'Insist [to stand or rest on] this Experiment' (98.25) partly because, as a simple experiment, he 'may possibly have been mistaken in

[65] By which he may mean inflammable and volatile parts, knowledge probably obtained through his own thermal analysis of the plant in question.

it' (98.27), but mainly because of the 'more full and eminent Experiment of the Separative Virtue [power] of extream Cold' (98.29 – 99.1-2) made by the 'forementioned Dutchmen that Wintered in *Nova* [Novaya] *Zembla* [Zemlya]' (99.4). The work in which the voyage is related is a 'very scarce [rare] Book' (99.6) and from it Carneades quotes an extract in which the freezing and subsequent thawing of beer is described.

The voyagers named were '*Gerard de Veer*, *John Cornelyson* and Others, sent out of *Amsterdam*, *Anno Dom*. [in the year of the Lord] 1596' (99.11-13). They describe how in October they 'laded [loaded] a Sled with Beer' (99.18) on the deck of the ship, but were forced to leave it exposed to the elements, due to 'so great a Storm and Cold' (99.21-22) forcing them to go below decks. The following day they found the barrel of beer still on the sled 'but it was fast frozen at the Heads' (100.1-2). However, the cold had caused the beer in the barrel to cool down, and as it approached the freezing point it began to expand (as water begins to expand on cooling below 3.98^{o}C) and 'the Beer that purg'd [was expelled] out' (100.3-4) froze solid to the sides of the barrel. They removed the barrel indoors, set it 'an [on] end' (100.7-8), and proceeded to thaw its contents.

In the freezing of the beer the first fraction to freeze would have consisted mainly of water, with little alcohol, and this is what they found as 'that which was frozen tasted like water' (100.14-15). This meant that the fraction which froze later was more concentrated in alcohol than normal beer, and that fraction which remained unfrozen contained the highest concentration of alcohol of all. They remark that ‘in the thick Yiest that was unfrozen lay the Strength of the Beer, so that it was too strong to drink alone’ (100.11-13), forcing them to mix this fraction with the frozen one, but clearly the freezing had ruined the quality of the beer, as the mixture had ‘neither Strength nor Taste’ (100.17-18).

Carneades goes on to quote an experiment of his own in relation to the freezing of ‘among other Liquors, some Beer moderately strong, in Glass Vessels, with Snow and Salt’ (100.21-23). He found, as the beer cooled and expanded in the glass vessels, that ‘there came out of the Neck a certain thick Substance’ (100.24-25), which was probably the last fraction of the beer to remain unfrozen, as it was better able ‘to resist a frost’ (100.28) than the rest of the liquor, which Carneades ‘found turn’d into Ice’ (100.27-28). Initially the material ‘by its Colour and consistence seemed mafestly[66] enough to be Yiest’ (100.29 – 101.1). He seems to mean by this a beer not fully fermented, and therefore not yet ready to drink, but he could not ‘decerne’ (101.3), either by ‘Taste’ (101.4) or ‘Enquiry’ (101.4), that ‘the Beer was at all too New to be very fit to be Drank’ (101.4-6).

He extends the discussion on the freezing of beer by relating how a ‘neere Friend’ (101.8) of his subjected some home brewed ‘Beer or Ale’ (101.10) to the ‘late bitter Winter’ (101.12) of Holland, and froze it ‘into Ice, and a small Proportion of a very Strong and Spirituous Liquor’ (101.13-15). Again what seems to have occurred here is that, in freezing, the initial fraction of the beer to freeze was almost pure water – which

[66] Corrected to ‘manifestly’ in the 1680 edition.

froze into the ice just mentioned in Carneades' account. The remaining fraction of liquor, containing as it did a higher proportion of alcohol than the original beverage, did not freeze but remained as an unfrozen, more strongly alcoholic liquor, as noted by Carneades.

In rounding off this part of the dialogue, Carneades says that he will not 'entertain [hold engaged] you any longer concerning Cold' (101.16-17) as he does not wish to continue with a topic which is not directly relevant to his 'present Undertaking' (101.20), but also because he has by now 'already enlarg'd [expanded himself in words] my self too much upon the first Consideration I propos'd' (101.21-23) *i.e.* his discussion of the effects of heat on various materials. He adds that it is a 'Paradox' (101.24), that is, seemingly absurd but actually true, that he should say so much in order to prevent his discussion from being considered a 'meere Extravagance [straying from his theme]' (101.26-27). He then justifies his reason for treating of his subjects as he has done, by stating that he 'Undertook but to make the common Assumption or our Chymists [Paracelsians] and *Aristotelians* appear Questionable' (101.27 – 102.1-2), but hopes that he has successfully dealt with the matter as to be ready to move on to his 'Following Consideration' (102.4-5) and promises to 'Insist [assert or maintain persistently] lesse on them than I have done on the First' (102.5-6).

A Commentary on *The Sceptical Chymist* of Robert Boyle: *The Second Part*

Introductory Remarks

In this section Boyle, to quote Boas (*q.v.*), 'argues that not everything separated from a body is necessarily pre-existent in it.' The importance of water as a primal element is stressed (119-121), with Carneades relating several experiments offering evidence that plants are produced through the transmutation of water: both his own (107-112) and those of van Helmont (112-114). He presents testimony on the production of living creatures from water (122-123) and asserts that plants may extract a substance from the air necessary to their development (112).

A long discussion on mixing takes place, with the Aristotelian doctrine on the subject being analysed, then discredited, using practical examples (136-161).

The Sceptical Chymist

The Second Part.

Without further ado Carneades states that the ‘Second Consideration’ (103.1) which he wishes to discuss is that, contrary to the opinions of both Aristotelians and Paracelsians, ‘it is not so Sure’ (103.3) ‘that every Seemingly Similar or Distinct Substance that is separated from a Body by the Help of the Fire was Pre existent in it as a Principle or Element of it’ (103.5-9).

He continues that in order not to make ‘this paradox’ (103.10), that is, his offering a statement which conflicts with the received opinion of his adversaries on the composition of thermal decomposition products, any ‘Greater then [than] I needs must’ (103.11) he will give a brief explanation of what his proposition means, then proceed to ‘Argue for it’ (103.13-14).

Carneades goes on to explain that he does not mean that any thing can be separated ‘from a Body by Fire, that was not Materially pre-existent in it’ (104.2-3), and continues that it is not within the capacity of ‘Meerly [purely] Natural Agents’ (104.4-5) including fire ‘to product anew so Much as one Atome of Matter’ (104.6-7) as they can only ‘Modifie and Alter, not Create’ (104.8-9). He adds that this is ‘so Obvious a Truth, that almost all Sects of Philosophers have Deny’d the Power of producing Matter to Second Causes’ (104.9-12), and continues that ‘the *Epicureans* and some others’ (104.12-13) apply the same belief in ‘Reference to their Gods themselves’ (104.14-15). What Carneades seems to mean is that, for Christians, all the matter in the universe was created by God, the First Cause, at the time of creation, and consequently, no Second Cause, such as nature, possesses the power to create it. Many of the Ancient Greek philosophers, including Epicurus[1], believed in the doctrine that the world was both uncreated and eternal. Hence the remark that Epicurus held that it was not created by the gods.

Carneades cites another case in which it is possible that some thermal decomposition products may have already been present in a compound body, saying that some things obtained from a 'Mixt Body' (104.18) by the fire 'may have been more then [than] barely [merely] Materially Pre-existent in it' (104.19-20). This he infers from 'several Documents' (104.22-23) which state that some 'Concretes [compound bodies]' (104.21) abound with either 'Salt' (104.24) or 'Sulphur' (104.24).

He then makes an interesting point in which he states that an argument could be made that if thermal decomposition yields products not originally present in a compound body, then these same products may be taken by some as elementary ingredients. He says that 'it will serve our present Turn [purpose]' (104.25) if it can be made to seem plausible 'that divers [many] things' (104.26) obtained from a compound body by the fire 'were not its Ingredients Before' (104.27-28). The reason for this being that 'if this be made to appear it, will be Rationall enough'[2] (104.28-29 – 105.1). That Chymists [Paracelsians] may firmly deceive 'themselves, and Others' (105.1-2), that 'those Substances to be the Elementary Ingredients of Bodies barely [simply] separated by the Fire' (105.3-6). He adds that the question will only be settled when 'some other Argument' (105.8) than that provided by the results of thermal analysis be applied to the problem.

[1] Epicurus (*c*. 341- *c*. 270 BCE) Greek philosopher who adopted an atomic theory of matter.
[2] Comma moved to 'if this be made to appear, it will be Rationall enough' in the *Errata*.

Carneades recapitulates the proposition he is 'Explaining' (105.12) as the reasonable doubt 'whether or no the Differing Substances Obtainable from a Concrete Dissipated by the Fire were so Exsistent in it in that Forme (at least as to their minute Parts) (105.14-18) as revealed at the end of the decomposition process. He also contends that the fire does no more than 'Dis-joyne and Extricate the Corpuscles of one Principle from those of the other wherewith [with which] before they were Blended' (105.20-23).

Carneades, having 'Explain'd' (105.24) his proposition, now offers two proofs of it. The first is to show that the Paracelsian principles (salt, sulphur and mercury) may be 'produc'd *De novo* [anew] (as they speak.)' (105.28-29). The second is to 'make it probable' (106.1) that thermal decomposition may yield from some compound bodies 'such Substances as were not in the Newly Expounded sense, pre-existent in them' (106.3-5).

He elaborates on the first proof by stating his assertion that if 'Compounded Bodies Differ from One Another but in the Various Textures Resulting from the Bigness, Shape, Motion, and contrivance of their smal parts' (106.8-12), then it could be allowed that a given particle of the 'Universal Matter' (106.14) may be caused to 'Deserve the Name, sometimes of a Sulphureous, and sometimes of a Terrene [earthy], or Aqueous Body.' (106.16-19). He will not now elaborate on this as 'our

Friend, Mr. *Boyle* has promis'd us something about Qualities' (106.20-22)[3], by whom the question will be 'Studiously Enquired into' (106.24).

Carneades continues that 'Wherefore [as a result of which]' (106.24-25) what he is about to adduce in support of his recent assertion 'shall be Deduc'd from Experiments made Divers [several] Years since [ago]' (106.27-28). The first of these was the growing of a vegetable which was commenced two months late (in May) due to 'some intervening Accidents' (107.1-2), the details of which he considers it not 'impertinent [irrelevant] to Give You' (107.9). He had his 'Gardener' (107.11) take some good earth, 'dry it well in an Oven' (107.15), weigh it and place it in 'an Earthen pot almost level with the Surface of the ground' (107.16-17), and to sow in it 'a selected seed' (107.18) of 'Squash, which is an Indian kind of Pompion [pumpkin], that Growes apace' (107.20-21). Carneades visited the rapidly growing specimen as his 'Occasions [business matters] permitted' (107.24). Despite being 'unseasonably sown' (107.26), only the fast approaching winter 'Hinder'd it from attaining any thing neer its due and wonted [habitual] magnitude' (107.27-29).

Carneades has in parentheses the interjection of finding that same autumn in his garden 'some of those plants, by Measure, as big about as my Middle' (108.2-3), by which he seems to mean that some other pumpkins were also growing there. He continues that his gardener carefully harvested the pumpkin in question in October and sent Carneades an account of it, in which he recorded a minimal weight loss in

[3] This seems to be a reference to the work 'The Origin of Forms and Qualities According to the Corpuscular Philosophy' first published in 1660, but consisting of a number of papers written in the 1650s. See: M.A. Stewart, ed. *Selected Philosophical Papers of Robert Boyle* (Cambridge: Hackett, 1991), xvii.

the earth after drying it three times in the oven, but in his second weighing of the earth he ‘found it Shrink little or nothing’ (108.16-17).

In an effort to ‘deal Candidly [honestly]’ (108.18) with Eleutherius, Carneades recounts a similar experiment, only this time ‘wherein the Earth seems to have been much more Wasted’ (108.22-23). This time the gardener relates how ‘two Indifferent Fair’ (108.27-28) cucumbers were grown in earth, and the earth baked ‘in several small Earthen Dishes in an Oven’ (109.3-4). He found the ‘Earth wanted [lacked] a Pound and a Halfe of what it was formerly’ (109.5-7). Having redried the earth in an oven ‘(after the Bread was drawn)’ (109.9), and finding no weight change, he reasoned that there ‘was no Moisture left in the Earth’ (109.12-13). He believes that the missing pound and a half was not ‘Drawn away by the Cucumber’ (109.14-15) and concludes that ‘a great part of it in the Ordering [managing or directing] was in Dust (and the like) wasted’ (109.15-17), subtly suggesting that those who were responsible for putting the pots of earth into the oven, and later removing them, may have caused the missing pound and a half of earth, in the form of dust, to spill from the earthen containers.

Carneades concurs with the gardener in accepting that the missing portion of earth was lost rather than absorbed by the growing cucumber, as he states that ‘it appears that though some of the Earth, or rather the dissoluble [soluble] Salt harboured in it, were wasted, the main body of the Plant consisted of Transmuted water’ (109.19-23). He goes on to relate that he caused the pumpkin-growing experiment to be ‘reiterated [repeated], which he recalls as not only surpassing his earlier efforts ‘But seem’d strangely to conclude what I am pleading [arguing] for’ (110.1-2), though due to his having lost his gardener's account of the experiment he 'dare not insist [stand or rest on] upon them' (110.5-6).

He begins to speak in general terms about how the same type of experiment may be attempted with the 'seeds of any Plant, whose growth is hasty, and its size Bulky' (110.8-9). He then shares his knowledge of tobacco growing, saying how he had leaves of it in his 'Garden neer a Foot and a Halfe broad' (110.15-16), and goes on to stipulate that the 'next time I try this Experiment, it shall be with several seeds of the same sort, in the same pot of earth, that so the event may be the more Conspicuous' (110.17-20).

Carneades, acknowledging that not everyone is in a position to carry out 'this Experiment neither [either]' (110.22-23), relates that he 'made in my Chamber [private room or bedroom], some shorter and more Expeditions[4] Tryals' (110.23-25). He placed 'a top of Spearmint, about an Inch Long' (110.25-26) into a 'good Vial [phial or smallish glass vessel] full of Spring water' (110.27-29) with the stem immersed in the water. The slip soon sprouted roots and leaves 'and aspire [reach] upwards, and in a short time it had numerous Roots and Leaves' (111.4-6), smelling strongly of mint. The well-developed plant with its swollen stalk and 'various and ramified [spread out as branches] Roots, which it shot into the Water as if it had been Earth, presented in its Transparent Flower-pot a Spectacle not unpleasant to behold' (111.11-15).

[4] Corrected to 'Expeditious' in the 1680 edition.

He successfully completed similar experiments with 'sweet Marjoram' (111.10) and 'Balme and Peniroyal' (111.19). He had one of these plants 'cherish'd only by Water' (111.21) when it was well developed, 'Distill'd in a small Retort' (111.23-24) and obtained as distillation products 'some Phlegme [aqueous fraction]' (111.25), 'a little Empyreumatical Spirit'[5] (111.25-26), 'a small Quantity of adust Oyl'[6] (111.26-27), and an inert residue 'a *Caput mortuum*; which appearing to be a Coal concluded it to consist of Salt [here: soluble solid] and Earth [insoluble solid]' (111.27-29). The amount of solid residue was 'so small that I forbore [dispensed with] to Calcine [heat strongly in air] it' (112.1-2).

Carneades says that he never changed the water in which the plant was grown, then goes on to explain why he chose spring-water over rain-water. The latter he avers 'is more discernably a kinde of πανσπερμία ' (112.6-7), *i.e.* panspermia or a substance containing the seeds of all things.[7] Even though it 'be granted to be freed from grosser Mixtures' (112.7-8) it seems to contain 'Streams of several Bodies wandering in the Air, which may be suppos'd to impregnate it'[8] (112.10-12). In addition it seems to contain 'a certain Spirituous Substance, which may be extracted out of it'[9] (112.12-14), which 'is by some mistaken for the Spirit of the World[10] Corporify'd [embodied]' (112.14-15), and about which Carneades may 'elsewhere perchance [perhaps] but must not now, Discourse to you' (112.17-18).

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[5] Tasting or smelling of burnt organic matter.
[6] A dark brown-coloured oil, or a burnt oil.
[7] From the theory that there is everywhere minute germs which develop on finding a favourable environment.
[8] Carneades may have in mind here the microscopic bodies, such as pollen grains, which are present in the air.
[9] Perhaps Carneades has here an inkling of the presence of some constituent of the air (which we now identify as carbon dioxide) which can be extracted from it by, for example, clouds and falling raindrops, and which plays a role in plant growth.
[10] A reference to The Platonic *anima mundi* [world soul] or the 'Spirit of Nature' of the Cambridge Platonist Henry More (1614-87).

He now goes on to describe the well-known tree growing experiment carried out by van Helmont[11], who is 'more considerable [notable] for his Experiments than many Learned men are pleas'd to think him' (112.21-23), and who 'had an Opportunity to prosecute [pursue] an Experiment' (112.24-25) very similar to those just narrated by Carneades 'for five years together' (112.27). At the end of the experiment he had obtained 'so notable a Quantity of Transmuted Water that I should scarce Think it fit to have his Experiment, and Mine Mention'd together' (112.28 – 113.3). The amount of time and leisure required deter its repetition, even though 'so Paradoxical a Truth' (113.6-7), as these experiments suggest would require confirmation by 'more Witnesses then [than] one' (113.9). This is especially so as 'the Extravagancies and Untruths to be met with in *Helmonts* Treatise of the Magnetick Cure of Wounds' (113.10-13) have made his findings 'suspected in his other Writings' (113.14). Carneades, however, has sufficient confidence in 'some of the Unlikely matters of Fact' (113.15-16), van Helmont asserts in his works, that he 'might safely undertake to be his Compurgator' (113.16-17), *i.e.* he would vouch for him.

He goes on to narrate how van Helmont 'took 200 pound of earth dry'd in an Oven, and having put it into an Earthen Vessel and moisten'd it with Raine water he planted in it the Trunk of a Willow tree of five pound Weight' (113.20-24). He watered the growing tree 'with Rain or with Distill'd Water' (113.25-26), and to prevent contamination of the earthen pot from 'Neighbouring Earth' (113.27) 'he employ'd a plate of Iron tinn'd over and perforated with many holes' (113.28 – 114.1). When five years had 'efflux'd [elapsed]' (114.2) he removed the tree and

[11] Jan Baptista van Helmont (1578/79-1644) Flemish physician and chemist.

reweighed it, ‘and (with computing the leaves that fell during four Autumnes) he found it to weigh 169 pound and about three Ounces’ (114.3-6). He reweighed the earth the tree had grown in, and found ‘it want [lack]’ (114.8), of its original weight of 200 pounds ‘about a couple only of Ounces; so that 164 pound of Roots, Wood, and Bark, which Constituted the tree, seem to have Sprung from the Water’ (114.9-13).

Perhaps in anticipation of what Eleutherius is about to ask, Carneades says that if ‘*Helmont* had the Curiousity to make any *Analysis* of this Plant’ (114.14-15), ‘You’ (114.18) would doubtless have believed that if ‘he had Distill’d this Tree, it would have afforded him the like Distinct Substances as another Vegetable of the same kind’ (114.19-22). Needless to say Carneades had in mind that some experiments of the same nature as those already related ‘would succeed in other Bodies then [than] Vegetables’ (114.26-27). However, ‘importunate [untimely] Avocations [distractions]’ (114.27-28) having so far prevented him from realising his ‘Design [plan]’ (114.29), he ‘can yet speak but Confecturally[12] of the Success’ (115.1-2).

Carneades then excuses his lack of further experimental work by saying that the experiments already quoted are sufficient to allow him to make his point. He says ‘but the best is’ (115.2) that the experiments just related are in no need of further ones ‘to Verifie as much as my present task makes it concern me to prove by Experiments of this Nature’ (115.5-7).

Eleutherius breaks his lengthy silence by remarking to his interlocutor that what he has just been relating is not only close to ‘*Helmonts* Opinion about the Origination of

[12] Corrected to ‘Conjecturally’ in the 1680 edition.

Compound Bodies' (115.11-12) but is approving of the 'Arguments which he imployes to prove it' (115.13-14). At Carneades' prompting Eleutherius goes on to offer an account of van Helmont's understanding of matter.

Eleutherius says to his companion that Carneades speaks as one who already knows that 'this bold and Acute Spagyrist [one who separates and combines materials]' (115.20-21) asserts that all 'mixt Bodies spring from one Element' (115.22-23) and that 'Vegetables, Animals, Marchasites [metallic sulphides or similar], Stones, Metalls, &c. are Materially but simple Water disguis'd into these Various Formes, by the plastick or Formative Virtue [operative influence] of their seeds' (115.23-28). Many of his 'Reasons [statements]' (115.28) are to be found scattered throughout van Helmont's writings, the three most important of which are: 'The Ultimate Reduction of mixt Bodies into Insipid Water, the Vicissitude [mutability] of the supposed Elements, and the production of perfectly mixt Bodies out of simple Water' (216 [116].2-7). Eleutherius elaborates on the first of these by saying that van Helmont holds that the '*Sal circulatus Paracelsi*[13] or his Liquor *Alkahest* [universal solvent]' separates 'Plants, Animals, and Mineralls into one Liquor or more, according to their several internall Disparities [dissimilarities] of Parts' (216 [116].10-12), but without causing damage or degradation to any of the individual components of the compound body, as there remains no '*Caput Mortuum* [inert residue]' (216.13) and their 'seminal Virtues [seeds or formative principles]' (216.14) remain intact.

[13] Paracelsus' salt produced by redistillation, possibly alcohol.

He continues that once the Alkahest or universal solvent has acted on the bodies it can be 'Abstracted [removed] from these Liquors in the same weight and Virtue [power] wherewith it Dissolv'd them' (216 [116].15-17), showing that it had not reacted chemically with any of the compound bodies it had dissolved. Eleutherius goes on to explain that, the bodies thus dissolved, 'the Liquor may by frequent Cohobations [redistillations] from chalke or some other idoneous [suitable] matter, be Totally depriv'd of their seminal Endowments [properties], and return at last to their first matter, Insipid Water' (216 [116].17-22).

