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Wilson, C. Anne Titre(s) : Distilling, sublimation, and the four elements : the aims and achievements of the earliest Greek chemists Recueil : Science and mathematics Pagination : 306-322 Résumé : Metalworkers skilled in distilling and sublimation were among the founders of the chemical art. Democritus' ideas on the nature of matter gave a theoretical explanation for how their extraction methods could reveal hidden aspects of the materials under treatment. Bolus of Mendes' doctrine of sympathies was a milestone in the evolution of the metal-tinting experiments, and he is likely the true author of the earliest chemical text, Φυσικά και μυστικά, whose supposed author was Democritus. Notice n° : 80-14406 Une notice est liée : Type de notice : monographie Titre(s) : Science and mathematics in ancient Greek culture / ed. by Christopher J. Tuplin and Tracey E. Rihll Publication : Oxford ; New York : Oxford University Pr., 2002 Description matérielle : XVI-379 p. ill. 2 index Compte(s)-rendu(s) : Phronesis 2003 48 (1) : 85-88 Keimpe A. Algra ; AJPh 2004 125 (1) : 140-144 Philip Thibodeau ; BMCRev 2004 (3) : non paginé William Wians ; CR 2004 N. S. 54 (1) : 82-84 George L. Huxley ; LEC 2004 72 (3) : 260-262 Michael Federspiel ; CW 2004-2005 98 (2) : 223-225 Mary Knight ; Eos 2002 89 (2) : 378-382 Joanna Komorowska ; Gymnasium 2005 112 (1) : 85-88 Markus Asper ; Nuncius 2004 19 (1) : 432-434 Fabio Acerbi Notice n° : 73-16572

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Distilling, Sublimation, and the Four Elements: The Aims and Achievements of the Earliest Greek Chemists

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A LARGE collection of chemical recipe texts has come down to us through the tenth-century manuscript Marcianus 299 and a number of later manuscripts now distributed through several European libraries.¹ The original texts date from the end of the first century BC to the Byzantine period. They are notable because they appear to describe actual chemical experiments and reactions carried out with the object of transforming the outward appearance of copper first to silver, then to gold. But the gold is not a realistic imitation designed to deceive the unwary, like the adulterated or imitation gold and silver of the recipes in the Egyptian goldsmiths' notebooks of the third century AD.² To determine what the experimenters were really trying to do, I shall first examine the theoretical background to the experiments; then I shall consider the role of distilling (the evaporating of liquids and collection of the recondensed vapour) and sublimation (the heating of minerals within a sealed vessel to release gases which can react with other substances placed in the vessel). Finally I shall suggest that metalworkers already skilled in those technologies were among the founders of the chemical art, and shall discuss the significance to them of Democritus.

I. The *Φυσικά καὶ μυστικά*: Physical Matters and Mystical Matters

Phusika kai Mustika (hereafter *PM*), the earliest chemical text, belongs to the late first century BC or early first century AD, but it is believed to have been recompiled from a text originally composed in Egypt about 200 BC or not much later.³ Its supposed author was Democritus, often named simply 'the philosopher', and still regarded as founder of the chemical art by

¹ M. Berthelot, *Collection des anciens alchimistes grecs* (Paris, 1887–8; repr. London, 1963). The 1963 edition contains separately paginated sections entitled 'Introduction', 'Textes', and 'Traduction', distributed across three volumes ('livraisons'). Hereafter cited by author's name.

² R. Halleux, *Les Alchimistes grecs*, i (Paris, 1981), 84–109 and 110–51 for texts.

³ Berthelot, text II.1, texte grec 41–53, traduction 43–57. Possible earlier version: Halleux (n. 2), 68; M. Wellmann, *Die Phusika des Bolos Demokritos* (Abhandlungen der preußischen Akademie der Wissenschaften, phil.-hist. Kl. 7; Berlin, 1928), 9 etc. The *terminus ante quem* is

Zosimus, who gathered a large number of existing chemical recipe texts into an encyclopaedia about AD 300.

But in the first century AD that art had become known to other groups, possibly because Anaxilaus of Thessaly had given a wider circulation to recipes hitherto kept secret. Recipe texts were produced which claimed other founders, including Hermes and Isis; and the chemical art also passed to the Sethian Gnostics,⁴ and to various Christian Gnostic sects. Basilides the Gnostic in the second century AD combined Zoroastrian and Christian teachings, and his followers first claimed Ostanēs as founder of the chemical art, backing up their claim with forged texts bearing Ostanēs' name.⁵

Our version of *PM* comprises recipes for the gold-tinting and silver-tinting of metals, originally followed by two more sections for artificial gemstones and purple-dyeing,⁶ but now simply preceded by a few purple-dyeing recipes. Most of the many later texts are devoted to metal treatments, but a few describe the production of *θειὸν ὕδωρ* (*theion hudōr*: sulphur water), often used in gold-tinting recipes. The latest of all are commentaries rather than instructions for practical metal-tinting.

In practice the experiments began with a thin tablet of copper or an amalgam of four base metals including copper (called the *τετρασώματα*: *tetrasōmata*). It was treated by contact with various earths, crystals, liquids, compound pastes, or volatile metals such as mercury or arsenic, applied by cooking, steeping, or simply prolonged juxtaposition. The base metal was silvered, and then tinted, often with sulphur-rich compounds, to change its appearance to gold. But realism was not the primary objective. The work was carried out, as explained in *PM* 15, as a 'healing and release from all pain for the soul' (τὸ τῆς ψυχῆς ἴαμα καὶ παντὸς μόχθου λύτρον). The chemical art thus emerges as one of the new mystery cults of the Hellenistic age.

In *PM* 3 Democritus, the supposed author, tells how through contact with a recently dead teacher and his living pupil (both unnamed: see below, p. 311) he learnt how to harmonize the natures, and how the entire *logos* could be summed up in three phrases: one nature delights in another nature, one nature conquers another nature, one nature overrules another nature.⁷ The gold-tinting and silver-tinting recipes follow, and after each recipe appears one of the three phrases, literally as 'the nature overrules the nature' etc., but usually translated as 'one nature overrules another nature' etc.

the use of the phrase 'one nature is conquered by another' in the astrological book *The Revelation of Nechepso and Petosiris* (E. Riess, *Nechepsonis et Petosiridis Fragmenta Magica* (Philologus, suppl. 6; Göttingen, 1891-3), p. 37, fr. 28 = Firm. Mat. Math. 4. 16), dated about the mid-2nd cent. BC by A. J. Festugière, *La Révélation d'Hermès Trismégiste* (Paris, 1944-54), i. 76-7, 232.

⁴ See Hippol. Ref. 5. 21 for the Sethians and their 'art of separation'.

⁵ C. A. Wilson, *Philosophers, Isis and Water of Life* (Proc. Leeds Phil. and Lit. Soc., Lit. and Hist. Section, 19.5; Leeds, 1984), 54-5 = 160-1. On Ostanēs see also below, p. 312.

