The Role of Gold In Alchemy. Part I

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Since ancient times and in every culture, gold has been valued for its beauty as well as for its unique physical and chemical properties. Hence it is not surprising that the pseudoscience of alchemy arose almost everywhere from earliest times in an attempt to convert base metals into the 'king of metals'. The idea of transmutation was based upon observation of the ubiquitous changes occurring in nature and the application of analogies and correspondences. Its primary theoretical basis lay in the various theories of matter which reduced the bewildering diversity of material substances to several fundamental 'elements'. Among the most important of these theories were those of the Two Contraries and the Five Elements (the Chinese), the Four Elements (the Greeks), the Sulphur-Mercury Theory (the Arabs) and the Tria Prima (Paracelsus). This review traces the history of alchemy and the role of gold in it. Part I takes us to the time of Paracelsus and the opinions of Robert Boyle on the subject.

The writer recently encountered the following quotations not in their original context of Scene 1 of Richard Wagner's opera 'Das Rheingold', the prologue to his monumental trilogy 'Der Ring des Nibelungen', but in the holograph papers of August Strindberg (1849-1912), Sweden's greatest writer and self-professed alchemist (1).

'Nur wer der Minne Macht entsagt,
Nur wer der Liebe Lust verjagt,
Nur der erzielt sich den Zauber,
Zum Reif zu zwingen das Gold'.
Woglinde
'... So verfluch' ich die Liebe!
Alberich

'He who the sway of love forswears,
He who delight of love forbears,
Alone the magic can master
That forces the gold to a ring'.

'... Love henceforth be accursed!'

Like Alberich, the Nibelung dwarf who seized the golden treasure from the depths of the Rhine despite the warning of Woglinde and her sister Rhinemaidens, Strindberg devoted many years to the attempted transmutation of base metals into gold. He was not the first or last person to fall under the spell of the 'king of metals', which has exerted a mystique and attraction on the human race since earliest antiquity.

The Antiquity, Mystique and Mythology of Gold

Wagner's ring cycle, in which the possessor of the Rhine gold has the power to rule the entire world, was derived from the 13th-century 'Nibelungenlied', the Middle High German epic poem, which itself was based on much earlier Scandinavian and Old Norse literature. Furthermore, the greedy pursuit of gold certainly did not originate with Alberich, for in Virgil's 'Aeneid' (ca. 29-19 B.C.) (Book III, line 56), we read, 'O cursed lust for gold, to what does thou not drive the hearts of men!' In fact, since gold occurs in

relatively pure form in the uncombined state, is beautiful, lustrous, malleable, and does not corrode or tarnish, it was one of the first — if not *the* first — metals known to man (2, 3).

Long before it became a symbol for royalty or a standard medium of exchange, gold was regarded as divine and was made into idols or offered to the gods (4). Mentioned in the Bible as early as *Genesis*, 2:11-12, gold was used by the Babylonians to crown their ziggurats, and the Israelite captives who were forced to rebuild the great ziggurat of Babylon in the 6th century B.C. referred to it as the 'Tower of Babel' (*Genesis*, 11:1-9). Its value was early recognized; the Psalmist described the judgements of the Lord as 'more to be desired ... than gold' (*Psalms*, 19:10), while, along with frankincense and myrrh, it was one of the gifts brought by the Magi to the Christ child (*Matthew*, 2:11). In building his temple (ca. 1000 B.C.) King Solomon sent his fleet, manned by his servants and the sailors of King Hiram of Tyre, to Ophir, which has never been exactly located. They returned with 420 talents of gold — more than US\$130 million in terms of current prices (*1 Kings*, 9:26-28).

Gold was known in every culture. The ancient Egyptians used it to represent the sun, which they worshipped. Thus the ornate gold collars worn by Egyptian ladies of the court had religious as well as ornamental value, and the first hieroglyph for the yellow metal was a stylized necklace (Figure 1). The richest golden treasure store ever unearthed by archaeologists was found in 1922 by Howard Carter in the tomb of an unimportant boy pharaoh named Tutankhamen (reigned 1361-1352 B.C.).

Although its production by transmutation of base metals was not as central a goal in Chinese alchemy as it was in the West, gold was well known to the ancient Chinese (5). In India, gold has long been considered a sacred metal, symbolic of Lakshmi, goddess of wealth and consort (*Shakti*) of the Hindu deity Vishnu (6). Sanctioned by the Vedic scriptures (ca. 1500-1200 B.C.), it has been an attribute of royalty from semimythical times to the present day, when it is still an integral part of the Indian dowry system and is often prescribed as a medicine. In probably no other country does the mystique and

Fig. 1 Ancient Egyptians worshipped the sun and used gold to represent this entity. The ornate gold necklace shown here and worn by an Egyptian lady of court would have had religious as well as decorative meaning. The first hieroglyph for gold was a stylized necklace, which is seen in all the hieroglyphic captions describing the sequence of goldsmiths at work. Rough English translations are given below the drawings. From J.G. Wilkinson, 'Manners and Customs of the Ancient Egyptians'. Gold necklace from the Metropolitan Museum of Art

Fig. 2 Scene from Agricola's 'De Re Metallica' depicting gold mining in his day, including metal divining

myth of gold so permeate society as in India.