Van Helmont, he elaborates, put forward other means by which some materials may have their micro-structures broken down, or be divested of their 'borrow'd shapes' (216 [116].25) – indicating that their fundamental material architecture is not inherent to them – and be caused to 'remigrate to their first Simplicity' (216 [116].25-26), *i.e*. be reduced to water.

He recalls that the second argument advanced by van Helmont of water being the origin of all compound bodies was 'that the other suppos'd Elements may be transmuted into one another' (117.1-3), but passes over this quickly by saying that van Helmont's experiments in this regard are 'so uneasie [difficult] to be made and to be judg'd of, that I shall not insist on [stand or rest on] them' (117.5-7). He adds that even if his findings were accepted as true 'his Inference from them is somewhat disputable' (117.8-9). Eleutherius says that he will 'pass on to tell You' (117.10) that van Helmont 'Endeavours to prove water the Sole Element of Mixt Bodies' (117.12-13) *i.e*. to show that all bodies can ultimately be reduced to water, with this being achieved by his '*Alkahest* [universal solvent] or some other conquering Agent'

(117.15-16). The seeds which 'Disguis'd' (117.17) the 'mixt' or compound bodies are either destroyed by the alkahest, or in time are rendered inactive through being 'Weari'd or Exantlated [exhausted] or unable to Act their Parts' (117.18-19).

He goes on to state that in his third argument van Helmont attempts to 'evince [vindicate]' (117.22) the same conclusion: bodies are no more than 'Water Subdu'd [prevailed over] by Seminal Virtues [seeds or formative principles]' (117.24-25). He gives several examples of this with 'Plants and Animals' (117.27), although 'divers [many] of them being Difficult either to be try'd or to be Understood' (117.27-28), and others 'not altogether Unobnoxious [not liable] to Exceptions [adverse criticisms]' (118.1-2). He adds that Carneades has identified the main and 'less Questionable' (118.3) of these *viz*. that involving the growing of a willow tree. So having answered Carneades' question on van Helmont's account of the constitution of compound bodies, he invites his companion to give him his 'Sence of it' (118.10) 'if' (118.10) in so doing he will not 'Divert' (118.11) him unnecessarily from his 'Discourse' (118.12-13).

Humorously, Carneades begins his reply by saying that the *if* prefaced just now by Eleutherius to his invitation to speak was not 'needlessly annex'd [appended]' (118.15), for a thorough presentation of van Helmont's ideas, would 'require so many Considerations [observations]' (118.17-18) that he would not now have the time or 'Liesure[14] to perfect such a Digression' (118.20) nor to conclude his own accounts. Adopting a more serious tone, he assures Eleutherius that he need not fear his 'rejecting this Opinion for its Novelty' (118.24), even though the Helmontians

[14] Corrected to 'leasure' in the Errata.

'may in complement to their Master' (118.25-26) present it as a 'new Discovery' (118.27), and while van Helmont puts forward his own case in relation to this experiment, 'the Opinion it self is very Antient' (118.28-29).

Carneades now goes on to cite the opinions of several ancient authors on the question of water as the primal element.[15] He begins by saying that '*Diogenes Laertius*[16] and divers [several] other Authors speak of *Thales*[17], as the first among the *Grecians* that made disquisitions upon nature' (118.29 – 119.1-3). He adds that of '*Thales*, I remember, *Tully*[18] informes us, that he taught all things were at first made of Water' (119.4-6). He goes on to say that according to '*Plutarch*[19] and *Justin Martyr*'[20] (119.7), the opinion pre-dated him, as according to them, he quoted '*Homer*'[21] (119.10) in defence of his belief.

He then quotes 'A Greek Author, (The *Scholiast* of *Apollonius*) upon these words

The Earth of Slime was made,

affirms (out of *Zeno*)[22] that the *Chaos*, whereof all things were made, was, according to *Hesiod*,[23] water' (119.10-17), which settled, became slime, and condensed into earth. He adds that the conversion of water into slime appears to have been accepted

[15] What follows seems to have been borrowed from Thomas Stanley's *History of Philosophy, The First Part* (London: Moseley and Dring, 1656), 9-10.
[16] A Greek author of the 3rd century, CE, who wrote *Lives, Teachings and other sayings of Famous Philosophers*.
[17] Thales of Miletius *c*. 624- *c*. 546 BCE, founder of Greek philosophy.
[18] Marcus Tullius Cicero, 106- 43 BCE, Roman orator, jurist, politician and Stoic philosopher.
[19] Plutarch, *c*. 45-120 CE, Greek Platonist philosopher, best known for his *Lives* of paired Greek and Roman statesmen and military leaders.
[20] Justin Martyr, *c*. 100-165 CE, Christian apologist of Greek origin, born in Samaria.
[21] Homer, 8th century BCE, Greek poet to whom the *Iliad* and the *Odyssey* are attributed.
[22] Zeno of Elea, 5th century BCE, Greek philosopher, famous for his paradoxes.
[23] Hesiod, *fl*. 7th century BCE, Greek poet, noted for his *Theogony* relating the myths of the gods, and *Works and Days*, describing peasant life.

by '*Orpheus*'[24], out of whom one of the Antients [clearly Athenagoras][25] cites this Testimony,

Of Water Slime was made' (119.21-25).

He goes on to say that '*Strabo*'[26] (120.1-2) quoting another, states of the '*Indians*, that they likewise held that all things had differing Beginnings, but that of which the World was made, was Water' (120.3-6). Some of the ancients attributed the same opinion to the Phoenicians, from whom the Greeks, including Thales, may have borrowed it, along with much of their theology and philosophy. He cites as evidence of this the 'Atomical *Hypothesis* commonly ascribed to *Lucippus* and his Disciple *Democritus*[27] is by Learned Men attributed to one *Moschus* a *Phoenician*,'[28] (120.13-16) adding that much Hebrew learning was borrowed by the Phoenicians.

Carneades goes on to cite the Bible, saying that many who accept the 'Books of Moses'[29] (120.21) believe that the account in the Book of Genesis begins 'where the Waters seem to be mention'd as the Material Cause, not only of Sublunary Compound Bodies[30] but of all those that make up the Universe' (120.25-28). Continuing with his exposition of the Biblical account of the emergence of the created universe, he says that 'Component Parts' (120.29) emerged out of 'that vast Abysse by the Operation of the Spirit of God' (121.1-2) who was 'Moving Himself

[24] The 'Orphic Literature' and the myth of Orpheus gave rise to a mystical Greek religious and philosophical cult, which involved stories of creation, reincarnation and punishment after death.
[25] Athenagoras of Athens, *c*. 133-190 CE, one of the Church Fathers.
[26] Strabo of Amesia, Pontus, *c*. 64 BC- *after* 21 CE, Greek geographer and historian, well known for his *Geography*.
[27] Leucippus was a 5th century BCE Greek philosopher and originator of an atomic theory, the details of which have come down through his follower Democritus.
[28] Moschus or Moschus of Sidon lived about 1200 BCE, and to him some trace the origin of ancient atomism. He came to be identified with the Biblical Moses by some 17th century authors.
[29] The Pentateuch or first five Books of the Bible.
[30] A reference to the Aristotelian model of the cosmos in which change occurred only below the orbit of the moon; above this, the moon itself, the stars and planets were unchanging.

as hatching Females do' (121.3-4) 'upon the Face of the Waters' (121.9) saying that the original term *Meracephet*[31] 'is said to Import' (121.5-6) in the rare cases where it occurs in the Hebrew Bible the meaning of the waters of creation as having been one surmises, 'Divinely Impregnated with the seeds of all things, were by that productive Incubation qualify'd to produce them' (121.10-13).

Relinquishing his Biblical theme, Carneades says rather apologetically, that his companion expects 'that I should Discourse [converse] of this Matter like a Naturalist [natural philosopher], not a Philologer [a literary scholar or linguist]' (121.14-16). Reverting to his discussion of van Helmont, Carneades says that he will add 'to Countenance [bear out] *Helmont's* Opinion' (121.16-17), which he recalls gives no instance of a mineral body, and hardly any of an animal generated from water, whereas 'a French Chymist, *Monsieur de Rochas*[32] has presented his readers an Experiment, which if it were punctually [precisely] such as he deliver'd it, is very Notable' (121.21-24).

He relates that de Rochas 'Discoursing [narrating] of the Generation of things according to certain Chymical and Metaphorical [not literal, figurative] Notions (which I confess are not to me Intelligible)' (121.25-28) gives 'among divers [many] Speculations' (121.29) the account recalled now as faithfully as possible and translated from the French by Carneades. De Rochas's account is of the conversion

[31] Corrected to *Merahephet* 'ם ר ה פ ת' in the 1680 edition. Von Rad says of this word: 'the much disputed *merahepet* … is not to be translated by "brood", but according to Deut. 32.11 and Jer. 23.9, the verb appears to have the meaning of "vibrate", "tremble", "move", "stir"'. In Gerhard von Rad, *Genesis a Commentary*, trans. John H. Marks (London: SCM Press Ltd., 1961), 47.

[32] Henricus de Rochas lived in the early part of the 17th century in Paris, was a councillor and physician to the king, and wrote some books on medicine and mineral waters.

of water into earth, which in turn was converted into various things, both animate and inanimate, which he subsequently subjected to chemical analysis.

He took water which he was sure ‘not to be compounded, nor to be mix’d with any other thing than that Spirit of Life’ (122.11-12) of which Carneades adds ‘he had spoken before’ (122.13). To this he applied a ‘Heat Artificial, Continual and Proportionate, I prepar’d and dispos’d it by the above mention’d Graduations of Coagulation, Congelation [freezing], and Fixation [the action of depriving of volatility or fluidity], until it was Turn’d into Earth, which Earth produc’d Animals, Vegetables and Minerals’ (122.14-21).

What may have happened is that de Rochas took some clean water and heated it, not so much continuously as continually to a temperature he considered suitable to the particular part of his experiment. So initially he may have heated it quite strongly for a time sufficient to greatly reduce its initial volume through evaporation. It is likely that the water was by this time sterile, as the heat it had been subjected to had destroyed any seeds or micro-organisms it might initially have contained. He then may have subjected it to a much lower continuous heat for some time which allowed some micro-organisms, spores or seeds to find their way into it and develop, until eventually larger creatures followed them and also developed there. The reduction in the volume of the water through evaporation would have allowed some of the minerals present to precipitate out – perhaps as lime deposition.

Some of the creatures which formed in the water were sufficiently large for de Rochas to study as these ‘did Move of themselves, Eat &c.’ (122.22-23). He made a 'true Anatomie [chemical analysis]' (122.23-24) of them, and found them to be composed of 'much Sulphur, little Mercury, and less Salt' (122.25-26), by which he may mean that he found the creatures to consist of an inflammable portion, a small liquid fraction, and a trace of a solid residue.

Carneades goes on to say that the 'Minerals began to grow and increase by converting into their own Nature one part of the Earth thereunto dispos'd' (122.26-29). What de Rochas seems to mean is that as the volume of the water decreased through evaporation, the minerals present in the water progressively precipitated out. He then adds that they were 'Solid and heavy' (122.29 – 123.1) – perhaps meaning that it was indeed lime deposition that was occurring – and that the lime-scale thus formed would be quite solid, and heavier than water. Upon analysis he found that these consisted of 'much Salt, little Sulphur, and less Mercury' (123.3-4), probably indicating that the minerals were largely composed of a solid fraction which showed flame, or perhaps just glowed somewhat, when heated, along with a small amount of a volatile fraction – perhaps simply water trapped within or among the particles of the mineral.

Carneades is quick to register his 'Suspitions concerning this strange Relation' (123.6-7), being unwilling to express an opinion on it without additional details on 'divers [several] Material Circumstances that our Author has left unmentioned' (123.9-11). He considers the 'Generation of Living Creatures, both Vegetable and Sensitive [endowed with the faculty of sensation]' (123.11-13) as possible, as water, already containing some 'Seminal Principles and Rudiments' (123.16-17), when kept for a long time undisturbed, may produce ‘Moss and little Worms, or other Insects’ (123.19-20), as determined by the ‘Seeds’ (123.21) present in it.

Carneades returns to discussing van Helmont, observing that he ‘gives us no Instance of the Production of Minerals out of Water’ (123.23-25), instead arguing for the reduction of both minerals and other bodies into water by the ‘Operations of his *Alkahest* [universal solvent]’ (123.28-29). As van Helmont alone possesses this particular reagent, the matter cannot be tested ‘by You and Me’ (124.1-2).

He next turns to the products of analysis of living things, and remarks ‘how great a share of Water goes to the making up of divers [many] Bodies’ (124.5-7), even though its varied forms or ‘Disguises promise nothing neere so much’ (124.7-8). Drawing on his personal observation he remarks that ‘The Distillation of Eeles’ (124.8-9), though yielding ‘some Oyle, and Spirit [inflammable liquid] and Volatile Salt [probably a strong-smelling solid fraction]’ (124.10), along with a ‘*Caput mortuum* [inert solid residue]’ (124.11). However, all of these were ‘so disproportionate to the Phlegm [aqueous fraction] that came from them (and in which at first they boyl’d as in a Pot of Water)’ (124.12-14), that they seemed to be ‘nothing but coagulated Phlegm’ (124.14-15). He goes on to liken vipers to eels in their high phlegm or aqueous content. The former are considered ‘very hot in Operation’ (124.18), and may ‘survive some days’ (124.19-20) the loss of vital organs.

Carneades moves on to discuss a related topic: the amount of phlegm present in ‘Mans Bloud’ (124.21), remarking how a ‘Spirituous [volatile organic liquid], and as

Elaborate a Liquor as 'tis reputed' (124.22-23) can also be rich in 'Phlegm' [aqueous fraction]' (124.24). He goes on to describe how on distilling 'about seven Ounces and a half of pure Bloud we drew neere six Ounces of Phlegm' (124.27-29). The aqueous fraction distilled over first, before 'any of the more operative [active] Principles began to arise, and Invite us to change the Receiver' (124.29 – 125.1-2), by which he seems to mean that only after the aqueous fraction had distilled over, did the less volatile products of distillation, and which give blood its characteristic qualities, begin to volatilise.

In an effort to establish that 'some of these Animal Phlegms were void enough of Spirit [here: volatile organic compounds] to deserve that Name' (125.3-5), not only did he 'taste them' (125.6-7), which would clearly enough disclose the presence of any non-aqueous organic compounds, but also 'fruitlessly poured on them acid Liquors' (125.7-8) as a test for 'any Volatile Salt [here: low boiling inorganic compounds]' (125.9) which, he reasons, had any been present 'would probably have discover'd it self by making an Ebullition [boiling or effervescence] with the affused [poured on] Liquor' (125.10-12). What exactly Carneades means is unclear, but he may be referring to the reaction of the acid with some of the ingredients present in the distillate, to cause the release of a gas, such as carbon dioxide, or more simply, that a strong mineral acid solution when added to water will result in an increase in temperature, causing some volatile organic compound present to boil off.

However, a clue to what Carneades has in mind may well be provided by his statement that 'now I mention Corrosive Spirits'[33] (125.13) in that he may have been

[33] Carneades has not actually mentioned 'Corrosive Spirits'.

thinking in terms of strong mineral acids which would probably interact strongly with any non-aqueous ingredients present in the distillate. He says that he is minded to tell his interlocutor that these same corrosive spirits ‘seem to be nothing else than Fluid Salts’ (125.15-16), by which he may mean chemical compounds in the liquid state, ‘yet they abound in Water, as you may Observe, if either you Entangle, and so Fix their Saline part, by making them Corrode some idoneous [suitable] Body’ (125.16-19). He seems to mean by this the reaction of the acid with an appropriate reagent, leading to the formation of water as one of the reaction products, along with those formed by the acid radical itself reacting with the added reagents. Water is also formed, Carneades argues, if ‘you mortifie it [the corrosive spirit] with a contrary Salt’ (125.20-21), by which he probably means that if an acid is neutralised (mortified) with a base such as sodium hydroxide, water is formed, as well as what is now understood to be a salt.

He goes on to say that he has done just this in ‘making a Medecine somewhat like *Helmont’s Balsamus Samech*, with Distill’d Vinegar [acetic acid] instead of Spirit of Wine [alcohol], wherewith [with which] he prepares it’ (125.22-25). Carneades narrates how substituting acetic acid for alcohol will yield a surprising result. He says that ‘that acid Spirit, the Salt of Tartar [potassium hydrogen tartrate],[34] from which it is Distill’d, will by mortifying [neutralising] and retaining the acid Salt turn into a worthless Phlegm [aqueous liquor] neere twenty times its weight, before it be so fully Impregnated as to rob no more Distill’d Vinagar of its Salt’ (125.27 – 126.4).

[34] Prepared by purifying tartar or argol, which is a substance present in grape juice, and which is deposited on the sides of wine casks; ‘ordinary’ salt of tartar (potassium carbonate) is formed by the thermal decomposition of potassium hydrogen tartrate.

What Carneades means here is that the distilled vinegar or acetic acid, when added to the salt of tartar or impure potassium hydrogen tartrate, neutralises the acid salt to form potassium tartrate. As part of this mortification or neutralisation, water is also formed, (hence the production of 'worthless Phlegm' (126.1-2)), and the reaction continues until all of the potassium hydrogen tartrate has been 'so fully impregnated' (126.3) or neutralised until no more vinegar reacts with it.

Carneades goes on to say that 'Spirit of Wine Exquisitely [extremely] rectify'd [distilled] seems of all Liquors to be the most free from Water' (126.5-7) and will 'Flame all away' (126.8) to complete dryness when ignited. Yet van Helmont believes that this 'Fiery Liquor' (126.10) is 'Materially Water, under a Sulphureous [here: inflammable] Disguise' (126.12-14). He then describes van Helmont's understanding of the production of 'that excellent Medicine *Paracelsus* his *Balsamus Samech*' [35] (126.15-16). He describes this *Balsamus Samech* as '*Sal Tartari* [potassium carbonate] dulcify'd [purified] by distilling from it Spirit of Wine [alcohol] till the Salt be sufficiently glutted with its Sulphur, and suffer[36] [allow] the Liquor to be drawn off, as strong as it was pour'd on' (126.17-21).

Van Helmont has, as narrated by Carneades, explained this process as the absorption of the inflammable part of the spirit 'its Sulphur' (126.19), whereas the *Sal Tartari* or potassium carbonate actually acted as a drying agent, absorbing the water from the Spirit of Wine or alcohol, which in this case contained a quantity of water. The potassium carbonate becomes saturated or 'glutted' (126.19) with absorbed water,

[35] Balsamus Samech is a medicament prepared by digesting spirit of wine (dilute alcohol) with salt of tartar (potassium carbonate). The salt of tartar absorbs water from the spirit of wine and dissolves to form a slimy liquid.
[36] Corrected to 'And till it suffer' in the *Errata*.

and at that point the Spirit of Wine reaches a limiting concentration: it is 'as strong as it was pour'd on' (126.21).

Carneades' account continues that 'when the Salt of Tartar [potassium carbonate] from which it is Distill'd hath [has] retain'd [absorbed] or depriv'd it of the Sulphureous [actually aqueous] parts of the Spirit of Wine [alcohol], the rest, which is incomparably the greater part of the Liquor, will remigrate into Phlegm [here: water]' (126.21-27). The 'rest' he speaks of does constitute the 'greater part' of the solution, and is actually an aqueous solution of alcohol. It is already present in the liquor, and does not need to be formed through 'remigration' of the liquor 'into phlegm'.

He goes on to express his unease regarding the veracity of van Helmont's account, but cannot arrive at a definitive conclusion either way, not having 'as yet sufficiently try'd it my self' (126.29 – 127.1). Carneades finds himself somewhat on the horns of a dilemma over the matter. His instincts as an experimenter incline him to the opinion that van Helmont's account is 'as many Chymists do, absurd' (127.2-3). Yet van Helmont, whom he greatly respects, 'often Relates it, and draws Consequences from it' (127.6-7).

It may well be that the differing results obtained by Carneades himself and van Helmont is that they were using two different compounds: 'that acid Spirit, the Salt of Tartar' (125.27-28), already discussed, which is actually potassium hydrogen tartrate, or Cream of Tartar, whereas what van Helmont employed was Salt of Tartar or potassium carbonate, so named because it can be made by heating tartaric acid.

Carneades reacted potassium hydrogen tartrate with acetic acid and ended up with potassium tartrate, water, and some other decomposition products such as carbon dioxide.

By contrast, van Helmont distilled an aqueous solution of alcohol off Salt of Tartar (potassium carbonate), a drying agent which absorbed water from the alcohol solution, and when distillation occurred the distillate was richer in alcohol than before due to the absorption of water from the alcohol solution.

That two different Salts of Tartar were employed in the experiments carried out by Carneades and van Helmont is reinforced by Carneades saying that both he and 'many Chymists' (127.3) 'in vain try'd it with ordinary Salt of Tartar' (127.4-5), indicating perhaps, that there is more than one Salt of Tartar, *viz*. 'that Acid Spirit, the Salt of Tartar' (125.27-28), which is potassium hydrogen tartrate, and 'ordinary Salt of Tartar' (127.5), which is potassium carbonate, a drying agent, and which gives an alkaline solution through hydrolysis.

Carneades related how he asked an experimenter, skilled in 'Spagyrical [Paracelsian] Preparations' (127.8-9) whether a more successful outcome would have resulted 'if the Salt and Spirit were prepar'd according to a way suitable to my Principles' (127.11-13). He replied that he had made van Helmont's 'Experiment succeed very well, without adding anything to the Salt and Spirit' (127.15-17). It is not clear whether he carried out van Helmont's experiment, and got the same result as van Helmont, but interpreted the result in accordance with Carneades' interpretation, rather than that of van Helmont, or whether he had changed one or other of the ingredients.

He adds cryptically that ‘our way is neither short nor Easie’ (127.17-18). He may mean by this that the style of performing chemical operations favoured by him and his associates is lengthier, more painstaking and more challenging than that of others.

Carneades, having spoken of the production of water (actually as a product of chemical reaction) expresses how he ‘sometimes wonder’d [marvelled] at the amount of ‘Phlegme [aqueous product]’ (127.21) which may be obtained from bodies by the fire, and may ‘anon [later] have Occasion [an opportunity] to note something’ (127.23-24) on the subject of that same phlegm, but which we will not now ‘anticipate [cause to happen earlier]’ (127.24-25).