⁶ Still present in the 4th cent. AD and referred to by Synesius: see Berthelot, text II. 3. 1.

⁷ ἡ φύσις τῇ φύσει τέρεται καὶ ἡ φύσις τὴν φύσιν νικᾷ καὶ ἡ φύσις τὴν φύσιν κρατεῖ.

So much for the mystical side. In chemical terms the silver and gold colorations were achieved, as Joseph Needham explained, 'by altering the composition of the surface layers (of the base metal), or by depositing microscopically-thin films'.⁸ Recipes in *PM* indicate by their result that sublimation methods were utilized in some cases to silver-coat copper with arsenic. Elemental arsenic, called 'mercury from orpiment or realgar' (20-1), could not have been obtained from those two sulphides by any other means, and *PM* 21 refers to the addition of vegetable oil, a necessary ingredient in the final sublimation process.⁹ Distillation is not described in *PM*, though sulphur water is named as an ingredient (10); and a recipe for producing it is in a later text.¹⁰ Both techniques are mentioned in *PM* 29, where the author refers the reader to his other writings, now lost, for accounts of sublimation (ἄρσις τῆς νεφέλης) and distilling (ἄρσις τοῦ ὕδατος).

But what were the real aims of the experimenters, and what was the theoretical basis for their practical chemistry? Their chemical art was established in Egypt before the mid-second century BC when the phrase about one nature conquering another nature was reused in the astrological treatise on *The Revelation of Nechepso and Petosiris* (cf. n. 3 above). Bolus of Mendes was involved somehow in its earliest phase; and Columella later claimed that Bolus wrote a book called *Cheirokmeta* 'under the false name of Democritus'. Bolus also wrote a book on sympathies and antipathies; and some modern scholars have believed him to be the true author of *PM*.¹¹ The Bolus question is too complicated to go into here, but the enigma is apparent from entries in the *Suda*, where he appears twice, first as Bolus Democritus and then as the Pythagorean, Bolus of Mendes.¹²

Pythagorean ideas certainly emerge in *PM*. In 15 the νεοί (newcomers) are attacked for their failure to appreciate the significance of the chemical changes because 'they do not understand the natures, how one form overturns ten'. The 'ten' must refer to the Pythagorean tetraktys, the fundamental formula of $1 + 2 + 3 + 4 = 10$, brought by Pythagoras himself to his followers, and honoured thereafter in their most sacred oath. The other system of ideas linked unquestionably with Pythagoras is metempsychosis or the transmigration of souls.

Theon of Smyrna listed eleven tetraktyes, beginning with that of the Pythagorean oath. The second is that of odd and even numbers, and the

⁸ *Science and Civilization in China*, v/2 (Cambridge, 1974), 253.

⁹ Realgar sublimed with sulphur yields orpiment. This, or mineral orpiment, must be fused with natron (soda) or mercury to yield arsenious oxide; and the oxide must then be combined with vegetable gum and resublimed to yield elemental arsenic. By a further sublimation the arsenic can be applied as a silver coating to copper. See R. P. Multhauf, *The Origins of Chemistry* (London, 1966), 107-8.

¹⁰ Berthelot, text III. 8. 1-3.

¹¹ Colum. 7. 5. 11. Bolus as author of *PM*: Halleux (n. 2), 62-74; Wellmann (n. 3), 1-69.

¹² See P. Kingsley, 'From Pythagoras to the *Turba Philosophorum*: Egypt and Pythagorean Tradition', *JWCI* 57 (1994), 1-13 at 5-9, for recent discussion of Bolus as a Pythagorean.

third that of the progression from point to solid body. The fourth, that of the elements (1 = fire; 2 = air; 3 = water; 4 = earth), is the earliest one to be linked to physical matter.¹³ The tetraktys introduced by Pythagoras to his followers in Italy was, however, too early for the concept of the four elements; and I would suggest that it derived its power originally from the belief that it represented the four realms.

The sources and limits of the four realms were already defined as heaven, earth, sea, and misty Tartarus in Hesiod's *Theogony* (807–10); and Homer's gods themselves swore solemn oaths by three of the four realms (heaven, earth, and the waters of the River Styx), giving a divine precedent for the underlying idea in the tetraktys oath.¹⁴ For Pythagoreans the 1 would have been the number of the heavenly realm filled with light and fire, which was also a place of stillness where the soul could find rest after having been buffeted through its lives in the other three realms of air (symbolized by 2), water (symbolized by 3), and earth (symbolized by 4).¹⁵ A very old concept, going back to Mycenaean times, made the 1 and the 3 male numbers, and the 2 and the 4 female ones.¹⁶

The Pythagoreans believed that their souls, having fulfilled their spans in the bodies of plants, animals, children, and women, were finally reborn into men who would become Pythagoreans, live ascetic lives, and carry out the required rituals, so ensuring that, after the body's death, they (the souls) would pass to their rest in the heavenly light and their release from all pain. The tetraktys was laid out on the ground as a triangular pebble figure, with one pebble at the apex and four at the base.¹⁷ In this form it may have had a role in initiation ceremonies, since it has the interesting characteristic that the relationship between the 1 and the 4 depends on the position of the

¹³ Theon Smyrn. *Math.* 97–8. Cf. Diog. Laert. 8. 25; Sext. Emp. *Adv. Math.* 10. 283. Arist. *Metaph. A* 5. 3, 986^a9–10, refers to the decad of the Pythagoreans, but not to the tetraktys, which may have been in his lost work about them.

¹⁴ *Il.* 15. 36–8; *Od.* 5. 185–7.

¹⁵ For fire rushing upwards and spreading through *aithēr* to form heavenly bodies, see P. Kingsley, *Ancient Philosophy, Mystery and Magic* (Oxford, 1995), 49–53, and cf. the Pythagorean *akousma*: 'What are the Islands of the Blest? Sun and Moon' (Iamb. *VP* 82). *Aēr* was already the 'lower air' in *Il.* 14. 288, though its other meaning, 'mist', survived through the 5th cent.: see C. H. Kahn, *Anaximander and the Origins of Greek Cosmology* (New York, 1966), 146–52. The verbal link with Hesiod's 'misty Tartarus' could have helped the shift from that realm to the airy realm to fit the Pythagoreans' beliefs: cf. also Emp. 31 B 6 DK and the ancient interpretation of Aidoneus as 'air'. P. Kingsley, 'Empedocles and his Interpreters: The Four-Element Doxography', *Phronesis*, 39 (1994), 239–47, argued convincingly for this interpretation as Theophrastean, probably going back to Xenophanes and to Pythagoreans of the late 5th cent..

¹⁶ J. Chadwick, *The Decipherment of Linear B*, 2nd edn. (Cambridge, 1967), 45: a male horse or pig is depicted as an animal head above a single stroke, and a mare or sow a head above either two strokes or one stroke with two crossbars. Aristotle's table of the Pythagorean pairs of opposites (*Metaph. A* 5. 6, 986^a22–7) assigns male to the same column as odd (of number), light, etc., and female to the other column, with even, darkness, etc.

¹⁷ W. Burkert, *Lore and Science in Ancient Pythagoreanism*, trans. E. L. Minar (Cambridge, Mass., 1972), 72.

viewer: the pebble at either end of the line of four representing earth could become the apex if seen from one of the other two sides. The tetraktys could thus have symbolized a bridge from earth to the fiery heaven.

After Empedocles had defined the elements as four, moving together and apart through love and strife,¹⁸ a second line was added to the Pythagorean oath which described the tetraktys as 'holding the fountain and roots of ever-flowing nature'.¹⁹ It links the tetraktys with the four 'roots', Empedocles' term for the elements, thus suggesting that the Pythagoreans soon identified each of the four with the number of the corresponding realm—not difficult, since the names of the three lower realms were the same as those of three of the elements, and fire could parallel the fiery heavenly realm. The identification would have taken place well before Plato developed, or adapted Pythagorean ideas for, the chemistry of the *Timaeus*.²⁰

In *PM* 15 the phrase 'one nature overturns ten' (ἐν εἶδος δέκα ἀνατρέπει) is a covert reference to the four elements contained in the tetraktys. But the chemistry of the recipes does not derive directly from that source, but from Plato's reworking of it in the *Timaeus*. There he assigns three-dimensional shapes to the basic particles of the elements: the four-sided pyramid to fire; the eight-sided octahedron to air; the twenty-sided icosahedron to water; and the six-sided cube to earth.²¹ In the particles of fire, of air, and of water the surfaces were made up in each case from triangles identical in shape, i.e. the halves of an equilateral triangle. The cube, the most stable of the solids, was assigned to earth, but the surfaces of the cube were formed from isosceles triangles, incompatible with the triangles of the other three elements (*Ti.* 53 A–56 C). Plato argued that the upper three elements could break up and change into one another because of their identical triangles, but the particles of earth, although they could be united temporarily with the others, would eventually dissolve out of their compounds and become earth again.

The changes of the elements begin, in *Ti.* 56 D–E, with the upward cycle, with one particle of water broken up to form two of air plus one of fire, and one particle of air forming two of fire. The downward cycle begins when a small quantity of fire is enclosed by a large quantity of air and water and

¹⁸ Act. 1. 3. 20; Arist. *Metaph.* A 4. 8, 985^a31–3; Simpl. *In Phys.* 158. 15–20 = KRS 346–7, 349.

¹⁹ οὐ μὰ τὸν ἀμετέρα γενεῇ παραδόντα τετρακτύν | παγὰν ἀενάου φύσεως ῥίζωμά τ' ἔχουσιν. Burkert (n. 17), 186, recognized that the second line could not have predated Empedocles. But Empedocles himself hinted at the link between the 'exchange' of the element and the tetraktys oath thus: 'the time of exchange . . . has been defined by a broad oath' (Arist. *Metaph.* B 4. 19, 1000^b9–16).

²⁰ For Pythagoreans' readiness to extend application of their number theory see Arist. *Metaph.* N 6. 10, 1093^b14–16.

²¹ See Iambl. *Th. ar.* 82 for Speusippus' view that the five shapes given by Plato to the elemental particles were Pythagorean. The fifth was the dodecahedron assigned at *Ti.* 55 C to τὸ πᾶν (the All). τὸ πᾶν appears in the protochemical texts in the phrase ἐν τὸ πᾶν: 'all is one'.

is conquered (*νικηθέν*), so that two particles of fire unite to make one of air. And when air is overruled (*κρατηθέν*), then two and half particles of air form one of water. The author of *PM* took these two verbs, *νικᾶν* and *κρατεῖν*, and applied them to the changes of the upper elements: 'the nature conquers the nature', 'the nature overrules the nature'. The 'ever-flowing nature' of the revised tetraktys oath could have inspired the adoption of the word 'nature' into the three significant phrases, one of which concludes each recipe in *PM*.

Plato's *Timaeus* (59 B) accounts for the choice of copper or the amalgam of four base metals including copper (four was the tetraktys number for earth) as the starting-point for the protochemical experiments. Copper is there described as having particles resembling those of gold but containing also small and fine portions of earth, so it is partially earth. But it is also a metal, and metals are defined by Plato (*Ti.* 58 D) as 'fusible water'; so copper represented earth already on its way to becoming water. Transformed to silver by mercury or arsenic, it represented water on its way to becoming air because both those metals were obtained from their sulphides by a vaporization process which seemed to demonstrate the gaseous or airy nature concealed within them. Gold coloration of the silvered metal was achieved by combination of ingredients, among which were sulphur, sulphur water, and various yellow earths and plant dyes. At this stage it could have represented air on its way to becoming fire, because it carried the gold colour of fire or light. The final stage was brought about either by further cooking with appropriate ingredients or by a lapse of time sufficient to prove that the colour was truly fixed. At that point the metal became *ἰός* (*ios*), or achieved *ἰώσις* (*iōsis*). *ἰός* was an archaic word meaning 'one' in use among Pythagoreans,²² so could have signified the tetraktys number for fire. But it may also have carried the idea of 'fiery verdigris', the counterpart to the 'earthy' *ἰός* (true verdigris) which Plato said would eventually separate out from copper. A few texts, including *PM*, contain recipes where *ἰός* appears to be the stage in which treated metal becomes reactive, i.e. can be used to tint gold another untreated tablet of copper.²³

In Hellenistic times Pythagoreans regarded Plato as the transmitter of true Pythagorean lore²⁴—hence the adoption of the theory of matter in the *Timaeus* to underpin chemical experiments aimed at changing the elemental nature of metals. The unnamed teacher in *PM* 3, said there to be guided by his daemon and to have died after taking a drug to separate his soul from his body, is Socrates; and his unnamed pupil is Plato.

²² Recorded as Pythagorean in the feminine form *ἴα* by Lyd. *Mens.* 4. 1. Some prefer to derive *ἰώσις* from *ἰός* = rust, e.g. J. Dillon, 'Greek Alchemy', *CR*, NS 36 (1986), 35–8 at 37.

²³ *PM* 5, 11, 13. Only one recipe (3) names the final stage as *ἰός*. For later examples of a reactive product see e.g. Berthelot, texts III. 8. 3, 11. 4, 16. 6.

²⁴ See Burkert (n. 17), 28–96, esp. 83–96, for a full survey of the evidence; and id., 'Hellenistica Pseudopythagorica', *Philologus*, 105 (1961), 16–43 and 226–46 at 236, for 3rd-cent. and later pseudo-Pythagorean literature identified as stemming from 'underground Platonism'.