He then goes on to ponder whether more than one form of water actually exists. He first considers the ‘Opinion of *Thales* and of *Helmont’* (127.25-26) and of the latter’s belief that his ‘*Alkahest* [universal solvent] could reduce all Bodies into water’ (127.27-28), yet it is not absurd to doubt that such ‘water, because insipid, must be Elementary’ (127.29 – 128.1). What Carneades seems to be arguing is that there may be insipid, water-like liquors, which are generically water, but may not, in fact, qualify for the term elemental water.

Next he mentions 'the Candid [fair] and Eloquent *Petrus Laurembergius*[37] in his Notes upon *Sala's*[38] Aphorismes' (128.2-4) states that he had sight of 'an insipid *Menstruum* that was a powerful Dissolvant' (128.5-6) which as Carneades recalls, 'could dissolve gold' (128.8).

He follows this with an example of a water which may not be elemental, this is 'the water which may be Drawn from Quicksilver [mercury] without Addition' (128.8-10), and although almost 'Tastless, You will I believe think of a differing Nature from simple Water, especially if you Digest in it Appropriate [allotted] Minerals' (128.11-14). What Carneades seems to mean is that the water liberated during a chemical reaction involving mercury – for example when a mercury salt is prepared[39] – that this water, despite its bland taste, is not the same as elemental water. This is all the more true, he seems to believe, when the water is acting as a solvent.

Carneades may be willing to consider that water as solvent is subtly different from pure elemental water, perhaps because he holds a suspicion that some forms of water may act as powerful solvents, capable of dissolving minerals, perhaps even gold.

A further consideration on water is that there is 'no Necessity to conceive that the Water mentioned in the Beginning of *Genesis*, as the Universal Matter, was simple and Elementary Water' (128.16-20). Carneades concedes that it behaved as water, or fulfilled the function of water, serving as the medium for containing 'an Agitated

[37] Peter Lauremberg (1583-1639) German – in fact, native-born – professor of philosophy, medicine, physics, mathematics and poetry in Rostock.
[38] Angelus Sala (1570-1637) Italian-born physician and chemist.
[39] A good actual example might be mercuric sulphate, formed by boiling mercury with concentrated sulphuric acid, when water is also produced.

Congeries [mass] or Heap consisting of a great Variety of Seminal Principles and Rudiments, and of other Corpuscles fit [requiring] to be subdu'd [overcome] and fashion'd [transformed] by them' (128.21-26). He continues that this primal liquor might even have been 'a Body Fluid like Water, in case [in a condition that] the Corpuscles it was made up of, were by their Creator made small enough, and put into such an actuall Motion as might make them Glide along one another' (128.26-29 – 129.1-2).

What Carneades seems to mean is that, still accepting that the primal liquor may have been very similar to water, in being a fluid behaving in a water-like manner, and in having a water-like micro-constitution. Yet these qualities do not necessarily mean that the fluid in question was water.

Another example is provided by sea-water which ([40]'notwithstanding the Saline, Terrestrial, and other Bodies mingl'd with it,)' (129.3-5) may justifiably be called water 'because that was the greatest of the known Bodies whereunto [unto which] it was like' (129.7-8). Carneades immediately qualifies this assertion by saying that just because something may appear by its physical constitution to qualify for the designation of fluid, it does not always mean that it really is a fluid. The example he gives here is of 'a good Quantity of Vitriol [iron sulphate] in a strong Vessel' (129.13-14) which is exposed to a 'Competent [suitable] Fire' (129.14) even though it contains 'both Aqueous, Earthy, Saline, Sulphureous, and Metalline Corpuscles, yet the whole Mass will at first be Fluid like water, and boyle like a seething pot' (129.15-19).

[40] Bracket specified here in Errata.

What Carneades is describing here is the behaviour of iron sulphate when heated strongly. Iron sulphate normally contains a fixed amount of water present as, so called, water of crystallisation. When heated strongly the iron sulphate dissolves in this water, forming a solution of iron sulphate. This solution will ‘at first be Fluid like water’, but the strong heat being applied to it will cause it to boil vigourously. It will ‘boyle like a seething pot’.

Carneades wishes to bring this part of the discussion to a conclusion by saying that there is no need to ‘enlarge [set forth at length]’ (129.21) himself on his ‘Judgement of the *Thalesian*, and *Helmontian*, *Hypothesis*’ (129.23-24). As to whether ‘we conclude that all things were at first Generated of Water, I may Deduce from what I have try’d Concerning the Growth of Vegetables, nourish’d with water’ (129.25-29), his only necessity at this stage of the discussion is to consider the production of physical materials, not at the time of creation, but rather as things now stand. His task now is to prove whether ‘Salt, Spirit, Earth, and ev’n Oyl’ (130.2), which is the material ‘most opposite to Water’ (130.4-5), and ‘consequently that a Chymical Principles as well as a Peripatetick Element, may (in some cases) be Generated anew’ (130.5-8) or be obtained from a material in which it was not already present.

He then goes on to say that having ‘Evinc’d [overcome]’ (130.11) the ‘Chymists [Paracelsians’]’ (130.13) doctrine that their ‘*Tria Prima* [salt, sulphur, mercury], may be Generated a new’ (130.14-15), he must next attempt to establish the probability that the process of burning ‘does Actually (sometimes) not only divide Compound Bodies into small Parts, but Compound those Parts after a new Manner’

(130.17-20). From this thermal processing there 'may Emerge, as well [to the same extent] Saline and Sulphureous Substances as Bodies of other Textures' (130.21-23).

Carneades next opines that the effects of thermal decomposition on bodies in general may be better understood if we 'Consider a little' (130.26-27) its effects on artificially prepared materials, as we 'best know the Composition' (130.29 – 131.1) of these. This leads him into a discussion about the preparation of soap[41].

This time he says that we might note 'that though Sope is made up by the Sope-Boylers of Oyle or Grease, and Salt [here: alkali], and Water Diligently Incorporated together' (131.2-5)[42] by contrast, if 'You expose the Mass they Constitute to a Gradual Fire in a Retort' (131.6-7), (presumably the retort is open to the air) the water will simply boil off, and when this happens the temperature of the reaction mixture increases, and 'You shall then indeed make a Separation, but not of the same Substances that were United into Sope' (131.7-10). Now the oil or grease will begin to break down into decomposition products 'of a Distant and yet not an Elementary Nature, and especially of an Oyle very sharp and faetid [stinking]' (131.11-13) and differing from that used to make the soap.

Carneades immediately cites another example of the behaviour of some chemicals when subjected to thermal processing. He begins abruptly by stating: 'so [thus] if you Mingle in a due proportion, *Sal Armoniack* [ammonium chloride] with Quick-Lime [calcium oxide] and Distill them by Degrees of Fire,[43] you shall not Divide the

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[41] A subject already discussed in the *First Part*, pp. 51-52.
[42] For the soap to form, the water would have to be distilled off.
[43] 'Degrees' was applied in the Natural Philosophy of the Middle Ages to the successive stages of intensity of the elementary qualities of bodies, here: heat and cold.

Sal Armoniack from the Quick-Lime' (131.15-20), and this in spite of the fact that one of them, the *Sal Armoniack* or ammonium chloride, is 'a Volatile, and the other a Fix'd [non-volatile] Substance' (131.20-21).

What actually happens is that the quicklime or calcium oxide is slaked or hydrated by the water to give calcium hydroxide or lime. Meanwhile, the water present in the retort will allow the sal armoniack or ammonium chloride to dissociate on heating, into hydrochloric acid and ammonia 'a Spirit much more Fugitive, Penetrant, and stinking, then [than] *Sal Armoniack*' (131.22-24). Carneades then adds that 'there will remain with the Quick-Lime [actually calcium hydroxide or lime] all or very near all the Sea Salt [here: the chloride radical] that concurr'd to make up the *Sal Armoniack* [ammonium chloride]' (131.24-27).

He goes on to describe the formation of another chemical compound produced in the retort: calcium chloride. He remarks how well the 'Sea Salt [here: chloride radical]' (131.28) was 'United to the Lime [here: the calcium radical]' (131.29 – 132.1). This he achieved 'by making the Fire at length very Vehement [intense]' (132.1-2), and this 'caused both the Ingredients to melt in the Retort it self into one Mass' (132.3-4). What actually happened here was that the calcium hydroxide or lime reacted with the hydrochloric acid to form calcium chloride and water. The crystals of calcium chloride are very deliquescent, *i.e*. they readily absorb moisture from the air, eventually dissolving in this moisture to form a solution. This effect Carneades notes by saying that 'such Masses are apt to Relent [dissolve] in the Moist Air' (132.5-6).

Anticipating that the examples just given involve 'factitious [artificial] Concretes [compound bodies] which are more Compounded' (132.7-9) than natural ones, Carneades forestalls any objections by saying that they were mentioned 'as much to illustrate what I propos'd, as to prove it' (132.11-12). He adds that 'it will be Difficult to Evince [convince] that Nature her self does not make Decompound Bodies [further compounded materials]' (132.12-14), by which he means mix together such compound bodies 'already Compounded of Elementary, or rather of more simple ones' (132.16-17).

He quotes as example 'Vitriol [iron sulphate]' (132.18) which he had sometimes extracted from 'Mineral Earths' (132.19-20) prepared naturally 'without any assistance of Art' (132.21-22). This, Carneades says, is 'a De-compounded [further compounded] Body Consisting' (132.23-24) of 'a Terrestrial [earthy] Substance, of a Metal, and also of at least one Saline Body, of a peculiar [distinctive] and not Elementary Nature' (132.25-28), even though 'Chymists' (132.22) regard it as a 'Salt' (132.23), which is closer to its actual composition: a sulphate radical, Carneades' 'Saline Body', and a metal [here: iron], as correctly stated by him.

Carneades goes on to say that animal blood 'may be compos'd of Divers [many] Differing Mixt Bodies' (133.1-2), noting the observation that several 'Sea-Fowle tast rank [strongly] of the Fish on which they ordinarily feed' (133.3-5). Continuing with this theme, he remarks how '*Hipocrates*[44] himself Observes, that a Child may be purg'd by the Milke of the Nurse, if she have taken *Elaterium*'[45] (133.5-8). The foregoing 'argues that the Corpuscles of the Medicament Concurr [flow together] to

[44] Hippocrates, *c*. 460 - *c*. 375 BCE, Greek physician, traditionally regarded as the father of medicine.
[45] Elaterium is a sediment or precipitate from the juice of the Squirting Cucumber (*Ecballium elaterium*) having a bitter, acrid taste, and acting as a drastic purgative and emetic.

make up the Milke of the Nurse' (133.8-11), and milk, most medics believe, is 'but [only] blanch'd [whitened] and alter'd Blood' (133.12-13).

He gives another example, saying that in a country close to the Alps, at a certain time of the year, the 'Butter' (133.16) was 'very Offensive to strangers, by reason of the rank [foul] tast of a certain Herb, whereon the Cows were then wont [habitually] plentifully to feed' (133.17-20). Carneades the goes on to give 'Instances of another kind to Shew [show] that things may be obtain'd by the Fire from a Mixt Body that were not Pre-existent in it' (133.21-24). In his first example he states that 'from many Vegetables there may without any Addition be Obtain'd Glass' (133.25-27), which one will surely agree was not 'Pre-existent in it, but produc'd by the Fire' (133.28-29).

In Carneades' second example he describes how 'by a certain Artificial way of handling Quicksilver [mercury], You may without Addition separate from it at least a 5th or 4th part of a clear Liquor' (134.2-5), which the 'Ordinary Peripatetick [Aristotelian]' (134.6), accepts as water, and a 'Vulgar Chymist would not Scruple [doubt] to call Phlegme [aqueous liquor]' (134.7-8). That he has no direct experience of this effect is hinted at by Carneades when he adds 'for ought [aught] I have yet seen or heard, is not reducible into Mercury again' (134.9-11). From this he reasons that this liquor 'Consequently is more then [than] a Disguise of it' (134.11-12).

He immediately goes on to doubt the veracity of the account he has just related, stating two reservations. The first is that of the composition of mercury, saying that 'divers [many] Chymists' (134.12-13) will not accept the presence in mercury of any great amount 'of the Ignoble Ingredients, Earth and Water' (134.15-15). His second reservation concerns the density of water relative to that of mercury. He argues that 'since Mercury weighs 12 or 14[46] times' (134.20-21) as much as the same volume of water, its 'great Ponderousness [density]' (134.17) 'makes it very unlikely that it can have so much Water in it, as may be thus obtain'd from it' (134.18-20). This seems to indicate that Carneades is considering only the possibility that any fluid which can separate off from mercury could only be of identical properties to mercury itself, and that as water is so much less dense than mercury it could not be a constituent of it.

He provides a 'further Confirmation of this argument' (134.22-23) by giving 'this Strange Relation [unusual account]' (134.24), given to him by 'two Friends of mine, the one a Physitian [physicist], and the other a Mathematician' (134.25-26), both of them men of 'unsuspected [not regarded with suspicion] Credit' (134.27-28), who have 'Solemnly assured' (134.28) him that following many attempts to 'reduce Mercury into Water, in Order [with respect to] to a Philosophical Work, upon Gold' (134.29 – 135.1-2), unsuccessfully. What they did achieve was 'once by divers [many] Cohobations [redistillations] reduce a pound of Quicksilver into almost a pound of Water' (135.4-6), without adding any other substance, 'but only by pressing [forcing, urging] the Mercury by a Skillfully Manag'd Fire in purposely contrive'd Vessels' (135.8-10).

What Carneades seems to be relating here is the distillation of mercury several times in a specially prepared still. Mercury has a boiling point of 357^{o}C, which means that

[46] Mercury is actually 13.5 times denser than water.

a very hot fire would have to be employed, in addition to a still capable of withstanding the rigours of containing the very dense condensate. Then there is the question of how water with a boiling point of 100°C could coexist as a distillate with distilled mercury. As any water present in the system would have distilled over well before the mercury, it may simply have been collected as a distillate in the receiver and removed. Then with a much higher temperature being required to boil the mercury, it may have been the case that the hot still leaked and allowed the mercury vapour to escape. Over repeated distillations the mercury may have evaporated away, without any being collected in the receiver. This would mean that all that was actually recovered was water, leading to the supposition that the mercury had been reduced to water.

Carneades, possibly wishing to avoid expressing his own incredulity at this outcome, refers the matter to 'our Friend' (135.11), Boyle himself, 'the Register of this Dialogue' [who, of course, is silently taking notes of the unfolding dialogue] (135.12-13), and who may give a 'more Particular [specific] Account then [than] it is necessary for me to do' (135.14-15).

He reiterates one of his central tenets 'Since [seeing that] what I have now said may sufficiently evince [convince], that the Fire may sometimes as well alter Bodies as divide them, and by it we may obtain from a Mixt Body what was not Pre-existent in it' (135.15-20). He then poses another question regarding the putative products of thermal decomposition: 'how are we sure that in no other Body what we call Phlegm [aqueous liquor] is barely [merely] separated, not Produc'd by the Action of the Fire' (135.20-24). And Carneades has in mind how other 'Mixt Bodies' (135.24-25) are more reactive than mercury. They are, he continues, of a much less Constant, and more alterable Nature, then [than] Mercury' (135.25-27) 'Appears to be' (136.1) which itself '(by many Tricks it is wont [accustomed] to put upon Chymists, and by the Experiments I told you of, about an hour since [ago])'.[47]

Carneades says that as he will 'ere [before] long have Occasion [an opportunity] to resume [take back] into Consideration' (136.2-3) fire's ability to produce 'new Concretes [compound bodies]' (136.4) he will no longer 'insist on [dwell at length on] this Argument' (136.5) for the moment. He then adds a proviso regarding van Helmont's doctrine on the solvent power of his *Alkahest* [universal solvent]' (136.10-11), arguing that if one believes van Helmont's 'powerful *Menstruum* [solvent]' (136.13-14) can reduce all materials to water, one must accept that the '*Tria Prima* [salt, sulphur and mercury] are neither ingenerable nor incorruptible Substances' (136.8-10), as these may themselves be produced out of other types of materials, all of which in turn may be decomposed 'into insipid Water' (136.15).

He is prevented from passing on to his 'Third Consideration' (136.17) by an interjection from Eleutherius in which he expresses his concern that Carneades' 'Second General Consideration' (136.19-20) might be 'repugnant to what he seem'd to think the true Theory of Mistion' (136.20-22). He wonders why Carneades, 'unsatisfied' (136.24-25) as he is with the 'Peripatetick [Aristotelian] Opinion' (136.26) should also seem to disagree with 'that Notion touching the manner of Mistion' (136.27-28) held by the 'Chymists [Paracelsians]' (136.29) in which they unwittingly agree with 'most of the Antient Philosophers that preceded *Aristotle*'

[47] Brackets added in 1680 edition.

(137.2-3), and this for 'Reasons so considerable' (137.3-4) that it puts them on the same side as 'divers [many] Modern Naturalists [natural philosophers] and Physitians [physicists]' (137.4-5), who usually oppose them, *i.e*. 'the Spagyrists [Paracelsians]' (137.6), and who now mutually disagree with them regarding 'the common Opinion of the Schools'[48] (137.8). Eleutherius explains what reasons he means: these come partly from the 'Writings of *Sennertus*[49] and other learned Men' (137.11-12), and partly from his own thinking, which together supply him with more 'then [than] 'twere at present proper for me to Insist [dwell at length on] largely on' (137.13-15).

He relates that he will briefly mention a few of these, the first 'from the state of the Controversie it self, and the genuine Notion of Mistion [mixing]' (137.17-19), which he complains, is 'much intricated [complicated] by the Schoolmen'[50] (137.20-21). The Aristotelian doctrine, in contradistinction to that of the 'Antients, declares Mistion [mixing] to be such a mutual Penetration, and perfect Union of the mingl'd Elements, that there is no Portion of the mixt Body' (137.25-29) no matter how minute, which does not contain all of the four elements of earth, air, fire and water.

Eleutherius now gives a lengthy account of the Ancients' doctrine on mixture, essentially saying that they believed that each of the components of the mixture retained its particular identity irrespective of how finely divided it was in the mixture, but in so doing would collectively constitute a homogeneous mixture. He begins by offering an Aristotelian critique of this doctrine by saying that 'he

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[48] The 'Schools' were the Medieval Universities of France, Germany, England and Italy.

[49] Daniel Sennert (1572-1637) German medic and chemist, professor of medicine at Wittenberg. Influenced in his thinking by both Paracelsus and Aristotle.

[50] The Schoolmen were the academics of the Schools or Medieval Universities of Western Europe. Later, their teachings came under increasing challenge as the New Science gained influence.

reprehends [condemns] the Mistion [mixing]' (140 [138].4) taught by them 'as too sleight [subtle] or gross [massive]' (140 [138].5), on the grounds that the components of a mixture, though invisible to humans, could be discerned 'by the acute Eyes of a *Lynx*' (140 [138].9) as their 'perfecter Sight would discerne the Elements, if they were no otherwise [if they were not mingled in a different way], than as his Predecessors would have it, to be but [only] Blended, not United' (140 [138].10-13).

Eleutherius seems to be saying that Aristotle held such a mixture to be a heterogeneous aggregate, albeit apparently, on a microscopic scale, whereas by contrast, despite disagreements regarding 'what kind of Bodies were Mixt' (140 [138].15-16), for the most part the Ancients accepted that 'in a compounded Bodie, through the *Miscibilia* [miscibles]' (140 [138].17-18) the component parts 'were associated in such small Parts, and with so much Exactness, that there was no sensible [evident] part of the Mass but seem'd to be of the same Nature with the rest, and with the whole' (140 [138].20-25). Yet despite this quality of homogeneous composition 'the Atomes or other Insensible [invisible] Parcels of Matter' (140 [138].25-26) constituting each of the *Miscibilia* [miscibles]' (140 [138].27) retained 'its own Nature, being but [merely] by Apposition [application] or *Juxta*-Position united with the rest into one Bodie' (140 [138].28 – 141 [139].1).

Although it may possess properties distinct from those of its component parts, this unitary body may still be decomposed into its original constituents. Despite the 'mixt Body' (141 [139].3) possessing 'Divers [several] new Qualities' (141 [139].3-4), its component parts 'retaining their own Nature, were by the Destruction of the

Compositum [composition] separable from each other' (141 [139].5-8) and reagglomerate to form their original 'Fire, Earth, or Water' (141 [139].11-12).

Eleutherius reinforces his analysis of the pre-Aristotelian model of mixing by drawing an analogy between it and a woven cloth. He argues that some cloth consisting of 'white and black threds interwoven, wherein the whole piece appear neither white nor black, but of a resulting Colour, that is gray' (141 [139].16-19). The individual threads retain their original identity in the woven cloth as is apparent if the piece of fabric is 'pull'd asunder and sorted each Colour by it self' (141 [139].23-24).

Eleutherius, having thus explained the pre-Aristotelian theory of mixing, quickly passes on to that of the Aristotelians who 'after their Master Commonly Defining, that Mistion [mixing] is *Miscibilium alteratorum Unio* [a union of other things into one]' (141 [139].27-29), which he thinks 'comports much better with the Opinion of the Chymists [Paracelsians] then [than] with that of their Adversaries' (141 [139].29 – 140.1-3) which he reiterates is nothing more than 'a *Juxta*-position' (140.5) of unchanged 'separable Corpuscles' (140.5-6). By contrast, the Aristotelians hold that when 'a mixt Body results from the Concourse [flowing together] of the Elements, the *Miscibilia* [miscibles] cannot be said to be Alter'd as Destroy'd' (140.8-12) with no trace whatsoever remaining of 'either Fir[51], or Air, or Water or Earth' (140.14-15).

[51] Corrected to 'Fire' in the 1680 edition.