Democritus' quest for knowledge in *PM* 3 takes him to the temple; and in this section Herman Diels inserted the name of Ostanēs as an emendation of the Greek οὐτ' ἄν τις ('no one'), an emendation which has been accepted by some modern editors.²⁵ A closer examination of the role of Ostanēs in the history of the chemical texts shows why it should be discarded. The *Περὶ συμπαθειῶν καὶ ἀντιπαθειῶν*, the book on sympathies and antipathies, variously ascribed to Democritus (by Columella and Tatian), Bolus the Democritean (by Stephanus of Byzantium and the scholiast on Nicander's *Theriaca*), and the Pythagorean Bolus of Mendes (by the *Suda*), was about the sympathies between various plants, animals, and stones;²⁶ and it drew on lore from the pseudo-Zoroastrian texts in the library at Alexandria. When Pliny referred to Democritus and Pythagoras as eager followers of the Magi, he supplied in each case details of strange properties of certain plants taken from the *Περὶ συμπαθειῶν*.²⁷ Even when Tatian wrote in c.AD 150 that Democritus 'having boasted of the Magus Ostanēs will be delivered on the day of consummation as fuel for the eternal fire' (*Ad Graec.* 17), he was abusing the supposed author of the *Περὶ συμπαθειῶν*, upon which he delivered a sharp attack. The link between Ostanēs and the Democritus of the chemical texts came later, after the followers of Basilides the Gnostic forged chemical texts under the name of Ostanēs;²⁸ and by the fourth century Synesius could claim that Ostanēs initiated Democritus into the chemical art.²⁹

With Plato's *Timaeus* underpinning *PM* we can appreciate why Bolus was called a Pythagorean. Democritus' link with the chemical art is less obvious, but his role may become clearer when we have examined the two technologies named at the end of *PM*, sublimation and distilling.

2. Distillation and Sublimation

Distilling is almost certainly the older of the two. It was the means whereby *θεῖον ὕδωρ*, the divine sulphur water, and other 'waters' were produced for use in the metal treatments. The distillates were always called 'waters', a usage which survives to this day: rose-water, eau de Cologne, Kirschwasser. Certain protochemical treatises include not only descriptions but also drawings of the stills themselves. In the tenth-century MS Marcianus 299 earlier

²⁵ 68 B 300. 18 DK (ii. 219 n.).

²⁶ Colum. 11. 3. 64; Tat. *Ad Graec.* 17; Steph. Byz. s.v. Ἀφύνθειον; sch. Nic. 764. *Suda* B 482 reads 'sympathies and antipathies of stones', but Halleux (n. 2), 64, believed the title originally included 'animals' and 'plants'. Ancient authors who drew on this work wrote of peculiarities of animals and plants, mainly plants.

²⁷ *HN* 24. 156, 160; 25. 13–14; 26. 19.

²⁸ Isidore was the son of Basilides, and part of a forged text may survive in Berthelot, text IV. 2, which is addressed by 'Ostanēs the philosopher to Petasios' (the Egyptian form of Isidore): see M. Berthelot, *Origines d'alchimie* (Paris, 1885), 158.

²⁹ Berthelot, text II. 4. 1.

drawings referred to in the text have been copied on the versos of the relevant pages. The stills of the first century AD, the *δίβικος* (*dibikos*) in the drawing entitled 'The Goldmaking of Cleopatra', and the *τρίβικος* (*tribikos*) invented, supposedly, by Maria the Jewess, have almost globular stillheads with two or three outlet tubes. The *βίκος* (*bikos*) was the receiving vessel, hence the names *δίβικος* and *τρίβικος*. The stillheads were called either *φιάλη* or 'the bronze' or sometimes just *βίκος*.³⁰ *φιάλη* (*phialē* = cup) suggests that these sophisticated stills had simpler predecessors with cup-shaped stillheads.

Closer to the cup shape was the *μαστάριον* (*mastarion*) or breast-shaped stillhead, employed in prolonged and repeated distillations of eggs to produce sulphur water. The *μαστάριον* had a single outlet tube and was made of glass after the invention of glass-blowing; but bronze would have been the material of any predecessor, as it often was of the later *τρίβικος* stillhead.³¹

In use each stillhead was sealed firmly to a wide cylindrical tube, which in turn was sealed to the base vessel, while the outlet tubes were sealed to the receiving vessels. Usually the base vessel stood over a furnace, but for the eggs distilled with the *μαστάριον* the sealed apparatus was warmed via a very low heat source such as a dung-heap or a pastry-cook's oven. Another type of still was the *σωλήν* (*sōlēn*), the tube-still, shaped like an inverted L and joined at the lower end to its base vessel and at the upper to its receiver. Here the vapour was cooled and recondensed not in a stillhead but within the long tube; and the upper part of the tube was itself cooled with cold water and a sponge.³² The terms used in the texts to indicate distilling were 'to boil' (*εἵπειν*) or 'to raise the water' (*ὑδωρ αἵρειν*).

Applications of the distilling technique were few outside the enclosed world of the chemical art. Although Aristotle (*Mete.* 2. 3, 358^b 16–18) knew 'by experience' that drinkable water could be evaporated from sea water, the practical usage probably came later. Sailors on long voyages, reported Alexander of Aphrodisias, made fires on deck and heated cauldrons of sea water with covers over them; the steam condensing on the covers turned into drinkable water. Another application, described by Dioscorides, was the boiling of pitch-pine wood with a clean fleece stretched above to catch the vapour; afterwards liquid pitch oil was wrung from the fleece.³³

Wine was distilled, but wine-distilling was practised in secret as a cultic activity in both Gnostic Christian and pre-Christian contexts, which explains why it has not been more widely recognized. The method appears

³⁰ *φιάλη* in 'The Goldmaking of Cleopatra' (Berthelot, Introduction 132, fig. 11); 'the bronze' (id., texts III. 47. 2, 50. 1); *βῆκος* = *βίκος* (id., Introduction 138, fig. 14).

³¹ Berthelot, texts III. 8. 1–2; for use of the *μαστάριον* to produce a different *θεῖον ὑδωρ* cf. text II. 3. 6. Invention of glass-blowing in the 1st cent. BC: D. B. Harden, 'Ancient Glass', *Archaeological Journal*, 126 (1969), 46–8.

³² Berthelot, Introduction 140, fig. 16; texts III. 47. 2, 50. 2.

³³ Alex. In *Mete.* 136 Smet; Dsc. 1. 72. 3.

in a Greek recipe of about AD 200 in Hippolytus, *Ref.* 4. 31. It is one of several for creating magic lights described there as 'tricks of the Gnostics and Magi'—at that date the followers of Basilides had already implicated Ostanēs in the chemical art³⁴—and Diels first identified it as instructions for wine-distilling.³⁵ The wine, with added sea salt, was 'boiled', i.e. distilled, in an earthenware jar. Thereafter the distillate was reheated and set alight with a lamp, and then 'if poured on the head it does not burn it at all'. This implies that the operation had concentrated the alcohol in the wine to a strength at or near 35 per cent, something which could only have been achieved via a distilling technique. The recipe in Hippolytus continues by recommending the addition of manna, a scented resinous sap, and ends with the words: 'it does better still if you put to it some sulphur'.

The distillate, or 'water', was applied to the head, and we know from Tertullian and other Christian writers that the Gnostic heretics baptized initiates on the head.³⁶ Tertullian also claimed that it was possible for the Gnostics 'by human ingenuity to summon a spirit into the water and animate their incorporated nature through hands held above with another spirit of such brightness [*tantae claritatis*]'.³⁷ He finished this curious statement with a reference to God being able to modulate upon the water-organ the music of spiritual sublimity, and there may be an implicit contrast between the fire-organ (*ὄργανον* was the word for a still in the protochemical texts) and the water-organ, used as a metaphor for the contrast between fire- and water-baptism.

The followers of Marcus the Gnostic were said by Saint Irenaeus to baptize initiates upon the head with oil and 'water', or sometimes with balsam and water, and here again 'water' may have meant distillate. The balsam corresponds to the scented manna of the recipe in Hippolytus' *Refutationes*, and could have symbolized the fragrance of the Holy Spirit. Elsewhere Irenaeus claimed that Marcus combined the tricks of Anaxilaus with the skulduggery of the Magi.³⁸

Anaxilaus of Thessaly was named in an earlier context by pseudo-Cyprian, when writing about the followers of Simon Magus, who had in-

³⁴ See above, p. 307; also nn. 5 and 28.

³⁵ *Die Entdeckung des Alkohols* (Abhandlungen der preußischen Akademie der Wissenschaften, phil.-hist. Klasse, 3; Berlin, 1913), 21–5, 35. The stillhead is not mentioned in the recipe in Hippolytus, which could indicate that his source was a secret recipe of practical use only to somebody already possessing the necessary technical knowledge and expertise.

³⁶ Tert. *De praescr. her.* 40; Iren. *Adv. haer.* 1. 21. 4.

³⁷ Tert. *De bapt.* 8: 'Sane humano ingenio licebit spiritum in aquam arcessere et concorporationem eorum accommodatis desuper manibus alio spiritu tantae claritatis animare, Deo autem in suo organo non licebit per manus sanctas sublimitatem modulari spiritalem?'

³⁸ *Adv. haer.* 1. 21. 5 (oil and water); 1. 21. 3 (balsam and water); 1. 13. 1 (Anaxilaus). Hipp. *Ref.* 5. 21 records an Art of Separation practised by the Sethians whereby they could 'separate out' the gold in bronze, 'and already someone separates the water mixed with wine'. He thus indicates that in his day the non-Christian Gnostic Sethians knew how to distil wine.

stituted a cultic baptism in which, as soon as the initiand stepped into the water (as for baptism by immersion), 'fire appears straight away upon the water'. The last-mentioned water could have been the distillate of wine, for the text continues: 'whether this is done by some trick which, as many of them affirm, is a trick of Anaxilaus . . . or whether it is the work of a malign being and the magic *virus* that can express fire from the water'.³⁹

The most striking examples of Gnostic baptism are those in *The Books of Jeu*, the English title for a Coptic manuscript brought to Britain from Egypt in the eighteenth century: Schmidt's edition was republished with a new English translation in 1978.⁴⁰ Here three baptisms are recorded in due order: that of the Water of Life, of Fire, and of the Holy Spirit. They show the concept of the upper three elements still attached to wine-distilling rituals, but the order now Christianized and changed from (a) water, air or πνεῦμα (*pneuma*), and fire at the apex to (b) water, fire, and πνεῦμα in the ultimate position as Ἁγιον Πνεῦμα (*Hagion Pneuma*), the Holy Spirit. For each baptism the disciples bring fire and the vine-wood, and the Gnostic Jesus-figure places one wine pitcher on the right and one on the left, with incense offerings above. He recites long prayers including many magic words, and calls on Zorokothora to bring forth the water of the baptism of life in one of the pitchers. 'And at that moment,' says the text, 'the wine which was on the right of the offering became water.'⁴¹

The critical piece of apparatus is the vine-wood,⁴² known later in the West as *vitis*. It was a long undulating cooling tube through which the distillate passed, and it gave its name to *aqua vitis*, an alternative term for *aqua vitae*.⁴³ For the disciples in *The Books of Jeu* (116, § 48) the three baptisms guaranteed immortality. Later Gnostic sects also used fire rituals: the Messalians, for example, had a rite at which, according to Saint Augustine, 'there enters into the initiate in visible form a fire which does not consume'.⁴⁴

Strong alcohol is highly inflammable, so how was it made safe? The clues lie in a short statement which concludes a few of the earliest medieval Latin recipes for wine-distilling:

³⁹ [Cypr.] *De rebapt.* 16. *Virus* (poison) is one of the meanings of the Greek *lóς*, the term which in the protochemical texts meant that the metal had achieved the stage of fixed gold, representing fire.

⁴⁰ *The Books of Jeu*, ed. C. Schmidt, trans. V. McDermot (Nag Hammadi Studies, 13; Leiden, 1978).

⁴¹ *Ibid.* 108, § 45.

⁴² *Ibid.* 106 n. 3 for Coptic *peloole* meaning literally 'vine-wood', though translated in the text as 'vine branches'.

⁴³ M. Savonarola, *Libellus . . . de Aqua Ardenti*, in Joannes de Rupescissa [=Joan de Peratallada, 14th cent.], *De Consideratione Quintae Essentiae* (ed. Basel, 1561), 250-1, 253. The 'serpentine tube' replaced *vitis* as the usual term for the cooling tube; hence the 'worm' and 'wormtub' of the English distillers.

⁴⁴ August. *Haer.* 57. Psell. *De op. daemon.* 7 reported on the authority of 'a Thracian' that the Euchites, the later Messalians under their Greek name, were still engaged in producing visible manifestations of δαίμονες with bodies 'either of air or of fire, or a mixture of those two elements'.

Hanc aquam si experiri volueris, sulphuris tres p. igitur in ea extinguas.⁴⁵

If you wish to test this 'water', you should extinguish three parts of sulphur in it.

Hermann Degering arranged for alcoholic spirits to be tested thus, and published the results in 1917. Lighted sulphur plunged into spirits of wine continued to burn until the alcohol content reached 35 per cent, when it was extinguished. If the liquid at a strength of 35 per cent alcohol was then ignited upon cloth or hair, it burnt away safely and completely leaving no mark.⁴⁶ This discovery may first have been made by people who plunged lighted sulphur into distillate of wine with a view to increasing its fire content. Accidental spillage of the liquid on hair or clothing in the vicinity of a naked flame would have revealed the safe-burning fire. An oblique reference to the sulphur test may be concealed in the final words of the wine-distilling recipe in Hippolytus' *Refutationes* (cf. p. 314 above): 'it does better still if you put to it some sulphur'. But the test could go back to a much earlier period.