Eleutherius goes on to discuss further Aristotle’s theory of mixing, his own understanding of it, and objections to it. He begins by saying that he cannot understand how bodies can be mixed except as ‘I have declar’d, or at least how they can be mingl’d, as our Peripateticks would have it’ (140.18-20). He then critiques an important feature of Aristotle’s doctrine on mixing, saying that ‘he speaks of my Apprehension [understanding], very improbably’ (140.25-26), by which he seems to mean that Aristotle’s teaching on the subject seems very unlikely to him. ‘*Aristotle* tells us, that if a Drop of Wine be put into ten thousand measures of Water, the Wine being Overpower’d by so Vast a quantity of Water will be turn’d into it’ (140.20-25). In other words the drop of wine when added to water, does not form an exceedingly dilute solution of wine, but rather is transformed into water.

He expresses his first objection by explaining his interpretation of dilution: if to ‘that Quantity of Water as many Drops of Wine as would a Thousand times exceed it all’ (140.27-29), what would result, according to Aristotle, would not be ‘a *Crama*, a Mixture of Wine and Water’ (141.2-3), consisting mainly of wine, instead there would be no wine present ‘but Water only’ (141.4). The Aristotelian explanation being ‘Since the Wine being added but by a Drop at a time would still Fall into nothing but Water, and Consequently would be turn’d into it’ (141.4-8).

Eleutherius adds slyly that if this transformative process held good for metals, ‘’twere a rare [uncommon] secret for Goldsmiths, and Refiners’ (141.9-10), for they could melt ‘a Mass of Gold, or Silver’ (141.11) and add to it ‘Lead or Antimony, Grain after Grain’ (141.12-13) and convert as much as they pleased of ‘the Ignoble [lead and antimony] into the Nobel [gold and silver] Metals’ (141.16-17).

He states a second objection to the Aristotelian theory of mixing, this time relying on the tendency of mixed liquids to retain their individual volumes, rather than for one to completely occupy the interstices between the micro-constituents of the other. Eleutherius does seem to realise that when alcohol and water are mixed there is a slight contraction in volume for he says that a ‘Pint of wine, and a Pint of water, amount to about a Quart of Liquor’ (141.17-19), from which he infers that ‘it seems manifest [obvious] to sense’ (141.19-20) that the two liquids do not totally interpenetrate each other ‘as one would have it’ (141.21-23) but rather that each retains its own volume or ‘Dimensions’ (141.23). This of course is only approximately true as there really is a slight contraction in volume when alcohol and water are mixed. He likens their behaviour to that of cereal grains: in mixing they are ‘only divided into minute Bodies that do not touch one another with their Surfaces’ (141.24-26) as is the case when various grains are formed into a common heap. And when greatly unequal quantities of barley and wheat are mixed together no interpenetration of the individual grains occurs, simply a ‘*Juxta*-position and Superficial Contact betwixt the Grains of wheat, and as many or thereabouts of the Grains of Barley’ (144 [142].4-7).

Eleutherius reinforces his argument by returning to the example of when ‘a Drop of wine is mingl’d with a great deal of water’ (144 [142].7-8) there occurs no more than an ‘Apposition’ (144 [142].9) or placing together ‘of so many Vinous [wine] Corpuscles to a Correspondent Number of Aqueous ones’ (144 [142].9-10). In other words no more interpenetration of the two different types of corpuscles occurs than with the blending of the different grains.

He continues that unless this line of reasoning be applied to mixing, he cannot see how 'that Absurdity will be avoyded, whereunto the Stoical Notion of Mistion [mixing] (namely by [what seems to be] ςιωχυσις[52] or Confusing) was liable' (144 [142].12-15). He says that the Stoical understanding of mixing holds that 'the least Body may be co-extended with the greatest' (144 [142].16-17), explaining that if one mixes 'one pound of water to ten thousand of Earth' (144 [142].20-21) the Stoics believe that there must not be the least part of that Compound, that Consisted not as well of Earth, as water' (144 [142].22-24).

Eleutherius seems to understand this as erring in the opposite direction from that of the Aristotelians. Only now, instead of the major ingredient subsuming the minor one so completely as to effect a transformation of it into the major one, the minor ingredient becomes no less predominant in the mixture than the major one, and although present in a much smaller quantity than the major ingredient, determines the character of the mixture to an equal extent as that of the major.

Eleutherius checks himself by saying that perhaps 'I insist [dwell at length upon]' (144 [142].24-25) 'upon the proofs afforded me by the Nature of Mistion [mixing]' (144 [142].26-27), and promises to name a few 'other Arguments' (144 [142].28-29). The first one he relates is that of Aristotle, who says that 'the motion of a mixt body followes the Nature of the Predominant Element, as those wherein the Earth prevails, tend towards the Centre of heavy Bodies' (145 [143].1-6). He continues with an argument in which he posits that there is evidence that the elements retain their identity in compound bodies. He believes that there is much evidence that 'in

[52] Corrected to 'Σύγχυσις' [meaning mixing or confounding] in the *Errata*.

divers [many] Mixt Bodies the Elementary Qualities are as well active, though not altogether so much as in the elements themselves' (145 [143].7-10). From which one can accept the 'actual Existence of the Elements' (145 [143].11-12) in the compound materials from which they are constituted.

Eleutherius now begins a 'convincing argument' (145 [143].14-15) concerning the presence of the matter and form of the ingredients of compound bodies and the possibility of their retrievability on decomposing such bodies. He says that 'Experience manifests [makes obvious], and *Aristotle* Confesses it that the *Miscibilia* [miscibles] may be again separated from a mixt Body' (145 [143].15-18), as demonstrated in the chemical decomposition of plants and animals, and this could not be so 'unless they did actually retain their formes[53] in it' (145 [143].20-21). He goes on to give an explanation of Aristotle's account of prime matter,[54] by which all matter exists in a potential state and is only realised by being combined with a form to give an actual substance. He says that since 'according to *Aristotle*, and I think according to truth, there is but one common Mass of all things, which he has been pleas'd to call *Materia Prima*' (145 [143].22-26). And also since it is not 'therefore the Matter but the Forme that Constitutes and Discriminates Things' (145 [143].26-28) to say that the elements [earth, air, fire and water] do not subsist in a compound material 'according to their Formes, but according to their Matter, is not to say that they remain there at all' (144.1-3). Eleutherius concludes his argument by speaking of the nature of a compound body as opposed to that of an element, saying surprisingly, that the elements comprising a compound body have, in being compounded, lost their forms, and as the forms only, and not the matter, differentiate

[53] 'Form' is used here in its Aristotelian sense to mean structure or organising principle.
[54] Although Aristotle's belief in prime matter is now disputed, obviously Boyle understood that he did believe in it.

bodies, the compound bodies, having no differentiating characteristic, are as simple as the elements. He says that ‘Since although those Portions of Matter were Earth and water, &c. before they concurr’d [combined]’ (144.3-5), the body they have combined to form ‘may as well be said to be simple as any of the Elements’ (144.7-9). This is so because the matter of which it consists if ‘confessedly [admittedly] of the same Nature’ (144.8-9) in all materials, with the ‘Elementary Formes being according to this *Hypothesis* perish’d and abolish’d’ (144.10-12).

What Eleutherius seems to mean is that because, according to Aristotle, mixtures of different materials tend to undergo a change in identity, with the predominant element subsuming those present in smaller amounts, and in which the forms of those ingredients present in smaller quantities are released, only to disappear in the combining process. With only one element prevailing in the compound body, one can see why it ‘may as well be said to be simple as any of the Elements’ (144.7-9).

Eleutherius now wishes to bring experimental evidence to bear on the question of mixing, and quickly asserts ‘the Advantages of the Chymical [Paracelsian] Doctrine above the Peripatetick [Aristotelian] Title [claim] little less than Palpable [obvious]’ (144.15-17). He immediately begins to narrate an experimental method by which gold alloyed with silver can be separated out through dissolution, with nitric acid, of the silver content of the alloy. He describes how in the process called ‘Quartation’ (144.18) that ‘although three parts of Silver be so exquisitely [minutely] mingl’d by Fusion [melting together] with a fourth Part of Gold’ (144.19-22) from which the process is ‘Denominated [named]’ (144.22-23), the mixing of the two metals is so thorough that the ‘resulting Mass acquires several new Qualities’ (144.23-24), so that there 'is scarce any sensible [evident] part' (144.26) of the alloy that does not consist of both metals. However, if 'You cast the mixture into *Aqua Fortis* [nitric acid], the silver will be Dissolv'd in the *Menstruum* [solvent]' (144.28-29 – 145.1), and the gold, which has not been dissolved by the acid, 'like a dark or black Powder will fall to the Bottom of it' (145.1-3). Both the silver nitrate and the powdered gold may, by heating, be 'again reduc'd into such a Metal as it was before' (145.3-5). Eleutherius says that this process 'Shews [shows]' (145.5) that each metal 'retain'd its Nature, notwithstanding its being mixt *per Minima* [most minutely] with the other' (145.5-7).

He gives another example of the separation of two alloyed metals: this time if 'pure Silver be mingled with eight or ten Parts, or more, of Lead' (145.8-10), when the 'Fire will upon the Cuppel easily and perfectly separate them again' (145.10-12). What Eleutherius is referring to here is the process of cupellation in which the two metals are placed in a bone-ash cup or cupel, and heated, with a forced draught being blown over the surface. The lead present in the molten metal mass oxidises to form the lead oxides *massicot*, then *litharge*, which float on top of the molten silver and can be skimmed off.

What Eleutherius wishes his hearers to 'peculiarly [particularly] Consider' (145.13) now is 'that not only in Chymical Anatomies [analyses] there is a Separation made of the elementary Ingredients' (145.14-16), but that the amount of 'this or that Element or Principle' (145.18-19) yielded by 'Mixt [compound] Bodies' (145.17) varies from one compound material to another. The examples he cites are

'Turpentine[55] and Amber'[56] (145.20), which he states 'yield much more Oyl and Sulphur than they do Water' (145.21-22). This is a reference to the inflammable, oily terpenes which can be distilled off from turpentine, leaving rosin as a residue, to the inflammable oil of amber which distils off from amber, and the amber pitch which remains. By comparison 'Wine, which is confess'd [admitted] to be a perfectly mixed Bodie, yields but a little Inflammable Spirit [here: alcohol, present in wine at approximately 8-12%] or Sulphur, and not much more Earth [here: the residue of tartar which forms as wine is aged]; but affords a vast proportion of Phlegm or water [the principal constituent of wine]' (145.22-27).

This, Eleutherius argues, could not be so, 'if as the Peripateticks [Aristotelians] suppose, every, even of the minutest Particles, were of the same nature with the whole, and consequently did contain both Earth and Water, and Aire, and Fire' (145.27-29 – 146.1-3), and 'Wherefore [because of which]' (146.3) comes the almost only objection of Aristotle, namely that 'unless his Opinion be admitted [accepted as valid], there would be no true and perfect Mistion [mixing], but onely Aggregates or Heaps of contiguous Corpuscles' (145.5-8). Although these may be invisible to the human eye, the 'Eye of a *Lynx*' (146.10) might detect the lack of thorough and complete blending of the miscibles 'with one another and with their *Totum* [totality], as the Nature of Mistion requires' (146.11-13).

This must be so if Aristotle is not to 'beg the Question [take for granted the question in dispute] and take mixing 'to consist in what other Naturalists [natural philosophers] deny to be requisite [necessary] to do' (146.15-16). He reasons that

[55] Turpentine is the distillation product of varies oleoresins which exude from coniferous trees. It is composed mainly of terpenes which are both inflammable and volatile.
[56] Amber is the fossilised resin of coniferous trees.

Aristotle objects 'That [the foregoing argument] as a great Inconvenience [absurdity]' (146.17), which position Eleutherius cannot accept 'till he [Aristotle] have brought as Considerable Arguments as I have propos'd to prove the contrary' (146.18-21). This is: 'to evince [convince] that Nature makes other Mistions [mixtures] than such as I have allowed [accepted]' (146.21-23). Eleutherius' understanding of mixing being 'wherein the *Miscibilia* [miscibles] are reduc'd into minute Parts, and United as farr as sense can discerne' (146.23-25). If one does not accept this as a 'true Mistion, he [Aristotle] must have the same Quarrel with Nature her self, as with his Adversaries' (146.27-29).

Eleutherius brings his monologue to a close by making a joking remark about Carneades, with which he sets the scene for the latter's next contribution to the discussion by saying 'Wherefore [on account of which]' (147.1) he must 'Marvail that *Carneades* should oppose the Doctrine of the Chymist[57] in a Particular [a detailed description or account]' wherein they [the Chymists] do as well agree with his old Mistress, Nature, as dissent [disagree with] from his old Adversary, *Aristotle*' (147.2-7). And Carneades, thus having been identified as probably agreeing with the Chymists [Paracelsians], in adopting an opinion in accordance with nature on the subject of mixing, rather than with Aristotle, begins his next contribution to the dialogue.

He commences by saying that he will not now concern himself with examining 'thorowly the Controversies concerning Mistion [mixing]' (147.9-10). And as to his position on the matter, he states that if he were forced to adopt one or other opinion

[57] Corrected to 'Chymists' in the 1680 edition.

on the subject, that is, if he ‘were reduc’d to embrace absolutely and unreservedly either the Opinion of *Aristotle*, or that of the Philosophers that went before him’ (147.12-15), he would plump for the latter ‘which the Chymists [Paracelsians] have adopted, as the more defensible Opinion’ (147.17-18). However, because his understanding of the elements differs from that of both groups, he believes that he can ‘take a middle Course’ (147.20-21) and he will ‘Discourse [converse] to you of Mistion [mixing]’ (147.21) which stands between the two, explaining that he will ‘not peremptorily [emphatically] define whether there be not Cases wherein some *Phaenomena* of Mistion [mixing] seems to favour the Opinion that the Chymists Patrons [perhaps the first Paracelsians] borrow’d of the Antients’ (147.24-28). And it is this sense of doubt in ‘some cases’ (148.1) which constitutes his ‘second General Consideration’ (148.2-3) and may prevent it from ‘being unreasonable’ (149.3-4).

Carneades goes on to discuss the subject of how bodies mix together, beginning with Aristotle’s understanding of the matter. He says that he is not ‘over well satisfi’d’ (148.6-7) with Aristotle’s teaching on mixing, his objection being that ‘it teaches that the four Elements may again be separated from the mixt Body’ (148.9-11). He goes on to say ‘whereas if they continu’d not in it, it would not be so much a Separation as a Production’ (148.11-14) *i.e.* a thing produced as the result of a process. What Carneades seems to mean here is that if the elements did not retain their individual identities in a compound body, then the mixing or compounding process would cause these same elements to break down and combine to form a compound body from which the original elements would not be retrievable.

He opines that the pre-Aristotelian philosophers along with ‘Chymists [Paracelsians] who have since receiv’d the same Opinion, do speak of this matter more intelligibly, if not more probably [plausibly] then [than] the Peripateticks [Aristotelians]’ (148.15-19). Carneades acknowledges that the chymists or Paracelsians speak ‘Congruously [appropriately] enough, to their believing, that there are a certain Number of Primogeneal [primary] Bodies, by whose Concourse [combined action] all those we call Mixts are Generated, and which in the Destruction of mixt Bodies do barely [simply] part company’ (148.20-25) and revert to their original condition. Carneades admits that he can entirely Acquiesce [accept reluctantly] in’ (148.29) ‘very few Opinions’ (148.28-29) now ‘must confess [acknowledge]’ (149.1) that he is inclined to differ with ‘the *Aristotelians*’ (149.2), ‘the old Philosophers’ (149.3), and ‘the Chymists [Paracelsians] about the Nature of Mistion [mixing]’ (149.3-4). He does not wish to give his ‘present Notion of it’ (149.6-7) which is to be understood as ‘an *Hypothesis*’ (149.8-9) rather than as ‘an Assertion’ (149.8), and that his intention is not to ‘debate the whole Doctrine of Mistion [mixing]’ (149.10-11). Instead, he wishes to make a specific argument in relation to the ability of fire to decompose compound bodies into their elemental constituents.

He wishes ‘to shew [show] that ’tis not Improbable, that sometimes mingl’d substances may be so strictly [tightly] united, that it doth [does] not by the usual Operations of the Fire’ (149.11-15), which would be the standard means by which the ‘Chymists [Paracelsians] are wont [accustomed]’ (149.15-16) to accept as revealing the ‘*Analysis* [composition] of compound bodies, it is not the normal application of fire ‘that in such Bodies the *Miscibilia* [miscibles] that concurr’d [combined] to make them up do each of them retain its own peculiar [distinctive] nature' (149.18-21).

They believe, he continues, that the compound bodies 'by the *Spagyrists* [those who take materials apart and put them together *i.e*. the Paracelsians] Fires may be more easily extricated [liberated] and Recover'd, than Alter'd' (149.21-24). Carneades specifies what processes may be brought to bear on the *Miscibilia* or miscibles by the fire in order either to retrieve or alter them in a compound body. The first is a 'Change of Texture in the Parts of the same Ingredient' (149.24-25), by which he means a rearrangement of the internal structure at the most fundamental level in the material itself, and the second is 'by an Association with some parts of Another Ingredient more strict [close] than was that of the parts of this or that *Miscibilia* [miscibles] among themselves' (149.25-29).

Now it seems that Eleutherius is about to make some response to what Carneades has just said, but the text only cryptically expresses his intention as 'having press'd him to do what he propos'd, and promis'd to do what he desir'd;' (150.1-2), then the text abruptly reverts to a further contribution from Carneades, who continues, on the subject of mixing by saying that the types of mixing he has in mind are not 'those improper [common] Kinds of mistion [mixing], wherein *Homogeneous* Bodies are Joyn'd' (150.4-6), as when water is mixed with water, or two containers 'of the same kind of Wine with one another' (150.8-9). Rather the example he now wishes to discuss 'seems, Generally speaking, to be but an Union *per Minima* [most minute] of any two or more Bodies of differing Denominations' (150.10-13). The examples he lists are 'when Ashes and Sand are Colliquated [fused] into Glass or Antimony, and

Iron into *Regulus Martis* [pig iron, or the impure iron as produced in the smelter]' (150.13-15).

The text seems to be corrupt at this point: ashes and sand are colliquated into glass, not into antimony; iron is not fused or colliquated into *Regulus Martis*, *i.e.* pig iron, or the impure iron as produced in the smelter. What Carneades actually intended to say may have been: 'as when Ashes and Sand are Colliquated into Glass, or Antimony [into Antimony Flowers],[58] and Iron [ore] into *Regulus Martis*' (150.13-15). His next example is when 'wine and Water are mingl'd, and Sugar is dissolv'd in the Mixture' (150.15-17).

The examples just given by Carneades, although they somehow involve the mixing of ingredients, actually describe two distinct types of material combination: one is simple mixing, as when wine, water and sugar are mixed together, with no chemical reaction occurring, in this case just dilute sweetened wine results. The individual ingredients may be separated and retrieved from such a mixture (albeit with some difficulty). For example the wine solution could be evaporated until the sugar crystallises out of solution.

The other examples, in so far as one can interpret what they actually are (in what may be, as already mentioned, a corrupt text) is that they involve some form of chemical change, with new chemical compounds being formed, as when glass is produced, for example. Although chemical reactions are in principle reversible, it would not be possible to retrieve sand or ashes from glass.

[58] As when Carneades said: 'Antimony sublim'd [volatilised] by its self is reduc'd but to a volatile Powder, or Antimonial Flowers' (67.3-5).

Carneades continues that 'in this general notion of Mistion [mixing] it does not appear clearly comprehended, that the *Miscibilia* [miscibles] or Ingredients do in their small Parts so retain their Nature and remain distinct in the Compound, that they may thence [from there] by the Fire be again taken asunder' (150.17-23).

Carneades, as seasoned experimenter, does realise the fact that when some miscibles are combined they may retain their individual elemental nature, but that sometimes they may be separable, as sugar from sweetened wine, but not others, as when wine and water are combined. He expresses his understanding of the matter by saying 'though I deny not that in some Mistions of certain permanent Bodies this Recovery of the same Ingredients may be made' (150.24-27), as perhaps, when sugar is crystallised out of a cooled solution of sugar in wine. He is 'not convinc'd that it will hold in all or even in most' (150.27-28) cases, as perhaps when efforts are made to separate added water from wine.

Neither does he believe 'that it is necessarily deducible from Chemical Experiments' (150.28-29 – 151.1), and neither is it deducible from 'the true Notion of Mistion [mixing]' (151.1-2), presumably because an account of mixing as the combining of primary bodies at the most fundamental level does not necessarily include a mechanism by which the mixing process might be undone. Carneades understands that a thorough mixture once produced may not readily unmix, even over a long interval of time. He goes on to explain this by saying that 'I assume, that Bodies may be mingl'd, and that very durably, that are not elementary or resolv'd[59] into elements or Principles that they may be mingl'd' (151.3-6).

[59] Corrected to 'nor have been resolved' in the *Errata*.

The first example he gives is that of 'the *Regulus* of Colliquated [fused] Antimony' (151.7-8), in fact antimony metal, which Carneades obviously did not consider as an element, but on account of its homogeneity as a material, was regarded by him as a thorough mixture of its constituents. He then mentions 'Iron' (151.8) again, for which the same reasoning would apply as with antimony. Then 'Gold Coyne' (151.9) in which he acknowledges that usually 'the Gold is alloy'd by the mixture of a quantity greater or lesser' (151.10-12) 'of either silver, or Copper, or both' (151.13-14), which despite its being an alloy of dissimilar materials, 'lasts so many ages' (151.10).

Carneades' next argument is based on his belief in a prime or universal matter common to all physical entities, and that bodies can differ only from one another in ways which depend on the disposition of their common matter. He says that 'there being but one Universal Matter of things' (151.15-16)[60] called '*Materia Prima*' (151.18) by the Aristotelians, with a 'Corporeal Substance' (151.24) being differentiated from all others 'but [only] in certain Qualities or Accidents' (151.21-22), which confer on the substance 'its Denomination [specific name]' (151.25), 'and is referr'd to this or that particular sort of Bodies' (151.25-27). If a given piece of material is depriv'd of these Qualities' (151.28) it still remains as 'a Body' (151.29), yet can no longer be identified as 'that kind of Body as a Plant, or Animal, or Red, Green, Sweet, Sowre or the like' (152.1-3).

[60] See also Proposition 1 on p. 37.