Evidence for pre-Hellenistic wine-distilling is tenuous, but hints at its practice in the Dionysus cult. It could have originated when someone heated wine in a vessel with a bronze cup over its mouth in an attempt to capture the fiery principle which escaped when wine was boiled in an open pot. If the operation was carried out slowly and carefully, very small amounts of alcohol-rich spirits would have condensed on the inside of the cup and run to the bottom if it was quickly turned upright again. By using a series of cups it would have been possible to collect more of the distillate. Later, perhaps much later, came the evolution of the stillhead equipped with a spout to carry off the distillate.

There are hints to suggest that real-life maenads once carried bronze cups. Nonnus says that Mystis, when teaching Dionysus the usage of the mystic objects, 'first thought of fitting bronze *φιάλαι* over her breasts' (*Dionysiaca* 9. 125-6)—a practice of which there is no record elsewhere in art or literature. Perhaps his source actually reported that real-life maenads carried (*φέρειν* = 'carry' or 'wear') bronze *φιάλαι*, adding that the *φιάλη* was a type of *μαστάριον*, and Nonnus, knowing nothing of stillheads, took *μαστάριον* to mean a breast covering.⁴⁷ Much earlier Euphorion and Callimachus told how the titans put the dismembered limbs of Dionysus in a cauldron (*λέβης*) and gave it to his brother Apollo. Euphorion added:

⁴⁵ H. Degering, 'Ein Alkoholrezepte aus dem 8. Jahrhundert', *Sitzungsberichte der preussischen Akademie der Wissenschaften*, phil.-hist. Klasse (1917), 506 (Weissenau recipe); I. Puccinotti, *Storia della medicina* (Livorno 1850-66), ii, doc. 6, p. lxiv, from which the version quoted here is taken.

⁴⁶ Degering (n. 45), 513.

⁴⁷ In Nonnus' day Gnostics had been banished beyond the imperial frontiers and pagan cults had almost ceased to exist. See C. A. Wilson, 'Dionysian Ritual Objects in Euphorion and Nonnus', *PLLS* 7 (1993), 216-17.

ἐν πυρὶ βάκχαν διὸν ὑπὲρ φιάλῃν ἐβάλοντο.

On the fire godly Bacchus over a φιάλη they threw.⁴⁸

This makes little sense, but it is susceptible to a different interpretation if ὑπὲρ ('over') is read as *following* the noun it governs. The literal translation then becomes '... godly Bacchus over they threw a φιάλη'.⁴⁹ If Bacchus' limbs in the cauldron represent wine, we may have here another reference to a distilling ritual. There was a tomb of Dionysus at Delphi,⁵⁰ and a possible scenario would be the distilling of wine in the spring when Dionysus departed on Apollo's return, the storing of the distillate in the tomb, and the flaming of the alcohol at the beginning of winter as an epiphany to mark the reawakening of trieteric Dionysus.

Various earlier authors referred to 'boiling' in connection with rebirth. Demos in Aristophanes' *Knights* (1321) is boiled to make him young. Plato, *Euthydemus* 285 c, used the simile of being destroyed and even boiled, as though being boiled by Medea, so as to be reborn as a good man with true knowledge. Most strikingly, the hypothesis to Euripides' *Medea* records that in Aeschylus' lost play *The Nurses* (fr. 246a Radt) Medea boiled the nurses of Dionysus, i.e. the maenads, and made them young again. A. B. Cook and F. M. Cornford both saw this as an allusion to a Dionysiac 'rite of regeneration or resurrection'.⁵¹ It may, in fact, hint at rituals of real-life maenads in Macedonia and Thrace, where 'boiling', i.e. wine-distilling, took place. Athenian soldiers on the Eion campaign in 476/5 could have brought back rumours about local initiation rituals which involved 'boiling'.⁵²

Euripides wrote the *Bacchae* in Macedonia, and at lines 755–8 the maenads carry unnamed objects of bronze and iron balanced on their shoulders, while fire burns harmlessly upon their hair.⁵³ They are not in a ritual situation, for they have rushed down the mountainside in fury after being spied upon by local herdsmen. My view is that the models for Euripides'

⁴⁸ Callim. fr. 643, Euphor. fr. 13. The translation of this line has caused difficulties. Lobeck, Meinecke, Scheidweiler, and Powell emended φιάλῃν to φιάλης, which yields the reading 'On the fire they threw godly Bacchus over a φιάλη.' It makes little sense; a φιάλη (drinking-cup) is not put onto a fire, and the god's limbs had already been thrown into a cauldron (λέβης), a vessel which is suitable for setting on the fire.

⁴⁹ Some words are corrupt in some texts, but ὑπὲρ φιάλῃν is present in all manuscripts: Wilson (n. 47), 217.

⁵⁰ Philoch. 328 F 7 and [Clem.] *Recog.* 10. 24 report tombs of Dionysus at (respectively) Delphi and Thebes; *Orph. Hym.* 53. 1–4 has a trieteric Dionysus sleeping in the halls of Persephone and returning as Chthonius in the alternate years. Further discussion: C. A. Wilson, 'Wine Rituals, Maenads and Dionysian Fire', *PLLS* 10 (1998), 157–68.

⁵¹ F. M. Cornford, *The Origin of Attic Comedy* (London, 1914), 88–9; A. B. Cook, *Zeus* (Cambridge, 1914), i. 627. Unaware of possible ritual wine-distilling, they both linked the 'boiling' with the Orphic phrase 'a kid I have fallen into the milk'.

⁵² M. L. West, *Studies in Aeschylus* (Stuttgart, 1990), 49, notes the possibility that Aeschylus took part in the Eion campaign.

⁵³ ὅποσα δ' ἐπ' ὤμοις ἔθεσαν, οὐ δεσμῶν ὕπο | προσείχετ' οὐδ' ἐπιπτεν ἐς μέλαν πέδον | οὐ χαλκός, οὐ σίδηρος, ἐπὶ δὲ βοστρύχος | πῦρ ἔφερον, οὐδ' ἔκαιεν.

herdsmen were Macedonian men who really had spied upon the nocturnal mountain rituals of the local maenads, and passed on to other men the secret that the safe-burning fire was somehow associated with the bronze *φιάλαι*.⁵⁴ In the *Bacchae* passage the maenads are no longer engaged in secret rituals, but the fire on their hair is a powerful indicator of the presence of Dionysus. It also suggests that wine-distilling and the associated ritual use of the distillate were already practised in fifth-century Macedonia.