He now concerns himself with how material bodies may come together, then separate, and how these changes may be accounted for. He believes that ‘it very often happens that the small parts of Bodies cohere together but [only] by immediate Contact and Rest’ (152.3-6). Such a degree of binding may not prove sufficient to withstand the dissociation of the material, as ‘there are few Bodies whose minute Parts stick so close together’ (152.7-8), in whatever manner they may be bound together, ‘but that it is possible to meet with some other Body, whose small Parts may get between them, and so dis-joyn them’ (152.10-13). Or perhaps, rather than smaller particles coming between larger ones and somehow pushing them apart, those smaller particles ‘may be fitted [prepared] to cohere more strongly with some of them, then [than] those some do with the rest’ (152.13-15). Carneades seems to mean by this, that a substance may be caused to break down if some of its micro-particles bond more firmly to another species of micro-particles than with their own. It is sufficient, Carneades continues, that the other species of micro-particles ‘may be combin’d so closely with them, as that neither the Fire, nor the other usual Instrument of Chymical Anatomies [analysis] will separate them’ (152.16-19).

Carneades shifts from speculating about the making and breaking of connections between micro-particles, to considering how such particles might behave in some actual materials. He begins by saying of the passage just narrated, ‘These things being promis’d’[61] (152.20). He will ‘not peremptorily [emphatically] deny, but that there may be some Clusters of Particles, wherein the Particles are so minute, and the Coherence so strict [close], or both’ (152.20-24), ‘that when Bodies of Differing Denominations [specific names], and consisting of such durable Clusters’(152.24-

[61] Does he mean ‘premis’d?’

26) are ‘mingl’d’ (152.17). Even if the compound material thus produced is quite distinct from either of its constituents ‘yet each of the little Masses or Clusters may so retain its own Nature, as to be again separable, such as it was before’ (153.1-4).

The example he quotes is that of the separation of the individual metals from an alloy of gold and silver. He relates that if these two metals are ‘melted together in a Due Proportion’ (153.5-6), then goes on to say [correctly] ‘(for in every Proportion, the Refiners will tell You that the experiment will not succeed)’ (153.6-8). This is correct as the dissolution of the silver will only occur if gold is present in the alloy at a proportion no greater than one-third[62].

Carneades continues that ‘*Aqua Fortis* [nitric acid] will dissolve the Silver, and leave the Gold untoucht’ (153.8-10), then reminds Eleutherius of having recently noted that ‘both the Metalls may be recover’d from the mixed Mass’ (153.10-12). He goes on to describe an example of the combining of dissimilar corpuscles. What is of particular interest is how Carneades understands the behaviour of distinct species of corpuscles when combined, for he seems to be saying that in some circumstances the corpuscles themselves are capable of changing their physical attributes when they aggregate to form a new material entity. Such an aggregation of the corpuscles of two different species does not simply result in the formation of a bi-corpuscular combination: they also seem to transform their fundamental morphology in such a manner as to become a new and distinct corpuscular entity. It seems that the two different corpuscles actually merge or coalesce to form what is, in effect, a new larger corpuscle incapable of being separated into its original constituent parts.

[62] See also Partington, *General and Inorganic Chemistry*, 354.

Carneades begins by describing how with 'other Clusters' (153.13-14) the 'Particles stick not so close together but that they may meet with Corpuscles of another Denomination, which are dispos'd to be more closely United with some of them, then [than] they were among themselves' (153.14-19). When this occurs 'two thus combining Corpuscles losing that Shape, or Size, or Motion, or other Accident, upon whose Account they were endow'd with such a Determinate [fixed] Quality or Nature' (153.20-24) means that 'each of them really ceases to be a corpuscle of the same Denomination [special name] it was before; and from the Coalition of these there may emerge a new Body' (153.24-28). These newly coalesced corpuscles, in constituting a material entity which is 'as really one, as either of the Corpuscles are before they were mingl'd, or, if you please, Confounded [mixed up]' (153.28-29 – 154.1-2). This material formed of conjoined corpuscles is possessed of its own unique physical characteristics, and is intrinsically as stable to the forces of separation or dissolution as single corpuscles. 'Since [seeing that] this Concretion is really endow'd with its own Distinct qualities' (154.2-4), and is no more capable of being decomposed by fire 'or any other known way of *Analysis* [breaking down]' (154.4-5) into 'the Corpuscles that at first concurr'd [combined] to make it, then [than] either of them could by the same means be subdivided into other Particles' (154.6-9).

Eleutherius makes an abrupt interjection, offering 'to make this more intelligible by particular examples' (154.10-11), and goes on to describe the production of cupric nitrate by dissolving copper in dilute nitric acid. He says that 'if you dissolve

Copper in *Aqua Fortis* [nitric acid] or Spirit of Nitre[63] [also, nitric acid]' (154.11-13) adding that '(for I remember not which I us'd, nor do I think it much Material)' (154.13-14). He continues that 'You may by Crystalizing the Solution Obtain a goodly Vitriol [cupric nitrate]'[64] (154.15-16). This product 'which though by Virtue of the Composition it have manifestly diverse Qualities, not to be met with in either of the Ingredients' (154.16-19). Still, Eleutherius argues 'yet it seems that the Nitrous Spirits, or at least many of them, may in this Compounded Mass retain their former Nature' (154.20-23). Which is of course true, as cupric nitrate does consist of both a copper and a nitrate portion or radical bonded together. The evidence he presents for this understanding of the material in question is that 'for having for tryal sake Distill'd this Vitrioll Spirit,[65] there came over store [large quantities] of Red Fumes, which by that Colour, by their peculiar stinke, and by their Sourness, manifested themselves to be, Nitrous Spirits' (154.23-28). This is a reference to the choking, pungent fumes of mixed nitrogen oxides, including the reddish-brown dinitrogen tetroxide, produced by heating cupric nitrate. He ends by saying that 'the remaining Calx (here: cupric oxide][66] continu'd Copper, I suppose you'll easily beleeve' (154.29 – 155.1).

Eleutherius argues that in the above example the two constituent parts of cupric nitrate, *i.e*. the copper portion and the nitrate portion, retain their individual identities

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[63] The two different names for nitric acid possibly results from two distinct methods for preparing it. Nitric acid can be produced by distilling nitre, or potassium nitrate, with ferrous sulphate. Fuming nitric acid may be prepared by distilling nitre and sulphuric acid, which method Partington attributes to Glauber (*c*. 1658). The fact that dilute, rather than concentrated, nitric acid is required to produce cupric nitrate may provide a clue to Eleutherius' actually using the dilute nitric acid produced by the traditional method of distilling nitre with ferrous sulphate (hence Spirit of Nitre).
See: Partington *General and Inorganic Chemistry*, 562-563.

[64] The blue prismatic crystals of cupric nitrate are prepared by evaporating a solution of copper dissolved in dilute nitric acid.

[65] Cupric nitrate deliquesces or absorbs water vapour from the atmosphere.

[66] Which remains when cupric nitrate is heated, and can be reduced to the metal by heating with charcoal, for example.

in the compound material, and can be separated out again by decomposing it. By contrast, he offers the example of the dissolution of '*Minium* [red lead][67] which is but [only] Lead Powder'd by the Fire, in Spirit of Vinager [acetic acid], and Crystalize the Solution' (155.2-4). The result will be 'a Saccharine [sugary] Salt [lead acetate], exceedingly differing from both its Ingredients' (155.5-7).

Lead acetate, though toxic, has a very sweet taste, and Eleutherius accounts for this by claiming that 'the Union of some Parts of the *Menstruum* [here: acetic acid] with some of those of the Metal is so strict [close], that the Spirit of Vinager [acetic acid] seems to be, as such, Destroy'd' (155.7-11), the reason being 'since the Saline Corpuscles have quite lost that acidity, upon whose Account the Liquor was call'd Spirit of Vinegar [acetic acid]' (155.11-14).

In describing some of the properties of the lead acetate, Eleutherius states that 'nor can any such Acid Parts as were put to the *Minium* be Separated by any known way from the *Saccharum Saturni* [lead acetate] resulting from them both' (155.14-18). He seems to mean by this that there is no acidic taste from the lead acetate, for he goes on to explain that 'there is no Sowreness at all, but an admirable Sweetness to be tasted in the Concretion' (155.18-20).

He then relates how 'Spirit of Wine [alcohol]' (155.21) will not 'immediately hiss when mingl'd with strong Spirit of Vinager [acetic acid]'[68] (155.22-24) but that Spirit of Wine or alcohol does not 'hiss being pour'd upon *Saccharum Saturni* [sodium acetate]' (155.24-25), as sodium acetate, though soluble in water, is only

[67] Dilead (II) lead (IV) oxide.
[68] Alcohol and acetic acid react together to form ethyl acetate.

sparingly so in alcohol. The reason why Eleutherius seems to find this remarkable is that the 'Acid Salt of Vinager, did it survive, may seem to be concentrated' (155.25-27) in the '*Saccharum Saturni* [lead acetate]' (155.25). Yet he doubts that an acidic quality or property does survive in the *Saccharum Saturni* or sodium acetate, as he found that in distilling it 'by its self I found indeed a Liquor very Penetrant, but not at all Acid' (155.28-29 – 156.1) which differed 'as well in smell and other Qualities, as in tast, from the Spirit of Vinager' (156.2-3).

What Eleutherius is describing here is acetone, which has a strong, though not unpleasant, odour. The thermal decomposition of lead acetate, in addition to acetone, produces a residue, the red liquor called 'fixed oil of lead'. Eleutherius identifies this as a derivative of both lead and acetic acid, 'which likewise seem'd to have left some of its Parts very firmly united to the *Caput Mortuum* [inert residue], which though of a Leaden Nature was in smell, Colour &c. differing from *Minium* [red lead or dilead (II) lead (IV) oxide]' (156.4-8).

Eleutherius draws a further comparison on the nature of mixing, this time with 'two Powders, the one Blew, and the other Yellow' (156.9-11) which although when mixed 'may appear a Green mixture' (156.11), each component actually retains its own colour, as microscopic examination of the mixture reveals. He now goes on to discuss a further chemical reaction, in which 'having Mingl'd *Minium* [red lead or Dilead (II) lead (IV) oxide] and *Sal Armoniack* [ammonium chloride] in a requisite Proportion' (156.14-16), and heating them in a glass retort 'the whole Mass became White, and the Red Corpuscles were destroy'd' (156.17-19). This discharging of the red colouration of the *Minium* fascinates Eleutherius, and he acknowledges that a lead compound 'Calcin'd Lead was separable from the Salt' (156.20-21), following its reaction with the *Sal Armoniack* or ammonium chloride. What may have happened is that these two materials reacted together to form the white crystalline lead chloride.

What seems to puzzle Eleutherius is how lead can retain its own leaden or saturnine nature and yet change its colour in a chemical compound from, in this case, red to white. In other words, lead corpuscles can be red in one lead compound, but white in another.

Eleutherius goes on to consider how the different constituents of blood, for example, retain their own particular qualities when they combine to form a compound material. He does not express an opinion on this, instead leaving it 'to be consider'd, whether in Blood, and divers [various] other Bodies' (156.25-26) the probability that perhaps 'each of the Corpuscles that concurr [combine] to make a Compound Body doth [does]' (156.27-28) sometimes 'retain its own Nature in it' (157.1-2), 'so that Chymists may Extricate' (157.2) the various components which combined to produce a 'Body of one Denomination [specific name]' (157.4-5).

He[69] next considers some examples of changes to materials which occur during the process of digestion in the human body, and prefaces this consideration with an account of two types of change, explained by the Scholastic terms 'Immanent'[70] and 'Transient'[71].

[69] It is unclear as to whether the speaker is Eleutherius or Carneades.
[70] Operating from within a thing or person; not external or transcendent.
[71] Passing out or operating beyond itself; transitive.

He begins by stating that ‘there may be a Distinction betwixt Matter *Immanent*, when the material parts remain and retain their own Nature in the things materiated’ (157.6-9), as some ‘Schoolmen’[72] (157.10) would have it, ‘(in which sence Wood, Stones and Lime are the Matter of a House,)’ (157.10-12) and ‘*Transient*, which is the materiated thing is so alter’d, as to receive a new forme, without being capable of re-admitting again the Old’ (157.12-15). He then explains that ‘the Friends of this Distinction say, that *Chyle*[73] is the matter of Blood, and Blood that of a Humane Body, of all whose Parts ’tis presum’d to be the Aliment [nutrient]’ (157.16-20).

What he seems to mean by this example is that in the case of a house the matter remains immanent as the component parts of the building retain their own identity, but that in human digestion the ingredients going to form blood lose their individual identity as one digestion product is transformed into another, meaning that each successive material is transient.

He goes on to discuss material principles, saying that some of these may be said to be ‘*Common* to all mixt Bodies, as *Aristotles* four Elements [earth, air, fire water] or the Chymists *Tria Prima* [mercury, salt, sulphur]’ (157.22-24). Others he says may be ‘*Peculiar* [individual] which belong to that sort of Bodies’ (157.24-26), giving the example ‘as Butter and a kind of whey may be said to be the Proper [characteristic] Principles of Cream’ (157.26-28). He acknowledges that in certain cases these principles may be useful, and that one may ‘easily enough guess in what sence I admit [permit] them’ (158.3-4), in the light of what he has already said, and is yet to

[72] The Schoolmen were a succession of writers, from about the ninth to the fourteenth century, who treat of logic, metaphysics and theology as taught in the ‘Schools’ or universities of Italy, France, Germany and England. Later, their teachings came under increasing challenge as the New Science gained influence.

[73] A term used to designate the white, milky fluid in the intestines just before absorption.

say, adding, without further elaboration, that ‘in such a sence’ (158.5) these principles will ‘illustrate’ (158.5-6) rather than overthrow [overturn]’ (158.6) any of his opinions.

He next makes a curious observation, contrasting the separation of lead from gold when the two have been mixed – a standard chemical operation – with their separation when the mixing is done using an alchemical method. He begins by saying that in order to ‘prosecute [follow up]’ (158.8) what he has already said, he will ‘add to this purpose [point at issue]’ (158.9) ‘that since the Major part of Chymists [Paracelsians] Credit [believe], what those they call Philosophers affirme of their Stone, I may represent [describe] to them, that though when Common Gold and Lead are mingled together, the Lead may be sever’d almost un-alter’d from the Gold’ (158.9-16). The separation of these two metals can be achieved by chemical means: the alloy is heated in a draught of air which causes the lead to oxidise and form a skin on top of the gold, from which it can be skimmed off, leaving pure gold. The oxidised lead can be reduced to the metal by further heating with a carboniferous fuel.

By contrast ‘yet if instead of Gold a *Tantillum* [so small a quantity] of the Red *Elixir*[74] be mingled with the Saturn [lead], their Union will be so indissoluble in the perfect Gold that will be produc’d by it, that there is no known, nor perhaps no possible way of separating the diffus’d *Elixir* from the fixed [non-volatile] Lead’ (158.16-23).

[74] A preparation by the use of which it was sought to change metals into gold. Sometimes identified with the Philosophers’ Stone.

Here a different kind of change within materials has occurred, this time not chemical but alchemical. Lead, by the action of the red elixir, has been transmuted into perfect gold, and this process is irreversible. The two ingredients 'both Constitute a most permanent Body, wherein the Saturne [lead] seems to have quite lost its Properties that made it be call'd Lead' (158.24-27). That this procedure is indeed an alchemical transformation is emphasised by Eleutherius when he says that the lead seems 'to have been rather transmuted by the *elixir*, then [than] barely [merely] associated to it' (158.27-29).[75]

Eleutherius concludes from the forgoing that when materials are combined at the most fundamental level, their individual identities may not be retained in the compound material, saying that 'the Bodies that are put together *per minima* [most minutely]' (159.1-2) do not necessarily 'each retain its own Nature' (159.2-3). He elaborates on this by saying that 'when the Mass it Self is dissipated by the Fire' (159.3-4) it is not necessary for it 'to be more dispos'd to re-appear in its Pristine [former] Forme, then [than] in any new one' (159.4-6). Any such new form having been acquired 'by a stricter [closer] association of its Parts with those of some of the other Ingredients of the *Compositum* [composition] then [than] with one another' (159.7-10).

Interestingly, Eleutherius in replying to a possible objection to his account of mixing resorts to an Aristotelian style of argument in order to counter any such objection. The potential objection is that 'in such Cases as I have proposed there would not be an Union but a Destruction of mingled Bodies, which seems all one [one and the

[75] West believes that in this passage Boyle is referring to the production of gold-ruby glass (of high lead content), see Muriel West, 'Notes on the Importance of Alchemy to Modern Science in the Writings of Francis Bacon and Robert Boyle' *Ambix* 9, no. 2 (June 1961), 102-114, 112.

same] as to say, that of such Bodies there is no mistion [mixing] at all' (159.13-18). His response is to resort to the Aristotelian understanding of material bodies as capable of being defined by substance and accident, by arguing 'that *though* the Substances[76] that are mingl'd remain, only their Accidents[77] are Destroy'd' (159.18-20). He seems to mean by this that certain physical characteristics of the reacting materials are lost in a mixture, with only the fundamental qualities of the reactants remaining intact.

He adds of the mixed substances that '*though* we may with tolerable Congruity [appropriateness] call them *Miscibilia* [miscibles], because they are Distinct Bodies before they are put together' (159.21-24) yet when actually mixed 'however afterwards they are so confounded [destroyed or corrupted] that I should rather call them Concretions [solid masses] or Resulting Bodies than mixt ones' (159.24-27). And here Eleutherius makes a subtle argument but is acknowledging that in some cases of mixing the resulting combination of bodies may not be a mixture, that is to say, an aggregate in which the participating bodies retain both their appearance and their true natures. Instead the new combination of materials may lose some of their outward features, with the result that they may no longer seem to be as they were in their original condition, yet they do retain their essential features.

In other words, in an aggregate of two or more bodies, the individual ingredients may lose their accidents, whilst retaining their substances, and these new arrangements may no longer legitimately be called mixtures, but some other

[76] In Aristotelian thought a substance is that which can exist by itself, or does not need a subject for its existence, in the way that properties need objects, hence that which bears properties.
[77] Again in Aristotelian thought, an accident is a quality which is not essential to the kind of substance or thing in question; it could be lost or be added without its host ceasing to be the same thing or the same substance.

aggregation in which the original bodies are no longer obvious, yet in which those same original ingredients retain their essential characteristics.

Eleutherius admits that '*though*, perhaps, some other and better Account may be propos'd' (159.27-29) which may still be called 'Mistion [mixing]' (160.1), he asks that if what he has said 'be thought Reason, I shall not wrangle about Words' (160.2-3). He adds that he thinks it 'fitter to alter a Terme of Art, then [than] reject a new Truth, because it suits not [is not in accord] with it' (160.4-6). This seems to be an invitation from Eleutherius for someone to give an hypothesis on mixing in which the original materials are mixed as adequately as he has described, and which form an aggregate as distinct from its constituent components as his account understands it to be, and if the word 'mistion' or 'mixture' is still applied to the compound body formed during the mixing process, then he will not complain, as it is the provision of a valid account of the combining process and its resulting aggregate which is important, rather than the terminology employed in that account.

A further possible objection to his account of mixing is identified by Eleutherius as one which holds that the combining of compound materials is different from that of the elements, or principles. His first response to this is that 'I here Consider the Nature of mixtion [mixing] somewhat more generally, then [than] the Chymists [Paracelsians], who yet cannot deny that there are oftentimes Mixtures, and those very durable ones, made of Bodies that are not Elementary' (160.13-19).

His next suggested objection constitutes, in effect, an attack on the Paracelsians' *tria prima*, or three principles of salt, sulphur and mercury, in which he slyly alleges that they may be destroyed in the mixing process, which would hardly be the case if they did actually exist as principles, as *true* principles could not be reduced to simpler bodies.

Eleutherius begins by stating 'that though it may be probably pretended that in those Mixtures that are made immediately' (160.20-22) of putative 'Principles or Elements, the mingl'd Ingredients may better retain their own Nature in the Compound Mass, and be more easily separated from thence' (160.23-27). He then launches his two-part objection to the Paracelsians' *tria prima*, or three principles: the first part of which is that 'it may be doubted, whether there be any such Primary bodies' (160.27-29). His second is that he sees no reason why what he has already 'alleadg'd [advanced in support of], of the destructibility of the Ingredients of Bodies in General, may not sometimes be Applicable to Salt, Sulphur or Mercury' (161.1-4), *i.e.* the three Paracelsian principles ''till it be shewn [shown] upon what account we are to believe them Priviledged' (161.4-6).

He invites Carneades to recall why 'I told you at First, I meant to speak of Mistion [mixing] at this Time' (161.8-9), that he may 'allow [acknowledge]' (161.10) that what he had already said about mixing may 'not only give some Light to the Nature of it in general' (161.11-12), saying that he will later have an opportunity to discuss 'that subject more fully' (161.15), but may also prove 'Serviceable to me in the Insuing Part of this Discourse' (161.16-17).

He then recapitulates some of the points raised in their discussion on mixing. The first is that they 'Deduc'd, from the differing Substances obtained from a Plant nourished only with Water, and from some other things' (161.21-24) that nature did not always need to 'compound a Body at first' (161.26) from the thermal decomposition products obtained from it. He goes on to say that more can be deduced from 'those Experiments' (161.29 – 162.1), namely 'something that Subverts an other Foundation of the Chymical Doctrine' (162.2-4). Recalling that '(as we have seen) out of Fair Water alone, not only Spirit, but Oyle, and Salt, and Earth may be Produced' (162.4-7), it follows that 'Salt and Sulphur are not Primogeneal [primary] Bodies, and principles' (162.8-9) since they are routinely made from plain water 'by the Texture [structure] which the Seed or Seminal principle of plants puts it into' (162.11-13). This would, perhaps, seem normal to us, Eleutherius preaches, 'if through pride, or negligence, We were not Wont [accustomed] to Overlook the Obvious and Familiar Workings of Nature' (162.14-17).

He elaborates on this by considering how little it takes to 'denominate [designate] one of the *Tria Prima* [salt, sulphur, and mercury]' (162.19-20). If a body is 'readily dissoluble [soluble] in water' (162.23-24) it can 'passe for a Salt' (162.25), a result of nature's ability to 'work as great Alternations in divers [many] parcells of matter' (162.21-23). He then notes that nature's ability to produce a water-soluble material is no more remarkable than her ability to produce water itself, or the liquid fraction of an egg. He says he cannot see why 'from a new shuffling and Disposition [arrangement] of the Component Particles of a Body' (162.26-28) it should be more difficult for nature to produce a 'body dissoluble [soluble] in water' (162.29 – 163.1) from some water which itself 'was not so before' (163.1-2), 'then [than] of the Liquid substance of an Egg' (163.2-3), which is readily water soluble, and cause 'by the bare [mere] warmth of a hatching Hen, Membrans, Feathers, Tendons, and other parts' (163.4-6) to be produced, and which unlike 'that Liquid Substance' (163.7-8) are insoluble in water. In a similar vein, he remarks 'nor is the Hardness and Brittleness of Salt more difficult for Nature to introduce into such a yielding body as Water, then [than] it is for her to make the Bones of a Chick out of the tender Substance of the Liquors of an Egg' (163.8-14).

Rather than maintaining this line of enquiry, he will move on, once he has 'taken notice [pointed out] of an objection that lies in my Way' (163.16-17). The objection is that the changes he has spoken of all occur in living systems, which operate on an organic principle which would readily be destroyed by fire. He adroitly counters this objection by speaking of the fire as acting at a sufficiently low temperature as to be capable only of promoting, rather than upsetting, organic change.

He can 'easily foresee it will be alledged [advanced], that the above mentioned Examples are all taken from Plants, and Animals, in whom the Matter is Fashioned by the Plastick power of the seed, or something analogous thereunto' (163.18-23). By contrast, 'the Fire do's not act like any of the Seminal Principles, but destroyes them all, when they come within its Reach' (163.23-26). He counters, or rather side-steps, this objection, not by considering it in full, but by considering fire as only producing warmth rather than destructive flame. He gives 'this easy Answer, That whether it be a Seminal Principle, or any other which fashions that Matter' (163.28 – 164.1), as already discussed, 'yet 'tis Evident, that either by the Plastick principle Alone, or that and Heat Together' (164.3-5), or indeed by another means 'capable to contex [form] the matter, it is yet possible that the matter may be Anew contriv'd into such Bodies' (164.5-8).

Carneades rounds off this section of the work by saying that with these three possible mechanisms in mind he will continue to argue his case. He says that ''tis only for the Possibility of this that I am now contending [striving]' (164.8-10).

A Commentary on *The Sceptical Chymist* of Robert Boyle: *The Third Part*

Introductory Remarks

The theme running through this short section of the dialogue is, to quote Boas (*q.v.*), that 'not all bodies are resolved into precisely three elements.' Carneades makes the point that, given that bodies are composed of corpuscles, the corpuscular aggregates of which they consist may be greater even than five (171), and that there are compound materials which no method of analysis can resolve into their elemental constituents (173-174), especially gold, for Carneades would remunerate the one who could decompose it into its *tria prima*.

Carneades describes his innocently-contrived chemical experiment of which the reaction products could be interpreted as indicating the presence of the *tria prima* (182-185).

The Sceptical Chymist

The Third Part

Carneades begins this part of the dialogue by reminding Eleutherius that his intention in the discussion so far is to question the fundamental assumptions – so fundamental as to be accepted as given – of his adversaries. He expresses his presumption that what he has 'hitherto Discount'd' (165.1) will have 'shew'n [shown] You' (165.3) that 'a Considering Man may very well question the Truth of those very [exact] Suppositions which Chymists [Paracelsians] as well as Peripateticks [Aristotelians], without proving, take for granted' (165.4-8), and as foundational beliefs 'upon which Depends the Validity of the Inferences they draw from their Experiments' (165.8-10). This to him 'though a Chymist Perhaps will not' (165.11-12), yet he does, 'look upon as the most Important, as well as Difficult, part of my Task' (165.13-14), and 'having dispatch'd' (166.11) it, 'Wherefore [and therefore]' (165.10) it will 'be Seasonable [opportune]' (165.15) for him to go on to consider their experiments, in which 'they are wont [accustomed] so much to Triumph and Glory' (166.2-3). This is a clear warning from Carneades that his adversaries will have little to exult in after he has completed his examination of their experimental evidence.

Continuing in similar vein, Eleutherius stresses that his motivation for the 'serious Examination' (166.4-5) of such experiments is 'because those that Alledge [advance] them are wont [accustomed] to do it with so much Confidence and Ostentation, that they have hitherto impos'd upon' (166.5-8) almost all those including 'Philosophers and Physitians [natural philosophers]' (166.10) who have encountered them or their books.

Carneades mentions three categories or groups from the learned community who have been swayed towards accepting such doctrines. In the first group are 'some learned Men' (166.12) who have been content to accept what the proponents of these teachings 'so boldly Affirm, then [than] be at the trouble and charge, to try [test] whether or no it be True' (166.14-16). The second group, who are sufficiently curious to 'Examine the Truth of what is Averr'd [declared true] want [lack] Skill and Opportunity to do what they Desire' (166.17-20). He makes a snide reference to the credulous third group, 'the Generality even of Learned Men' (166.20-21), who 'not contenting themselves with the Schools[1] to amuse the World with empty words' (166.22-24), 'seeing the Chymists [Paracelsians]' (166.21) 'Perform'd [2] divers [many] strange things' (166.24-25) including resolving compound materials 'into several Substances not known by former [earlier] Philosophers to be contain'd in them' (166.26-28).

He goes on to suggest that there is an expectation that those who are considered expert in a given field should be believed when speaking of matters within their competence. The case in point is 'with what Confidence Chymists [Paracelsians] Averr [declare true] the Substances Obtain'd from Compound Bodies by the Fire to be True Elements' (167.1-4) or 'Hypostaticall [elemental] Principles of them' (167.5), and that they consider it 'but Just as well as Modest, that according to the *Logicians* Rule, the Skilfull *Artists* should be Credited [believed] in their own Art' (167.6-9). What Carneades seems to mean here is that a body of philosophers – the logicians – teach that it is rational to accept the authority of the experts in a given discipline, which belief is

[1] Here: the universities, in which the Aristotelian doctrines on matter were taught.
[2] Corrected to 'Perform' in the 1680 edition.

reinforced when they alone are capable of producing the things upon which they make their pronouncements.

Carneades continues that the Paracelsians take advantage of the ignorance of others to reinforce their position. Their confident teaching on the things which they 'take upon them [themselves] to teach others are not only Productions of their own Skill, but such as others know not else what to make of' (167.11-15).

This note of confident assertion has enabled some of the Paracelsians' accounts 'not only to Delight but Amaze, and almost to bewitch even Learned Men' (167.18-20). Carneades warns that 'You and I, who are not unpractic'd in the Trade, must not suffer [allow] our Selves to be impos'd upon by hard Names, or bold Assertions' (167.21-24), then curiously adds 'nor to be dazl'd by that Light which should but [only] assist us to discern things the more clearly' (167.24-27). What he seems to understand by the word 'light' has two meanings: the first is real light, the type emitted by laboratory furnaces, and the second is the light of reason, and he may mean that the light from the incandescent fire should not be allowed to stand in the way of a reasoned account of the process of thermal decompositions.

He continues with an observation in which the word 'nature' is cleverly used in two senses, saying that 'it is one thing to be able to help Nature to produce things, and another thing to Understand well the Nature of the things produc'd' (167.27-29 – 168.1). Carneades gives as an example the begetting of children, saying that those who beget children are as 'Ignorant of the Number and Nature of the parts' (168.3-4) and internal organs of a child's body 'as they that never were Parents' (168.6-7). He then makes a subtle point in which he argues that those who skilfully decompose a material do not have an automatic right to control the interpretation of their findings. He believes that 'if as I thank the Chymists [Paracelsians] for the things their *Analysis* shews [shows] me, so I take the Liberty to consider how many, and what they are, without being astonish'd at them' (168.8-12), adding that possessing the skill to 'shew [show] men some new thing of his own making' (168.13-14) does not confer the right to foist his beliefs about it on them.

Carneades states his 'Third General Consideration' (168.19), namely, 'That it does appear, that *Three* is precisely and Universally the Number of the Distinct Substances or Elements whereinto mixt Bodies are resoluble [resolvable] by the Fire' (168.20-24). He develops this by arguing that the 'Chymists [Paracelsians]' (168.25) have been unable to prove that chemical analysis of all 'compound Bodies, which are granted to be perfectly mixt' (168.26-27) separates them into 'just Three Distinct Substances' (168.29) without exception, 'which are wont [accustomed] to be lookt upon as Elementary' (169.1-2). He then qualifies this by adding 'or may as well be reputed so as those that are so reputed' (169.2-4). Carneades explains that 'the last Clause I subjoyne [add]' (169.4-5) to forestall any objections that some of the substances he may mention later 'are not perfectly Homogeneous, nor Consequently worthy of the name of Principles' (169.7-9). He goes on to assert that what he is about to consider is 'into how many Differing Substances, that may plausibly pass for the Elementary Ingredients of a mix'd Body, it may be Analys'd [broken down] by the Fire' (169.11-14). What he now adds is, perhaps, the real intention of his investigation: 'whether each of these be uncompounded [unitary], I reserve [set aside] to examine' (169.18) that those materials which the Paracelsians 'not only allow [sanction], but assert to be the Component Principles of the Body resolv'd into them, are not wont [accustomed] to be uncompounded' (169.19-23).

Carneades goes on to specify the two 'Kind of Arguments' (169.24-25) which serve to make his 'Third Proposition seem probable' (169.26-27): one type of which is of a 'more Speculative Nature, and the other drawn from Experience' (169.28-29 – 170.1).

Just as he was about to treat of 'the first of these' (170.1-2) he is interrupted by Eleutherius, who says to him half-smilingly that if he has 'no mind [does not remember] I should think, that the Proverb, *That Good Wits* [those of high intellectual ability] *have bad Memories*, is Rational and Applicable to You' (170.7-10). Eleutherius wishes to remind his interlocutor that he is about to speak of the 'Speculative Considerations, that may relate to the Number of the Elements' (170.11-13), and that in giving the three prepositions on the fundamental nature and behaviour of matter, in the first few pages of *The First Part* of this work, where he did 'Deliver and Concede some Propositions in Favour of the Chymical Doctrine which I may without disparagement to you think it uneasie [difficult], even for *Carneades* to answer' (170.14-18).

Carneades replies that he has not ‘Forgot the Concessions you mean’ (170.19-20) and hopes that Eleutherius has ‘not forgot neither [either] with what Cautions [provisos] they were made when I had not yet assumed [taken upon oneself] the Person I am now sustaining [supporting]’ (170.21-24). Carneades assures his companion that he will bear in mind what Eleutherius ‘would have me remember’ (170.28-29) when speaking about his ‘Third general consideration’ (170.26).

Carneades, reverting to ‘such principles’ (171.1-2) as he earlier employed, says that he will ‘represent [assume]’ (171.3) that if the rational supposition adopted earlier by him is allowed, ‘that the Elements consisted at first of certain small and primary coalitions of the minute Particles of matter into Corpuscles very numerous, and very like each other’ (171.4-8) it is sensible ‘to conceive, that such primary Clusters may be of far more sorts than three or five’ (171.9-11). Consequently it is not necessary to suppose, ‘that in each of the compound bodies we are treating of there should be found just three sorts of such primitive Coalitions’ (171.12-15), as already discussed.

He next considers that if the existence of numerous elements is accepted, then the number of elements going to form a compound body becomes a consideration. He argues that ‘it seems very possible, that to the constitution of one sort of mixt Bodies two kinds of Elementary ones may suffice’ (171.19-22), as, for example, ‘that most durable Concrete, Glass’ (171.23-24). Some compound bodies may consist of between three and five elements, others ‘perhaps of many more’ (171.27). From this it follows that ‘no determinate number’ (171.29) of the elements, assigned ‘of [to] all sorts of compound Bodies whatsoever' (172.1-2). Most probably 'some Concretes [compound bodies] consist of fewer, some of more Elements' (172.3-4).

Continuing with this theme, he raises the possibility that 'according to these Principles, but that there may be two sorts of Mixts [compound bodies]' (172.5-7) not consisting of a shared set of elements, as is often the case with two words which do not share any letters in common, or 'as we often meet with diverse Electuaries,[3] in which no Ingredient (except Sugar) is common to any two of them' (172.12-15). He goes on to make a connection between the elements and their constituent corpuscles, first saying that he 'will not here debate whether there may not be a multitude of these Corpuscles, which by reason of their being primary and simple, might be called Elementary' (172.15-19), here positing the connection between corpuscles as singular entities and their being considered as elements. He then considers whether 'several sorts of them should convene to compose any Body' (172.20-21), or whether 'they are as yet free, and neither as yet contex'd [woven together] and entangl'd with primary Corpuscles of other kinds' (172.21-23).

He develops this point regarding the aggregation of primary particles, not simply by the operation of random or simple mechanical forces, but by natural powers which cause the corpuscles to remain 'liable to be subdu'd [won over] and fashion'd by seminal Principles, or the like powerful and Transmuting Agent' (172.24-26), which may cause them to be connected either 'among themselves, or with the parts of one of the bodies,

[3] An electuary is a medicinal conserve or paste, consisting of a powder or other ingredient mixed with honey, preserve, or syrup of some kind.

as to make the compound Bodies' (172.27-29 – 173.1). The ingredients of these compound bodies may be 'resoluble [resoluable] into more, or other Elements then [than] those that Chymists have hitherto taken notice of' (173.2-4).

Carneades now raises the possibility that there may be compound bodies which remain incapable of being reduced to the elemental state by thermal decomposition. He says that from his remarks on the 'permanency of Gold and Silver, that even Corpuscles that are not of an Elementary but compounded Nature, may be of so durable a Texture, as to remain indissoluble in the ordinary *Analysis* [decomposition] that Chymists make of Bodies by the Fire' (173.7-13). He suggests the possibility that even though there may be only three elements, there may be 'a greater number of Bodies, which the wonted [usual] ways of Anatomy will not discover to be no Elementary Bodies [will not discover not to be elementary bodies]' (173.15-18). Carneades seems to mean that with some bodies normal means of chemical decomposition cannot lead to their true state of aggregation being determined, simply because such means are not sufficiently powerful or effective to allow a decision to be made as to whether they have been reduced to smaller bodies of their ultimate stage of decomposition.

He now introduces the question, not of the number of the elements *per se*, but rather of their number in compound bodies as revealed by chemical analysis. Carneades says that he has so far 'in compliance to you, talk'd conjecturally of the number of the Elements' (173.20-23) and now wishes to consider, not the number of the elements from which nature 'may compound mix'd Bodies, but (at least as farr as the ordinary Experiments of

Chymists will informe us) of how many she doth [does] make them up' (173.23-27). He states pointedly that, to him, the evidence from such chymical experiments is not 'that there is any one determinate number of Elements to be uniformly met with in all the several sorts of Bodies allow'd [acknowledged] to be perfectly mixt' (173.29 – 174.1-4). In offering 'the more distinct [decided] proof of this Proposition' (174.5-6), firstly he will 'Represent [here: argue] That there are divers [many] Bodies' (174.7) which he believes will never be separated into 'so many as three Elementary substances' (174.9-10). He says that 'I would fain [gladly] (as I said lately to *Philoponus*)[4] see that fixt and noble Metal we call Gold separated into Salt, Sulphur and Mercury' (174.10-13). So confident is Carneades of not seeing gold separated into three principles that he offers to cover the costs accruing for both materials and charges to the experimenter who achieves 'prosperous success' (174.15-16) in the experiment. He is cautious enough to discourage cheating by the applicant, who must 'submit to a competent [suitable] forfeiture [monetary penalty] in case of failing' (174.13-14). He goes on to say that in light of his own experimental findings he dare not 'peremptorily [emphatically] deny' (174.19) that there may 'out of Gold be extracted a certain substance' (174.20-21) which he accepts is called 'its Tincture or Sulphur' (174.22), and which would cause the residue to be 'depriv'd of its wonted [customary] colour' (174.24).

Continuing with this line of thought he says that he is not sure that from gold also there cannot be extracted 'a real quick and running Mercury' (174.26-27). He does, however, draw the line at the 'Salt of Gold' (174.27), as he never either saw or was assured that it

[4] In making this remark, Carneades seems to be indicating that Philoponus is no longer present at the discussion.

was ever separated '*in rerum natura* [in the nature of things] by the relation [account] of any credible eye witnesse' (175.1-2). Carneades raises two further objections to the risky venture of extracting this component of gold. The first of these being the high cost of the gold, objecting that it is 'too pretious [precious] and costly to be wasted upon so groundlesse adventures of which not only the successe is doubtful, but the very possibility is not yet demonstrated' (175.5-9).

His second objection arises from the difficulty of determining the true origin of any compound material associated with the chemical manipulation of gold: how does one determine whether such a product is extracted from the gold, or is simply the gold itself combined with another material? The true deterrent to 'such tryalls, is not their chargeablenesse [cost or expense], but their unsatisfactorinesse, though they should succeed' (175.10-13). He explains that the accepted method for the extraction of 'this golden Salt' (175.13-14) is by means of 'corrosive *Menstruums*[5] or the Intervention of other Saline Bodies'[6] (175.15-17), and it is the origin of the gold compound thereby formed that remains in doubt. He continues that 'it will remain doubtful to the wary person, whether the Emergent Salt be that of the Gold it self; or of the Saline Bodies or Spirits employ'd to prepare it' (175.17-21).

Carneades – the skilled and experienced experimenter – explains that the inability to interpret what exactly is occurring during chemical transformation is part of the lot of the practitioner of chemistry, adding wearily that 'such disguises of Metals do often

[5] The only solvent in Boyle's day known to dissolve gold was *Aqua Regia* – a mixture of nitric and hydrochloric acids.
[6] Perhaps a reference to the reaction of gold with fused alkalis, such as sodium hydroxide.

impose [place] upon Artists [here: experimenters]' (175.21-22), and that Eleutherius is 'not so much a stranger to Chymistry as to ignore' (175.23-24) this fact.

He lists a groups of materials from which he would also 'willingly see the three principles separated' (175.25-26), given as: 'the pure sort of Virgin-Sand[7] from *Osteocolla*[8], from refined Silver[9], from Quicksilver [mercury], freed from its adventitious Sulphur[10], from *Venetian* Talck'[11] (175.26-29). This last named he heated at length in 'an extreme *Reverberium*'[12] (176.1-2) in which he could not decompose the talc, instead he 'could but divide it into smaller Particles, (not the constituent principles)' (176.2-4). Talc he found was unchanged when held for a lengthy time 'in a Glasse-house fire' (176.5-6). It emerged 'in the Figure it's Lumps had when put in' (176.6-7). The only change to it being its colour which had been 'alter'd to an almost *Amethystine* [violet-purple] colour'[13] (176.8). He also experimented on 'divers [many] other bodies, which it were now unnecessary to enumerate' (176.9-10).

Yet Carneades will not dismiss out of hand the claims of his adversaries: he dare not 'absolutely affirme it to be impossible to Analyse [decompose] these Bodies into their *Tria prima* [salt, sulphur and mercury]' (176.11-13), but because neither his own

[7] Sand consists mainly of silica which is so stable as to strongly resist efforts at its thermal decomposition.
[8] Osteocolla is a calcareous deposit forming an incrustation on the roots and stems of plants in sandy ground, especially in some parts of Germany. Formerly called glue-bone stone, from its supposed ability to help in the knitting of broken bones.
[9] Silver will do no more on heating than melt and form an oxide.
[10] Carneades may be here referring to the most common ore of mercury – mercuric sulphide or cinnabar – which when refined liberates sulphur to give the metal.
[11] Talc is a white or pale green form of hydrated magnesium silicate.
[12] A reverberatory furnace, in which the fuel does not come into direct contact with the material being heated.
[13] The talc may have been maintained at so high a temperature for its water of hydration to be driven off. Hence the change in colour.

'Experiments, nor any competent Testimony' (176.14-15) has so far 'taught me how such an *Analysis* [decomposition] may be made' (176.16-17), nor assured him that it 'hath [has] been so' (176.17-18), he will not believe it until either the 'Chymists [Paracelsians] Prove it, or give us intelligible and practicable processes to performe what they pretend' (176.19-22). He then launches a barb at his opponents by accusing them of employing pretence and ostentation to mislead the readers rather than provide a true exposition of the elements. On the one hand 'they affect that *Aenigmatical* [perplexing] obscurity with which they are wont [accustomed] to puzzle the Readers of their divulg'd Processes concerning the Analytical[14] Preparation of Gold or Mercury' (176.22-26), they fail to convince the 'wary [circumspect] persons' (176.27) that they have really produced the 'Hypostatical Principles [elements]' (177.1).

It may also be the case that, rather than separating out the elemental constituents of bodies, what may actually be the case is that the individual components of a compound material may be separated out. In such cases what actually form are 'intermixtures of the divided Bodies' (177.2), and gives as examples 'the seeming Crystalls of Silver, and those of Mercury [*i.e.* crystalline compounds of these two materials]; which though by some inconsiderately [imprudently] supposed to be the Salts of those Metalls'[15] (177.4-8) are, according to Carneades 'plainly but [only] mixtures of the Metalline Bodies with the Saline parts of *Aqua fortis* [nitric acid]'[16] and this only becomes 'evident by their being reducible into silver or Quicksilver [mercury], as they were before' (177.8-12).

[14] Prepared by the resolution of compounds into their elements.
[15] Which is exactly what we would now say that they were.
[16] *i.e.* mercury nitrate or silver nitrate.

That is to say the nitrates of silver and mercury can be reduced to the metal by heating strongly in the presence of a carboniferous fuel.