A somewhat later date is likely for the invention of the technique of sublimation, developed initially to ease the task of extracting mercury from its red sulphide, cinnabar. Cinnabar (alias vermilion) was in use as a pigment in the Greek world from the sixth century onwards; and small amounts of free mercury occurred—and still occur—in the deposit near Ephesus which Theophrastus regarded as the main source of cinnabar in his day.⁵⁵ But the Greeks apparently paid little attention to mercury before the fourth century, for our earliest reference to it comes from the comic poet Philippus, who wrote that Daedalus made a hollow wooden statue of Aphrodite and poured mercury into it to make it move.⁵⁶ Aristotle told this tale, saying it came from Democritus, who was among those who believe that the soul moves the body.

Near Ephesus the cinnabar was sandy, and Theophrastus said that mercury was extracted by mixing the red earth with vinegar and grinding it in a copper bowl with a copper pestle. Modern experiments have shown this to be a very slow method of obtaining mercury.⁵⁷ Theophrastus also knew of cinnabar in two other places, Colchis and Iberia, and in both it was 'hard and stony'. The uplands behind Colchis, at the eastern end of the Black Sea and adjoining Iberia, were in the foothills of the Caucasian mountains, in Scythian territory.⁵⁸ The hard crystalline cinnabar could have stimulated metalworkers in the neighbouring regions to find an easier mode of extraction,⁵⁹ and this was achieved by the invention of sublimation.

Dioscorides described the method: 'For putting an iron saucer containing

⁵⁴ 'The bronze' was one name for the stillhead (n. 30). 'The iron' could have been the short sword carried by Macedonian maenads to enable them to sacrifice a goat or hare to Dionysus at the beginning of secret rituals held in a mountain glen or cave. Vase paintings show the sword-bearing maenads in association with Lycurgus or Pentheus, and Macedonian maenads carried short swords in the grand procession of Ptolemy II (Callixen. 627 F 2 = Ath. 198 E). See Wilson (n. 50).

⁵⁵ Theophr. *Lap.* 60. E. R. Caley and F. C. Richards, *Theophrastus: On Stones* (Columbus, 1956), 194, note the use of cinnabar as pigment on 6th-cent. statues in the Acropolis Museum and on 5th-cent. lekythoi. ⁵⁶ Fr. 1 KA, reported in Arist. *De an.* 1. 3, 406^b 15–20.

⁵⁷ Theophr. *Lap.* 60; Caley and Richards (n. 55), 204–5.

⁵⁸ Theophr. *Lap.* 58. I follow Caley and Richards (n. 55), 195–6, in locating Iberia in the Caucasus, and accept their interpretation of Vit. 7. 8. 1, 7. 9. 4. D. E. Eichholz, *Theophrastus: De Lapidibus* (Oxford, 1965), 125–6, takes a different view; but there is no evidence that Spanish cinnabar was either worked or exported before Roman imperial times.

⁵⁹ For cross-influences between Thracians, Greek colonies, and the Caucasus in classical times see R. F. Hodkinson, *The Thracians* (London, 1981), 97.

cinnabar upon an earthenware dish, they fit onto the latter an ἄμβιξ (*ambix*), luting it around with clay. Then they heat it over charcoal. For the vapour adhering to the ἄμβιξ, when scraped off and cooled, becomes mercury' (5. 95). The ἄμβιξ was a deep earthenware cup tapering towards its brim, and, as with the φιάλη-stillhead of the wine-distillers, it was inverted over the base vessel and sealed to it to exclude the air.

Because the method has affinities with wine-distilling, i.e. both rely on the reaction of vapour or gas recondensing in the upper part of a sealed vessel, it is tempting to believe that this sublimation process was devised by people who already knew something about the use of the φιάλη in wine-distilling. Although maenads may have carried out distilling rituals, the cups themselves must have been made by metalworkers; and the goldsmiths who created delicate gold foliage wreaths for initiates and other precious objects for the Dionysus cult could have produced the bronze φιάλαι and understood their usage.

If cinnabar was heated in a pottery base-vessel fitted with a bronze cup (a combination often used in wine-distilling), then some part of the mercury displaced from its sulphide by the copper would have adhered to the upper walls of the pottery base. Further experiment would have produced the optimum combination of earthenware base, earthenware cup or ἄμβιξ, and a copper saucer (later replaced by cheaper iron which yielded the same reaction) to hold the cinnabar.

A further pointer to a north-eastern provenance for the invention of the sublimation process is the secret name for mercury in a much later word-list compiled by the experimenters in Egypt, viz. Scythian water.⁶⁰ Egypt lacked cinnabar deposits, and interest in its sublimation is unlikely to have arisen there prior to the arrival of the Ptolemies. They introduced the cult of Dionysus, already greatly honoured in their Macedonian homeland, and encouraged newer cults such as that of Serapis, and some of the skilled metalworkers from Macedonia and Thrace almost certainly migrated to Egypt in their wake to help provide artefacts of precious metal for temples and for the many adherents of the new cults.

Either in Macedonia or later in Egypt, the metalworkers began to exercise their skills in distillation and sublimation on new materials: the distillation of eggs and the sublimation of the arsenical sulphides.⁶¹ They already recognized that their extraction methods could reveal hidden aspects of the materials under treatment: the fire in the water distilled from wine, the

⁶⁰ Berthelot, text 1. 2 s.v. ὕδωρ Σκυθικόν. The name remained a cultic secret, but could have been coined by metalworkers in the Thracian/Macedonian region when they first used the sublimation method to extract mercury from Caucasian cinnabar. Later, when the experimenters in Egypt practised their chemical art, their cinnabar could have come from near Ephesus or (in imperial times) Spain.

⁶¹ The latter (see n. 9) is more likely to have been developed in Egypt, where deposits of natron in dry lake beds were already being exploited for various purposes.

mobile shining mercury within the red-earth cinnabar. Interest in those hidden properties is clear from the terms used in *PM* and other protochemical texts, where mercury is sometimes called 'cinnabar turned outwards', and arsenic is called either 'the mercury of orpiment' or 'the mercury of realgar' or 'orpiment turned outwards'.

The experimenters may even have regarded the hidden nature as a form of soul—certainly in the case of the fire in the 'water' distilled from wine. Democritus said that both fire and soul were formed from the most mobile atoms, those that were spherical in shape.⁶² Mercury was endowed with soul-like properties by the story about mercury being poured into a statue to make it move as the human soul moves the body (cf. n. 56). For Democritus, as for Socrates, the soul was a physical entity, but made from finer material than other physical things, except perhaps fire.

If the techniques of distilling and sublimation, along with some of Democritus' ideas on the nature of matter, reached Egypt from the northern Greek world in the manner here suggested, then it was not long before a further theme was added. The adoption of Bolus' doctrine of sympathies could well have been a milestone in the evolution of the metal-tinting and other experiments of the incomers into one of the new mystery cults of Hellenistic Egypt, for it provided authority for the belief that bringing forth the fire in wine or the gold nature representing fire hidden 'within' base metal could by sympathy draw forth the fieriest part of the soul of the operator and release it from future toil and pain. Bolus' reputation for writing books under the name of Democritus may have arisen at that stage.