Eleutherius interjects at this time his acceptance that the 'Chymists [Paracelsians]' (177.14) probably obtain their '*Tria Prima* [salt, sulphur and mercury] from Animals and Vegetables' (177.16-17), yet does not understand why 'they should so confidently pretend also to resolve all Metalline and other Mineral bodies into Salt, Sulphur and Mercury' (177.18-21). He recalls the saying of 'those Chymists themselves that are accounted Philosophers' (177.22-24), and especially of '*Roger Bacon*'[17] (177.25) 'that *Facilius est aurum facere quam destruere* [it is easier to make gold than to destroy it]' (177.26-27). He joins with Carneades in his concern that 'Gold is not the only Mineral from which Chymists [Paracelsians] are wont fruitlessly to attempt the separation of their three Principles' (177.27-29 – 178.1). He goes on to quote from 'the Learned *Sennertus*'[18] (178.3) in the book in which he acts not as 'Advocate for the Chymists [Paracelsians] but the Umpier betwixt them and the Peripateticks [Aristotelians]' (178.5-7). His words may be translated as:

> 'It is very well known that salt is present in all things (that is, mixtures) and from them that it can be converted into all things by chemical conversion' (178.8-10).[19]

'and in the next Page, *Quod de sale dixi*, [what I have said of salt], saies he, *Idem de Sulphure dici potest* [the same can be said of sulphur]' (178.10-12).

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[17] Roger Bacon (*c*.1220 - *c*.1292) English-born Franciscan, taught at Oxford and Paris, and wrote extensively on philosophy, theology and science.

[18] Daniel Sennert (1572-1637) German-born professor of medicine at Wittenberg. He accepted Paracelsus's theory of salt, sulphur and mercury as the three principles, but rejected other parts of Paracelsus's doctrines.

[19] '*Salem omnibus inesse (mixtis scilicet) & ex iis fieri posse omnibus in resolutionibus Chymicis versatis notissimum est.*'

Eleutherius, however, remains unconvinced, saying that by ‘his favour [permission] I must see very good proofs, before I believe such general Assertions’ (178.13-14), adding that if he is to be won over he must have demonstrated to him ‘some true and practicable way of separating Salt and Sulphur from Gold, Silver’ (178.17-19) and also from ‘those many different sort of Stones, that a violent Fire does not bring to Lime, but to Fusion’ (178.19-21), by which remark he seems to have in mind the distinction between limestone or marble which are converted into quicklime or calcium oxide when heated strongly, and some other mineral substances which simply melt when heated.

Not only Eleutherius himself saw none of the ‘newly [recently] nam’d Bodies so resolv’d’ (178.23-24), but also ‘*Helmont*, who was much better vers’d in the Chymical Anatomizing [analysing] of Bodies then [than] either *Sennertus* or I’ (178.23-26) and who provides ‘this resolute [determined] passage’ (178.27), which translates as follows:

> ‘I know (saies he) that sulphur or mercury can never be extracted from sand, flints and non-calcareous stones’ (178.28-29 – 179.1).[20]

Eleutherius continues in similar vein by saying that ‘*Quercetanus*[21] though the grand stickler for the *Tria Prima*, has this Confession of the Irresolubleness of diamonds’ (179.1-4), which passage may be translated as:

> ‘Diamonds (saith he) are of all stones the most solidly and hardest made and [in which] one can see the closest and most cohering union of the three principles,

[20] ‘*Scio* (saies he) *ex arena, silicibus & saxis, non Calcariis, nunquam Sulphur aut Mercurium trahi posse*;’

[21] Joseph du Chesne (Quercetanus) (1521/44-1609) French-born physician-in-ordinary to King Henry IV, and follower of Paracelsus.

> which no art of separation can resolve into their three spiritual principles' (179.4-10).[22]

What follows is a remarkable insight into how Eleutherius and Carneades understand both the nature of gold and its chemistry. Eleutherius continues the discussion by saying that he 'was not only glad, but somewhat surprised to find you inclined to Admit that there may be a Sulphur and a running Mercury drawn from Gold' (179.11-14). This statement imparts a certain decisive quality to Carneades' position on gold, in that it is at least intimated or half-acknowledged that he accepts the reality that gold – in many ways the most perfect-seeming of substances – is not a pure, elemental material but one which has both mercury and sulphur associated with it.[23] Eleutherius, however, qualifies his statement by immediately adding what he understands by the word 'sulphur', for he says that unless Carneades rightly seems to 'take the word Sulphur in a very loose sense, I must doubt whether our Chymists can separate a Sulphur from Gold' (179.16-19).

He goes on to mention the experiment which seems to have caused Carneades to 'speak as you did' (179.21), which may be a reference to the description of how he may have extracted its sulphur or tincture from gold, and prompted by the earlier statement: 'after what I have try'd myself' (174.18) by Carneades. Referring to the results of this experiment Eleutherius says that 'I did not judge the golden Tincture to be the true principle of Sulphur extracted from the body, but an aggregate of some such highly

[22]'*Adamas* (saith he) *omnium factus Lapidum solidissimus ac durissimus ex arctissima videlicet trium principiorum unione ac Cohaerentia, quae nulla arte separationis in solutionem principiorum suorum spiritualium disjungi potest*.'

[23] This attitude towards gold harks back to the medieval alchemical theory that all metals were a synthesis of mercury and sulphur, whose union might achieve varying degrees of harmony. A perfectly harmonious marriage of the mother and father of metals might produce gold. All other metals were in varying degrees imperfect, corrupt and subject to corrosion.

colour'd parts of the Gold' (179.21-25). He adds that a 'Chymist' (179.25) would have called this separated fraction 'a *Sulphur incombustible*, which in plain English seems to be little better than to call it a Sulphur and no Sulphur' (179.25-28). What he seems to mean by this is that as sulphur is in itself a highly inflammable material, and likewise the term 'sulphur' is applied to some of the inflammable decomposition fraction of materials, which serves to make any reference to an incombustible sulphur a contradiction in terms.

Eleutherius goes on to discuss 'Metalline Mercuries' (179.29) he 'had not *wondered* at it' (179.29 – 180.1) *i.e*. he would not have wondered at it, though Carneades 'had expressed much more severity [harshness of criticism] in speaking of them' (180.1-3). He then narrates his meeting with 'an old and famous Artist [a person engaged in a practical science]' (180.4) who was 'Chymist to a great Monarch' (180.5-6) and of an honest reputation. Eleutherius asked him to 'tell me ingenuously [candidly] whether or no' (180.8) 'he had ever really extracted a true and running Mercury out of Metals' (180.9-11). His reply was that 'he had never separated a true Mercury from any Metal' (180.12-13), nor had 'ever seen it really done' (180.14).

He then describes how most effort has been applied by 'Chymists' (180.16) to the extraction of the mercury of gold, how 'yet the Experienced *Angelus Sala*,[24] in his

[24] Angelus Sala (1576? – 1637) Italian-born physician and chemist, heavily influenced by Paracelsus.

Spagyrical [Paracelsian] account of the seven *Terrestrial* Planets (that is the seven metals)'[25] (180.19-21) gives the following account, which may be translated as:

> 'Although (saies he) etc. nevertheless experience (which we call the instructress of fools) has certainly established, that the mercury of gold is so fixed, perfect and closely bound to the other substances of the same body that it cannot be separated from them by any means' (180.23-29).[26]

Sala 'sub-joynes [adds] that he himself had seen much Labour spent upon that Design' (180.29 – 181.1-2) without seeing it deliver any mercury. Eleutherius can 'easily believe what he annexes; *that he had often seen Detected many tricks and Impostures* [deceptions] *of Cheating* Alchymists' (181.4-7). He adds that the 'unskilfull or Credulous, or both' (181.9) being 'fond of *Charlatans*' (181.8) are readily taken in by such unscrupulous operators, with the result 'though many profess'd *Alchymists*, and divers [many] Persons of Quality [ability in respect of some trade] have told me that they have made or seen the Mercury of Gold, or of this or that other Metal' (181.13-17). He is still inclined to fear that these workers either had 'a Design [intention] to deceive others' (181.19-20), or lacked the capacity to prevent themselves from being deceived.

Carneades begins to speak again, saying that his interlocutor causes him to recall an experiment which he 'once devis'd, innocently to deceive some persons' (181.24-26), with the intention of alerting them to the ease with which the 'unskillfull or unwary' (181.28-29) are misled 'when they tell us they have seen *Alchymists* make the Mercury of this or that Metal' (181.29 – 182.1-2). He accentuated his lesson by making his

[25] A reference to the alchemical account of associating the Sun, Moon and each naked-eye planet with one of the then known metals: the Sun-gold, the Moon-silver, Mercury-mercury, Venus-copper, Mars-iron, Jupiter-tin, Saturn-lead.

[26] '*Quanquam* (saies he) *&c. experientia tamen (quam stultorum Magistrum* [corrected to *Magistram* in the *Errata*] *vocamus) certe Comprobavit, Mercurium auri adeo fixum, maturum, & arcte cum reliquis ejusdem corporis substantiis conjungi, ut nullo modo retrogredi possit.*'

experiment 'much more Slight, Short and Simple, than the Chymists usual processes to Extract Metalline Mercuries' (182.4-6) and than the lengthy 'Elaborate and Intricate' (182.8) 'Operations' (182.7) of the alchemists. This gives them 'a greater opportunity to Cozen [cheat], and Consequently are more Obnoxious [subject] to the Spectators suspicion' (182.10-12). He further explains that 'wherein [in which] he attempted to make this 'Experiment look the more like a True *Analysis* [decomposition into simpler constituents]' (182.14-15), was to pretend to 'extract a Mercury from the Metal I wrought [worked] upon, but likewise to separate a large proportion of manifest [obvious] and inflamable Sulphur' (182.17-20).

That Carneades has carried out the experiment more than once is clear from the description, beginning with his opening statement 'I take then, of the filings of Copper, about a Drachme[27] or two, of common sublimate [mercuric chloride], powder'd the like Weight, and *Sal Armoniack* [ammonium chloride] near about as much as of Sublimate' (182.20-25). These he places 'into a small Vial [phial, or small glass bottle] with a long neck' (182.26-27), or, better still, into 'a glass Urinall'[28] (182.28), which he stops with cotton 'to avoid the Noxious Fumes' (182.29 – 183.1). This he gradually introduces to either 'a competent [appropriate] Fire' (183.2), close to the 'well kindled coals' (183.2-3), or, to a candle flame. In about a quarter of an hour, 'or perchance [perhaps] in halfe that time' (183.9-10) one may 'perceive [see] in the Bottom of the Glass some running Mercury' (183.10-11). If one removes the glass vessel and breaks it, one will 'find a

[27] A drachm is equivalent to 1/16 of an ounce Avoirdupois, or (nominally) 1.8 gram.
[28] A glass vessel or phial employed to receive urine for medical examination or inspection.

parcel of Quicksilver [mercury], Perhaps altogether, and perhaps part of it in the pores of the Solid Mass' (183.13-16).

He describes how the 'remaining Lump being held to the Flame of the Candle will readily burn with a greenish Flame' (183.17-19). Then 'after a little while (perchance [perhaps] presently [immediately]) will in the Air Acquire a Greenish Blew' (183.19-21). This colour is that which is 'ascrib'd to Copper, when its Body is unlocked' (183.22-23), which facilitated the belief that this is 'the True Sulphur of *Venus* [copper]' (183.25). What Carneades seems to be explaining here is the putative separation of the chemical products into the Paracelsian *Tria Prima* of salt, sulphur and mercury. Mercury has already been released, just now sulphur, and he says that the 'Salts may be Suppos'd partly to be Flown away, and partly to be Sublim'd to the upper part of the Glass, whose inside (will Commonly appear Whitened by them)' (183.26-29 – 184.1). Continuing with this mode of explanation Carneades says that 'the Metal seems to be quite Destroy'd, the Copper no longer appearing in a Metalline Forme, but almost in that of a Resinous Lump' (184.2-5).

Carneades now offers *his* explanation of what has actually occurred in the course of this chemical reaction. It is 'only this, that the Saline parts of the Sublimate [mercuric chloride] together with the *Sal Armoniack* [ammonium chloride], being exited and actuated by the Vehement heat, fall upon the Copper' (184.6-10) – which they can more easily corrode than silver – 'whereby the small parts of the Mercury, being freed from the Salts that kept them asunder [*i.e*. the chloride radical of the corrosive sublimate or mercuric chloride]' (184.12-14). That is to say the tiny particles of mercury are now free to coalesce, which process is effected through being by 'the heat tumbled up and down and after many Occursions [collisions] they Convene [assemble] into a Conspicuous Mass of Liquor' (184.14-17).

Continuing with his account of the reaction, Carneades says that with the salts 'some of the more Volatile of them Subliming to the upper part of the Glass, and others Corrode the Copper' (184.18-20), explaining that these corrosive salts 'uniting themselves' (184.20-21) with the copper 'do strangely alter and Disguise its Metallick Form, and compose with it a new kind of Concrete inflamable like Sulphur' (184.21-24).

What seems to have actually occurred is that Carneades took copper, ammonium chloride and mercuric chloride, put them into a long-necked, stoppered glass vessel, and heated them. The central reaction occurring was the reaction of the copper with the mercuric chloride to form a 'Parcel of Quicksilver [mercury]' (183.13-14), with a brown resinous mass of cuprous chloride, called a 'Solid Mass' (183.16) by Carneades, in the form of 'a Resinous Lump' (184.5) which burns with the 'greenish Flame' (183.19) characteristic of copper halides, and which material within a short while turns green due to the formation of green basic cupric chloride, of which Carneades said 'after a little while (perchance [perhaps] presently [immediately]) will in the Air Acquire a Greenish Blew' (183.19-21).[29]

[29] Partington says that cuprous chloride was obtained by Boyle as a brown resinous mass (*resin of copper*), turning green in moist air, by heating copper with mercuric chloride.
See also: Partington, *General and Inorganic Chemistry*, 338.

The ammonium chloride dissociated into ammonia and hydrogen chloride when heated, hence the 'Noxious Fumes' (183.1) mentioned by Carneades, but condensed on the cooler part of the glass apparatus, which process was described by Carneades as its having 'Sublim'd to the upper part of the Glass' (183.28-29) causing it to 'appear Whitened' (184.1); some may have escaped altogether 'to be Flown away' (183.27).

Carneades adds that he will speak no further of this product, referring Eleutherius to the 'Diligent Observations which I remember Mr. *Boyle* has made concerning this Odde kind of Verdigrease' (184.27-29).

Carneades distances himself from the alchemists and their understanding of chemical reactions by smiling as he says 'you know I was not cut out to be a Mountebank [charlatan], and therefore I will hasten to resume the person of a Sceptick' (185.1-4). He continues with his narrative by pointing out that some bodies 'in their Resolution Exhibite more principles than three' (185.10-11), and some fewer, 'And that therefore the Ternary Number is not that of the Universal and Adequate Principles of Bodies' (185.11-14). He adds that 'if you allow [acknowledge] of the Discourse I ately[30] made You, touching the primary Association of the small Particles of matter' (185.14-17) it will not seem improbable 'that of such Elementary Corpuscles, there may be more sorts than either three, or four, or five' (185.18-20).

He goes on to make a further point on the possibility of resolving materials into their most fundamental component parts. He argues that if it may reasonably be assumed that

[30] Corrected to 'lately' in the *Errata*.

the 'Corpuscles of a compounded Nature may in all the wonted [customary] Examples of Chymists pass for Elementary' (185.22-25), and if it can readily be granted that 'as *Aqua Fortis* [nitric acid], or *Aqua Regis* [a mixture of hydrochloric and nitric acids] will make a Separation of colliquated [melted together] Silver and Gold, though the Fire cannot' (185.26-29), then it can hardly been denied that 'some Agent' (185.29 – 186.1) may be found which is 'so subtle [fine] and so powerful' (186.1-2) as to be capable of acting on those 'particular compounded Corpuscles' (186.2-3), and of resolving them into even smaller components. If this were to happen it would 'encrease the number of the Distinct Substances' (186.6-7) into which materials had been 'hitherto thought resoluble [resolvable]' (186.8-9). He attempts to lend additional weight to this by recalling what he has just recounted from van Helmont 'concerning the Operations of the *Alkahest* which divides Bodies into other Distinct Substances, both as to number and Nature, then [than] the Fire does' (186.11-14), and which if true 'will not a little countenance [bear out] my Conjecture' (186.15-16).

Carneades goes on to consider the question of the number of the elementary bodies from another perspective: it may be that in addition to the three principles, there may also be even smaller bodies incapable of detection by the means employed by the chemists. He argues that in restricting the 'Analyzing [decomposing into their constituents]' (186.17) of compound bodies by techniques 'not unknown to Chymists [Paracelsians]' (186.18-19) it may legitimately be asked whether 'Besides those grosser [more massive] Elements of Bodies, which they call Salt Sulphur and Mercury, there may not be Ingredients of a more Subtile [fine] Nature' (186.20-24). These smaller bodies may remain undetected by virtue of their invisibility, and thereby 'may escape unheeded at the Junctures [joining] of the Destillatory [distillation] Vessels, though never [ever] so carefully Luted [sealed]' (186.26-28).

He reinforces his belief in the existence of active, though invisible particles, by appealing to two phenomena which to him were of a physical, though undetected nature: magnetism and electricity. Moving beyond the sphere of interest of the chemists to 'a notion of good Use in divers [several] cases to a Naturalist [natural philosopher or scientist]' (187.2-3), whereby there may exist 'severall Sorts of Bodies, which are not Immediate Objects of any one of our senses' (187.4-6). Such bodies, although incapable of detection by the senses, give rise to phenomena which can be detected. Carneades quotes as examples 'not only those little Corpuscles that issue out of the Loadstone [magnetic iron oxide] and perform the Wonders for which it is justly admired' (187.7-10), by which he means the phenomenon of magnetism, but also 'the *Effluviums* of Amber[31], Jet[32], and other electrical Concretes' (187.10-12). These emanations 'though by their effects upon the particular Bodes dispos'd to receive their action, they seem to fall under the Cognizance [notice] of our Sight' (187.12-15). In other words their effects – magnetic and electrical forces – can readily be sensed, as Carneades puts it: 'yet do they not [they do not] as Electrical immediately Affect any of our senses, as do the bodies, whether minute or greater, than we See, Feel, Taste, &c.'(187.15-19). He concludes this line of thought by suggesting that his hearers may expect him, in

[31] A fossil resin, known since ancient times as capable of building up electrostatic charges on its surface by rubbing with, for example, a silk cloth.
[32] A hard, black semi-precious form of lignite, also capable of building up electrostatic charges on its surface by rubbing.

common with the 'Chymists [Paracelsians]' (187.20-21) to 'consider only the sensible Ingredients of Mixt Bodies' (187.21-22), and wishes now to 'see, what Experience will, even as to these, suggest to us' (187.22-24).

Carneades begins by asserting that it seems 'questionable enough, whether from Grapes variously order'd [arranged]' (187.25-26) there may not by thermal decomposition be obtained 'more distinct Substances' (187.27-28) 'then [than] from most other mixt Bodies' (187.28.-29). He goes on to detail the variety of products obtained from grapes. When they are 'dryed into Raysins and distill'd will (besides *Alcali* [here: a substance having a caustic or acrid taste], Phlegm [aqueous fraction], and Earth [here: a solid fraction]) yield a considerable quantity of an Empyreumatical[33] Oyle, and a Spirit of a very different nature from that of Wine'[34] (188.1-6). He states that the 'unfermented Juice of Grapes affords other distil'd Liquors then [than] Wine doth [does]' (188.6-8), by which he seems to be referring to the aqueous fraction and solid residue which would obviously occur in grape juice, but without any alcoholic fraction. He goes on to speak of the 'Juice of Grapes after fermentation' (188.8-9), and he seems to mean by this fermented wine must, which has not yet been converted wholly into wine, which will 'yield a *Spiritus Ardens* [burning spirit]' (188.9-10), an alcohol-rich liquor. This point is borne out by Carneades adding that if it is 'competently [appropriately] rectifyed [purified by distillation] will all burn away without leaving any thing remaining' (188.10-12).

[33] Tasting or smelling of burnt organic matter.
[34] What is probably meant here is a highly alcoholic liquor – in effect, a brandy-like product.

The next process listed is 'the same fermented Juice degenerating into Vinager, yields an acid and corroding Spirit [acetic acid]' (188.12-15). The next set of products listed are those produced when 'the same Juice tunned up [put into casks], armes itself with Tartar'[35] (188.15-16) 'out of which may be separated, as out of other Bodies, Phlegme [aqueous fraction], Spirit [volatile fraction], Oyle [a non-aqueous liquid fraction] Salt [a solid, soluble, non-inflammable fraction] and Earth [solid, insoluble residue]' (188.16-18). He continues, 'not to mention what Substances may be drawn from the Vine it self' (188.19-20), perhaps a reference to the *Aqua Vitis* or vine water, mentioned also on p. 412.

Remarking that they are 'probably differing from those which are separated from Tartar' (188.20-22), of which material he adds curiously 'which is a body by itself, that has few resemblers in the World' (188.22-23), perhaps a reference to the fact that tartar – a solid residue deposited during the preparation and storage of wine – is different in character from both grapes and wine, which of itself yields an array of products quite distinct from wine. His conclusion from the foregoing is that 'what force soever you will allow this instance' (188.24-25) to 'evince [vindicate]' (188.26) that materials when decomposed yield differing numbers of elements, he argues that it is difficult to deny that 'the Major part of Bodies that are divisible into Elements, yield more than three' (188.28-29 – 189.1). The evidence he offers for this is the array of products obtained when materials are decomposed, arguing that 'besides those which the Chymists [Paracelsians] are pleased to name Hypostatical [elementary], most bodies contain two others, Phlegme

[35] Tartar is a brownish-red substance, consisting mainly of potassium hydrogen tartrate, present in grape juice and deposited during the fermentation of wine.

[aqueous product] and Earth, which concurring [cooperating] as well as the rest to the constitution of Mixts' (189.1-6), and as these are usually present 'in their *Analysis* [the breaking down of substances into simpler constituents]' (189.7-8), it seems reasonable to consider them as elements.

Carneades now establishes a criterion by which he is willing to accept the elemental status of materials. He says that the '*Paracelsians* are wont [accustomed]' (189.11-12) to acknowledge the '*Tria prima* [salt, sulphur, and mercury]' (189.12) as 'the most useful Elements, and the Earth and Water but worthless and unactive' (189.12-14). By contrast, Carneades argues that the factor which should determine a material's fitness to be considered as elemental should lie in its 'Ingrediency, not of its use' (189.17-18), and that 'the pretended uselessness of Earth and Water' (189.20-21) stands only in 'Respect or Relation to us' (189.23), but that such considerations 'alters not the Intrinsick nature of the thing' (189.25-26).

He offers two analogies to illustrate his argument. The first is somewhat humorous, concerning as it does 'the hurtful Teeth of Vipers' (189.26), which are 'for ought [aught] I know useless to us' (189.27), yet truly are parts of their bodies. The second example is that of invisible stars which are revealed telescopically 'in many Blanched [whitened] places of the Sky' (186 [190].4), and it would be difficult 'to shew [show]' (189.29) how these are of any greater use to us 'then [than] Phlegm [aqueous product] and Earth' (186 [190].1-2), yet they form an important constituent part of the universe.

Carneades develops his argument by comparing the utility to us of individual components against that of the compound materials made from such components. If a compound material is of utility to us, then, Carneades argues, so too are the components from which it is produced, even though these individually may be of no immediate utility to us. Applying this insight, he states that even 'though the Earth and Water be not so conspicuously Operative [productive] (after separation) as the other three more active Principles' (186 [190].16-19). [36]

He gives two examples to illustrate his point. The first is 'the lucky Fable of *Menemius Aggrippa*, of the dangerous Sedition of the Hands and Legs, and other more busie parts of the Body, against the seemingly unactive stomack' (186 [190].20-24).[37] The second example given is 'that Reasoning of an Apostle' (186 [190].26), which is also applicable 'to another purpose; *If the Ear shall say, because I am not the Eye, I am not of the Body; Is it therefore not of the Body? If the whole Body were for hearing, where the smelling*' (186 [190].26-29 – 187 [191].1-3).[38]

He sums up this line of reasoning by saying that earth and water, even though they may be of no immediate use to us 'or rather to Physitians [natural philosophers or physicists]' (187 [191].8-9) but are so to the materials they constitute, making them 'in somewhat a remoter way' (187 [191].10-11) useful to us. Since these two materials 'appear, as

[36] Aristotle, in describing the formation of his four elements: earth, air, fire and water, describes hot and cold as active, and moist and dry as passive. See Aristotle's *Meteorology*, IV, 378^{b} 20-26.
[37] Menenius Agrippa was a consul of the early Roman Republic who, in 503 BCE, averted a rift between the plebs and the patricians by relating to the seceding plebs the 'Fable of the Belly and the Limbs'.
[38] This is taken from the Analogy of the Body given in the first letter of St Paul to the Church at Corinth, *i.e*. 1 Corinthians 12:16-17.

clearly and as generally as the other Principles upon the resolution of Bodies, to be the Ingredients whereof they are made up' (189 [191].4-7), if they were not considered as elements it would not be 'to imitate Nature' (187 [191].13).

Some three pages of text were omitted by the printer from the first edition of *The Sceptical Chymist*, and were placed at the end of the book between pages 438 to 441. They are relocated to their rightful place in the present work – whilst retaining the original pagination.

See also pp. 437-441.

Carneades then considers 'the great Argument which the Chymists are wont to employ to vilify Earth and Water' (438.14-16) which is that they are 'not endow'd with Specifick Properties, but only with Elementary qualities' (438.20-21) which disbars them from being considered among the 'Principles of Mixt Bodies' (438.19), and results in their being considered 'very sleightingly [of little importance], as of qualities contemptible and unactive' (438.22-24). He can see no reason for this, and goes on to speak of the importance of heat in chemical transformations. Carneades seems not to be alone in his opinion of the elemental status of heat, for he says that ''tis confess'd that Heat is an Elementary Quality' (438.26-27) and the vast number of things effected by heat is evident to those 'that duly consider the various *Phaenomena* wherein it intervenes as a principall Actor' (439.1-3), a fact to be acknowledged by more 'then [than] a Chymist' (439.4-5). The reason for this being that most chemical reactions 'are performed chiefly by means of Heat' (439.6-7).

Interestingly, he then adds that cold, 'upon whose account they so despise the Earth and Water' (439.8-9), 'they would not perhaps think is so despicable' (439.14-15), if they only read in the accounts of 'English and Dutch Navigators in *Nova* [Novaya] *Zembla* [Zemlya] and the other Northern Regions what stupendious things' (439.11-13) it can effect. He goes on to mention 'what I lately recited to You out of *Paracelsus* himself, who by the help of an intense Cold teaches to separate the Quintessence[39] of Wine' (439.16-19).[40]

Carneades discusses how a body's normal functioning is dependent upon a relatively warm environment, and that if subjected to unusual cold will be upset. He 'will now observe' (439.19-20) that 'the Conservation of the Texture [constitution or structure] of many Bodies both animate and inanimate do's so much depend upon the convenient motion both of their own Fluid and Looser Parts and of the ambient [moving round] Bodies, whether Air, Water, &c.' (439.20-26). He seems to mean that a body in itself must be capable of free movement, and that in addition the external environment must also be capable of allowing the body to function fully in it. He goes on to speak of how unusual cold acting on (especially, over-heated) human and other bodies 'do's very frequently discompose [unsettle] the *Oeconomie* [the way in which they are managed] of them, and occasion [give rise to] variety of Diseases' (440.1-3).

He next describes the effect of sudden cooling on the hardness of iron or steel – a process by which medium to high carbon steel when quenched (usually in water)

[39] A highly refined essence or extract.
[40] This account is given on pp. 95-96.

undergoes a microstructural change – causing it to become harder, and thereby much better able to retain an edge. He begins by remarking that one should not expect 'that suddain Cold should produce any notable change' (440.5-6) in the 'solid and durable Body of Iron' (440.3-4). Yet 'if you take a Wire, or other slender piece of steel, and having brought it in the fire to a white heat, You suffer [allow] it afterwards to cool leasurely in the Air, it will when it is cold be much of the same hardnesse it was of before' (440.7-13). Whereas, if instead of allowing the piece of steel to cool naturally 'you plunge it into cold water, it will upon the sudden Refrigeration' (440.14-16) become both much harder 'and manifestly [obviously] brittle' (440.18).

Just when his interlocutor might be tempted to believe that Carneades is about to attribute the hardening of steel to quenching in water alone he says, so that 'you may not impute this to any peculiar Quality in the Water, or other Liquor, or Unctuous [oily, greasy] matter, wherein such heated steel is wont [customarily] to be quenched that it may be temper'd'[41] (440.19-23). He goes on to describe how 'a very skilful Tradesman' (440.23-24) whom he knows and has seen at work, 'that divers [many] times hardens steel by suddenly cooling it in a Body that is neither a liquor, nor so much as moist' (440.24-27).

Carneades reverts to his discussion of the qualities of water by returning to the hardening of steel. He states that whatever quality it is that operates on the heated steel quenches in it 'whether upon the Account of its coldness and moisture' (441.1-2) or

[41] Tempering is a further heat treatment carried out on hardened steel by which it is reheated to a lower temperature and re-quenched, thereby reducing its hardness somewhat.

other qualities, it does seem ‘that water is not alwaies so inefficacious and contemptible a Body, as our Chymists would have it passe for’ (441.4-6).

In wishing to end this particular discussion he says that what he has ‘said of the Efficacy of Cold and Heat’ (441.7-8) might be extended through ‘other considerations and experiments’ (441.9-10), but as he has mentioned them ‘only upon the Bye [incidentally], I must not insist [dwell on] on it, but proceed to another Subject’ (441.11-13).

Here ends the three page insertion, now the text returns to its original pagination.

He goes on to adduce experimental evidence in favour of the existence of more than three elements in material bodies. Carneades begins by observing that although he believes ‘it Evident, that Earth and Phlegme [aqueous fraction] are to be reckon’d among the Elements of most Animal and Vegetable Bodies’ (187 [191].15-18), yet this is not the sole reason why he considers ‘divers [many] Bodies resoluble [resolvable]’ (187 [191].19-20) into more components ‘then [than] three’ (187 [191].21). He describes two experiments which he has carried out which ‘shew [show], that at least some Mixts are divisible into more Distinct Substances then [than] five’ (187 [191].23-25). In the first of these, although ‘’twill be more seasonable [opportune] for me to mention it fully anon [in a short while]’ (187 [191].26-27), he avers that ‘out of two Distill’d Liquors, which pass for Elements of the Bodies whence they are drawn’ (187 [191].29 – 192.1-2) he can ‘without Addition make a true Yellow and Inflamable

Sulphur, notwithstanding that the two Liquors remain afterwards Distinct' (192.2-6). What Carneades seems to be claiming here is that from each of two separate distillates, each one is classified as a distinct element precisely because they distil over as two separate (therefore individual) fractions. Yet he can exact a yellow sulphur-like product from these fractions, thereby demonstrating that they cannot actually be elemental in constitution.

The second experiment, which is not 'altogether unworthy your Notice' (192.7-8), he now describes. He prefaces his account by noting 'that by the Destillation of divers [several] Woods, both in Ordinary, and some unusuall sorts of Vessels, the Copious [abundant] Spirit that came over, had besides a strong tast, to be met with in the Empyreumaticall[42] Spirits of many other Bodies, an Acidity almost like that of Vinager' (192.10-17). He continues that 'Wherefore [as a result of which] I suspected that though the sowrish Liquor Distill'd, for Instance, from Box-Wood, be lookt upon by Chymists as barely [merely] the Spirit of it, and therefore, as one single Element or Principle' (192.17-22). That this is so is probably because the liquor came over as just one fraction of distillate, and was thereby adjudged to consist of one single element.

Carneades challenges this notion, saying that this liquor 'does really consist of two Differing Substances, and may be divisible into them' (192.22-24), and the two different substances he probably has in mind are the acidic vinegar-like liquor as well as the collection of organic compounds which have partially decomposed in the distillation process, and which consequently have a burnt odour – the 'Empyreumatical Spirits'

[42] Tasting or smelling of burnt organic matter.

(192.14-15) already referred to. The presence of this vinegar-like liquor, which is in fact dilute acetic acid, in ‘such Woods and other Mixts as abound’ (192.25-26) with it, ‘may be said to consist of one Element or Principle, more then [than] the Chymists as yet are Aware of’ (192.26-29).

Carneades ‘Wherefore [in consequence of which] bethinking [considering] my self, how the separation of these two Spirits might be made’(192.29 – 193.1-2), quickly discovered several ways of ‘Compassing [contriving] it’ (193.3-4). He then relates that ‘Having Destill’d a Quantity of Box-Wood *per se* [by itself], and slowly rectify’d [distilled] the sowrish Spirit, the better to free it both from Oyle and Phlegm [aqueous fraction]’ (193.6-9), he added to ‘this Rectify’d [distilled] Liquor a convenient quantity of Powder’d Coral[43], expecting that the Acid part of the Liquor would Corrode the Coral’ (193.10-13), that is, expecting that the acetic acid present in the distillate would attack it, and in so doing ‘would be so retain’d by it, that the other part of the Liquor, which was not of an acid Nature, nor fit [competent] to fasten upon the Corals’ (193.14-17), meaning not capable of reacting with them, ‘would be permitted to ascend alone’ (193.17-18), or distil over.

And this is exactly what Carneades found, ‘For having gently abstracted [extracted] the Liquor from the Coralls, there came over a Spirit of a Strong smell, and of a tast very piercing, but without any sourness’ (193.19-23). This liquid was probably the other destructive distillation product of wood, namely a mixture of methanol and acetone, which substances would have strong, distinctive tastes and smells, with methanol having

[43] Coral is a precious or semi-precious mineral, and consists mainly of calcium carbonate.

a sweeter taste than the next member of its homologous series – ethanol or alcohol, and acetone having a rather sharp, though not unpleasant, odour. This distillation product Carneades found 'in diverse qualities manifestly [obviously] different not only from a Spirit of Vinager [acetic acid], but from some Spirit of the same Wood, that I purposely kept by me without depriving it of its acid Ingredient' (198.23-28). This latter spirit was probably the initial distillation product obtained from the destructive distillation of box-wood, which would have consisted mainly of water, acetic acid, methanol, acetone and tarry compounds.

In order to 'satisfy you' (193.28-29) that these two compounds were quite different in nature, he 'might informe you of several Tryals that I made' (194.1-2), some of which he is shy about disclosing for fear of 'making some unseasonable [inappropriate] discoveries' (194.4-5), by which he means that in revealing all of the analytical techniques employed by him in examining this non-acidic liquor (what was in fact a methanol/acetone mixture) he may not yet wish to disclose what exactly he has found, until perhaps he has more conclusive evidence of his discovery.[44]

Carneades now relates how these two destructive distillation products of wood – acetic acid, and methanol/acetone – differ from one another. 'the sowre Spirit of Box' (194.6-7) *i.e*. acetic acid, would 'dissolve Corals' (194.8) which one would expect of an acid, but the 'other [methanol/acetone] would not fasten on' (194.9), or react with it, which is how an alcohol/ketone mixture would be expected to behave. The acetic acid 'being

[44] Boyle is credited with identifying methanol as one of the products of the destructive distillation of wood.

pour'd upon Salt of Tartar [potassium carbonate] would immediately boil and hiss, whereas the other [methanol/acetone] would lye quietly upon it' (194.9-12), again behaving in the expected way.

In his next test he found that 'the acid Spirit pour'd upon *Minium*[45] made a Sugar of Lead [lead acetate] which I did not find the other to do' (194.12-15), by which he means that when he added acetic acid to minium, the sweet, though toxic, lead acetate was formed, which reaction did not occur with the other solvent mixture. The 'penetrant spirit' (194.15-16) when mixed with the indicator 'blew [blue] Syrup of Violets seem'd rather to dilute then [than] otherwise alter the colour' (194.17-18), 'whereas the Acid Spirit turn'd the syrup of a reddish colour' (194.19-20), demonstrating that the liquor was indeed acidic, although the intensity of the colour was reduced, as the acid effect was 'hindered by the mixture of the other Spirit' (194.23-24).

A further colour change was noted by Carneades when the 'compound Spirit being Shaken into a pretty [considerable] quantity of the infusion of *Lignum Nephriticum*',[46] 'presently [immediately] destroyed all the blewish colour' (194.27-28). The same effect did not occur with 'the other Spirit' (194.28). He adds further validation to his explanation of the products of his experiment with the powdered coral and the distillate refined from the destructive distillation of box-wood. The acetic acid present in the distillate, as Carneades has recently explained, was removed from the solvent mixture

[45] A lead oxide, dilead(II)lead(IV) oxide, also called red lead.
[46] *Lignum Nephriticum* is a tropical wood known for its colour change, here used as an indicator.

by reaction with the powdered coral – which, of course, consists mainly of calcium carbonate – to form calcium acetate.

Carneades related that 'for trials sake' (195.1-5) he 'pour'd fair [pure] water upon the Corals that remained in the bottom of the glass' (195.2-3) in which he had 'rectifyed [distilled] the double spirit' (195.4) produced during the initial destructive distillation of the box-wood. As expected, he found that 'the Acid Spirit had really dissolved the Corals, and had coagulated with them' (195.7-9). What Carneades seems to mean is that the acetic acid present in the distillate reacted with the calcium carbonate present in the corals, to form a solution of calcium acetate. He then found that 'by the affusion [pouring on] of fair [pure] Water, I Obtain'd a Solution, which (to note that singularity upon the bye [incidentially]) was red' (195.9-12), which colour obviously comes from the original red coral used in the experiment. He evaporated this solution to dryness and found that 'there remained a soluble Substance much like the Ordinary Salt of Coral' (195.13-15), called a 'Magistery of Corals' (195.16)[47] by 'Chymists' (195.15), and prepared by them by dissolving coral in 'common Spirit of Vinager [acetic acid] and abstracting [removing] the *Menstruum ad Siccitatem* [evaporating the solvent to dryness]' (195.17-18). What Carneades seems to mean is that what he himself obtained was a solution of calcium acetate, which is exactly what is obtained by reacting acetic acid with coral, and by evaporating the mixture to dryness, when crystalline calcium acetate may be recovered.

[47] A magistery is composed of the original elements of a body with the impurities removed; hence it is a mixture of pure 'elements'.

He goes on to disclose that he believes that there is present in ‘the simple [pure] spirit of Box’ (195.21), by which he probably means the strong smelling spirit with a piercing taste, referred to in 193.21-23, and which he thinks is a hitherto unrecognised product. He is hesitant as to whether he should ‘subjoyne [add]’ (195.20) this information. He begins his consideration by stating that ‘this simple spirit’ (195.21) ‘will furnish [supply] us with a new kind of Saline bodies, differing from those hitherto taken notice of (195.23-26). He employs the word ‘Saline’ because he surmises that the ‘Chymists will have it therefore Saline because it has a strong tast’ (195.22-23). He elaborates on this by saying that ‘of the three sorts of Salts, the Acid, the Alcalizate [alkaline] and the Sulphureous [here: inflammable], there is none that seems to be friends with both the other two’ (195.26-29 – 196.1), as he may ‘E’re [before] it be long, have occasion [the opportunity] to shew [show]’ (196.1-2). His tests revealed that ‘the simple [pure] spirit of Box did not agree very well’ (196.3-4) ‘both with the Acid and the other Salts’ (196.5-6), in so far as he had ‘occasion’ (196.4) to test it. What Carneades seems to mean by this is that his methanol/acetone mixture did not react with any of the materials with which he tested it, which is just as one would expect of this particular solvent mixture.

Carneades is struck by the unreactivity or chemical inertness of the solvent mixture he has prepared, saying that it ‘would lye very quiet with salt of Tartar [potassium carbonate], Spirit of Urine [ammonia solution], or other bodies, whose Salts were either of an Alcalizate [alkaline] or fugitive [here: volatile] Nature’ (196.6-9), which is as one would expect as a methanol/acetone mixture would not react with substances such as ammonia or potassium carbonate. He continues that ‘yet did not the mingling of Oyle of Vitriol [sulphuric acid] [*i.e*. the mingling of Oyle of Vitriol did not] it self produce any hissing or Effervescence [bubbling up]’ (196.9-11), which he reminds us is ‘wont to ensue’ (196.12) following from the ‘Affusion [pouring on]’ (196.13) of sulphuric acid onto either of the ‘Bodies newly [just now] mentioned’ (196.14-15).

Eleutherius now speaks, expressing his gratitude to his interlocutor for the account of the experiment just related for two reasons: the first is because he believes it would aid him in the ‘Enquiry you are now upon’ (196.19-20), meaning, perhaps, it will be of service to him in his investigation of the claims made in relation to matter and its changes. His second reason is that it is helpful, not only to Carneades personally ‘but because it teaches us a Method, whereby we may prepare a numerous sort of new spirits’ (196.20-22), by which he means that Carneades is employing techniques, not only of distillation, a process well known even before Boyle’s time, but distillation coupled with a means for rendering inactive one of the products thereby obtained and redistilling in order to produce purer distillation products. Eleutherius goes on to say that these new spirits, ‘which though more then [than] any that are thought Elementary’ (196.22-24), thereby disproving existing elemental theories, ‘are manifestly [obviously] endow’d with peculiar [individual] and powerfull qualities’ (196.24-26), some of which products may be quite powerful in ‘Physick [medicine]’ (196.27), alone or in combination. The specific example quoted by Eleutherius is the red solution made by ‘your sour Spirit [acetic acid]’ (197.1) with corals.

Continuing with this theme Eleutherius surmises that instead of coral being employed to separate 'the Acid parts of these compound Spirits from the other' (197.5-7) by, in this case reacting with the acid, he suggests other materials be used instead: 'any Alcalizate [alkaline] Salt' (197.8-9), which would neutralise it, or 'of Pearls' (197.9), also made of calcium carbonate, or 'Crabs Eyes'[48] (197.9) or other material with which 'Spirit of Vinager' (197.11) [acetic acid] will react, 'and, to speak in an *Helmontian* Phrase, Exantlate [exhaust] it self' (197.11-13).

Taking control of the narrative again, Carneades says that he has not yet assessed of what use his new liquors 'may be in Physick [medicine], either as Medicines or as *Menstruums* [solvents]' (197.15-17), but still anxious to establish the nature of these materials, says that he reserves the possibility to mention 'divers [many] of the tryals' (197.18) made by him to confirm the 'difference of these two Liquors' (197.19-20). He says to Eleutherius that as 'I allow [acknowledge]' (197.21) what his interlocutor has related about corals, that he will in turn 'allow [sanction]' (197.23) Carneades, 'from what I have said already, to deduce this Corollary [result]' (197.23-24) 'that there are divers [several] compound bodies, which may be resolv'd into four such differing Substances, as may as well merit the name of Principles, as those to which the Chymists freely give it' (197.24-29).

Carneades resorts to a Paracelsian mode of identification and explanation of the behaviour of materials by arguing that 'since they scruple not to reckon that which I call

[48] Crab's eyes (or crab stones) consisting mainly of calcium carbonate, are formed in the stomach of crayfish and some other crustaceans, and were used, finely powdered, as an absorbent and antacid, the name being given later to a similar powder from any source.

the compound Spirit of Box, for the spirit, or as others would have it, the Mercury of the Wood' (197.29 – 198.1-4). He reasons that the two liquors identified by himself as present in the box-wood distillate (the one acidic and the other a methanol and acetone mixture) should not 'each of them' (198.5-6), especially the methanol/acetone mixture, 'be lookt upon as the more worthy to be called an Elementary Principle' (198.6-8). His reason for this being that this particular solvent mixture had been separated from another liquor, 'the Acid Spirit' (198.11), both of which combined to form what the Paracelsians would have called a Spirit or Mercury of Box-wood.

Carneades elaborates on his belief of the feebleness of the experimental means employed by the Paracelsians in establishing their *tria prima* or three principles by salt, sulphur and mercury, by arguing that his own experimental efforts in separating the distillate derived from box-wood into two fractions 'may give us a rise [present itself] to suspect' (198.14-15) that a liquid held by the 'Chymists [Paracelsians]' (198.16) to be indisputably homogeneous, 'is by so slight a way divisible into two distinct and more simple Ingredients' (198.17-18), and that 'some more skilful or happier Experimenter then [than] I' (198.19-20) may find a means 'further to divide one of these Spirits, or to resolve some or other, if not all' (198.20-22) of the other components of compound bodies, which have been held by the 'Chymists for their Elements or Principles' (198.24-25).