The Pythagorean input could have been a later development, leading to the adoption of the mysterious phrases about the 'natures' which we now realize were derived from terms used about changes of the three upper elements in Plato's *Timaeus*. With them came the newly invented myth that Democritus, by now accepted as a founder figure for the cult, had learnt the chemistry of the natures from Socrates and Plato. Later still, breakaway groups claimed different founders, and some practised different techniques, using a little gold to act as a ferment for base metal and transform it all into gold.⁶³ But the discoveries made through chemical experiments on metals and minerals remained throughout Roman imperial times as secret knowledge within the cultic groups, who attached to them meanings far beyond simple recognition of the chemical reactions which took place.

The one exception was mercury, less rare once Spanish cinnabar became available.⁶⁴ Mercury was employed in gilding, and in silver-coating copper with tin; and its ability to amalgamate with fine particles of gold led to its

⁶² Arist. *De an.* 1. 2, 405^a3-13.

⁶³ Berthelot, texts III. 10. 3 (gold as a leaven or ferment) and I. 13. 7 (Isis: gold engendering gold).

⁶⁴ It was sent under seal to Rome for processing: Pliny *HN* 33. 118.

use for gold ink and for removing gold from embroideries in old discarded clothing.⁶⁵

3. Later Developments

Chemical experimentation in the Hellenistic and Roman periods did not lead to great advances in knowledge outside the cultic groups. Even within them the achievement is difficult to evaluate. Some results are verifiable: elemental arsenic could only have been extracted from its sulphides and used to coat copper through sublimation. But many experiments in the texts are impossible to repeat because of uncertainty about ingredients. In the Greek world different names were often given to the same mineral when found in different places, and the same name to different minerals of similar appearance. Gold colour in any ingredient was thought to indicate fire content. Some recipes offer many alternative ingredients and methods are often unclear, with instructions such as *οικονόμει ὡς ἔθος* ('operate as usual') or *ὡς ἐπινοεῖς* ('as you know how'). In so far as the work was noticed outside the cults, it met with disapproval from state and early Church alike, as a form of magic, and the heretical 'baptism' using distilled wine was particularly abhorrent to the Church. The further expansion of experimental chemistry was thus destined to take place beyond the frontiers of the Graeco-Roman world.

The activities of the gold-makers had already come under suspicion in the time of Diocletian, who commanded their books on gold- and silver-making to be burnt in 296 'lest the opulence of the Egyptians should inspire them with confidence to rebel against the empire'.⁶⁶ Some gold-makers crossed into Persian territory at that stage, and more followed them a century later to avoid converting to orthodox Christianity. All experimental work of the type described in the protochemical recipes ceased within the Byzantine empire, though at a later date some of the ancient recipe texts reached Constantinople and were studied by Christian commentators, who regarded the progress from base metal to gold as an allegory for the journey of the Christian soul.

The Persians, however, welcomed a chance to learn new technology from Egyptian gold-makers, Gnostic Messalians, and other migrants from the Roman empire. The preparation of medicinal herbal waters was a new application of the distilling technique, perhaps first fully developed using the plants of the medical botanical garden established by Khusro I Anoshirvan

⁶⁵ Ibid. 33. 65. Gilding: Leiden Papyrus X (Halleux (n. 2), 84-109), nos. 55, 73, 79; silver-coating: *ibid.*, no. 26; gold ink: *ibid.*, nos. 33, 69; embroideries: Vit. 7. 8. 4.

⁶⁶ Io. Ant. fr. 165; *Suda* s.v. Διοκλητιανός: μηδὲ χρημάτων αὐτοὺς θαρρούντας περιουσίᾳ τοῦ λοιποῦ Ρωμαίους ἀνταῖρεω. Translation: E. Gibbon, *Decline and Fall of the Roman Empire*, i. 13.

(531–79) around his famous hospital at Jundishapur in Khuzistan.⁶⁷ Later, under the Arabs, rose-water was distilled on a vast scale with multiple stills evolved from Greek *φιάλη* prototypes. Early in the Arab period some ancient Greek protochemical texts were translated into Syriac and Arabic, and their content studied, reinterpreted, and transformed into alchemy.⁶⁸

The last and most striking achievement of Greek chemical distilling was probably due to experimental work by Gnostics settled in the Persian–Syrian borderlands. The importance they attached to elemental fire or light meant that they continued the practice of wine-distilling and fire-baptism. Thus they already possessed the technological ability to distil ‘Median oil’ (crude petroleum); but they also discovered and added a suitable ‘filler’ to the distillate, which vaporizes very rapidly at ordinary temperatures, and invented a method of propelling it through ‘siphons’ (force-pumps).⁶⁹ The secret was given, or sold, to the Byzantine emperor when Arab naval forces threatened Constantinople. Their wooden ships were defenceless against the flaming ‘moist fire’ or ‘sea fire’ (later known as ‘Greek fire’) projected at them through siphons, and so the city was saved.⁷⁰

⁶⁷ H. M. Leicester, *The Historical Background of Chemistry* (New York, 1956), 50–1; R. N. Frye, *The Golden Age of Persia* (London, 1975), 22, 163–4; *CHI* iii/1, 161, 486, 573; D. Gutas, *Greek Thought, Arabic Culture* (London 1998), 14, 118, 133, 135–6. M. Levey, *Early Arab Pharmacology* (Leiden 1973), 30, calls it ‘the world’s greatest center of scholarship at the time’. In the protochemical texts the *πνεῦμα* of plants was their colour, removed by the distilling process (Berthelot, texts III, 47, 7). The Persians and Arabs took *πνεῦμα* more literally to be the aroma of essential oils in herbs and flowers, which they extracted by distillation.

⁶⁸ Rose-water stills: R. J. Forbes, *Short History of the Art of Distillation* (Leiden, 1948), 29–54 and figs. 16–20. Possible Persian original of an Arab text in the Greek protochemical tradition: H. E. Stapleton *et al.*, ‘The Sayings of Hermes’, *Ambix*, 3 (1949), 88.

⁶⁹ One of the two recipes for ‘Greek fire’ in the 13th-cent. Latin *Liber Ignium* of Marcus Graecus (J. R. Partington, *A History of Greek Fire and Gunpowder* (Cambridge, 1960), 50, no. 26) appears to derive from a Greek text composed when the earliest vocabulary of distilling was still current, since it contains the verb ‘to boil’ (*ἄβρω*) with the meaning ‘distil’.

⁷⁰ Moist fire (*πῦρ ὑγρόν*): Const. P. *Adm.* 48; sea fire (*θαλάσσιον πῦρ*): Theophan. 295. The first critical sea battle took place in the 670s, the second in 715. Later the Arabs and Franks learnt the process: see Partington (n. 69), 47–8, no. 10, for a Latin recipe using the Arab cucurbit. For the coming of wine-distilling to the west as a secret Cathar practice, and the later adoption of distilled wine as a wonderful new medicine, see Wilson (n. 5), 192–7.