Gold also played a prominent role in Hellenic civilization, as attested to by some of the most familiar Greek myths. The myth of King Midas (4, pp. 33-34; and 7) was an attempt to explain the occurrence of gold in the river Pactolus (believed to be located near Sardis in modern Turkey), which was the source of wealth of Croesus, King of Lydia (ruled 560-541 B.C.), renowned for his wealth and wisdom. No other river, ancient or modern, ever yielded gold in such quantities over such a long period of time. According to the myth, Midas, King of Phrygia (a country located in Anatolia, now Asiatic Turkey) was granted a wish by Bacchus, the Greek God of wine and vegetation. Midas requested that everything that he touched be turned into gold. When this blessing had turned out to be a curse in disguise, Midas prayed to Bacchus to take back his gift. He was told to wash in the river Pactolus, whose waters absorbed the power and transformed into gold the rocks and sands over which they flowed.

The well-known myth of Jason, who with his Argonauts set out in the Argo, the first longship, in search of the Golden Fleece, which was guarded by a dragon in a sacred grove in the land of Colchis in the region of the Caucasus (7, pp. 203-204), has been subject to various interpretations. According to Allen (4, pp. 38-39), Jason and his crew set sail (ca. 1200 B.C.) because they had heard that gold was plentiful in Colchis. They may actually have brought home some of the gold in glittering fleece, for sheepskins were the sluice boxes of the ancient world. The skins were placed on the bottom of gold-bearing streams, where the heavier particles of gold were trapped

in the tangled, greasy wool, a forerunner of the corduroy tables sometimes used in the collection of gold particles from their milled ores. On the other hand, Hopkins cites a tale in which the Greek word δῆρας, meaning fleece, is interpreted as parchment. According to this version, the fleece was a book written on sheepskin describing how gold might be produced alchemically (9).

The Uniqueness of Gold

The physical and chemical properties of gold, its alloys, and its compounds have been extensively investigated down through the ages (10-13), and, as we have seen, the metal has had an immense influence on the economic and cultural history of man (14), largely because of its unusual properties. Its metallurgy, developed since ancient times, is fully described in the two Italian Renaissance classics of mining and metallurgy, Vannoccio Biringuccio's 'De la Pirotechnia' (1540) (15) and Georgius Agricola's 'De Re Metallica' (1556) (16). The latter work gives the first comprehensive description of gold metallurgy in all its branches. It contains 289 brilliantly executed drawings, which present a detailed picture of the first age of technology (4, pp. 150-155) (Figure 2).

In 'Utopia' (1516), Sir Thomas More (1478-1535) wrote,

'They wonder much to hear that gold,
which in itself is so useless a thing,
should be everywhere so much esteemed,
that even men for whom it was made,
and by whom it has its value, should
yet be thought of less value than it is'.

Pace Sir Thomas, gold is far from useless! A good conductor of heat and electricity, it is also the most malleable and ductile of metals. One troy ounce (31.1 grams) can be beaten into a sheet (gold leaf) 300 square feet (about 30 square metres) in area, so thin that it transmits green light, and one troy ounce of gold can be drawn into a wire 45 miles (72 kilometres) long (14). One of the few metals found uncombined, either as fine particles and/or disseminated in gold-bearing rocks and nuggets in alluvial deposits, it has always been a symbol of immortality because it does not corrode or oxidise. In Geoffrey Chaucer's words ('The Canterbury Tales', Prologue, line 500), 'If gold rust, what shal iren do?' Many of its applications are based on its inertness; e.g., it is used in the jewellery, dental, electronics and aerospace industries. Although widespread in nature, it is exceedingly scarce, accounting for only 0.0000005 per cent of the earth's crust, compared to iron at ca. 5 and aluminium at about 8 per cent.

This scarcity and inertness made gold the prized possession of kings and nobles and led to its use as a medium of exchange and the basis of most monetary systems (4, pp. 105-106, 228-249). Greed for its acquisition provided the impetus for numerous exploratory expeditions. From Jason's travels mentioned above, through Marco Polo's travels to Cathay (1271-1295), Columbus' discovery of the New World, the Spanish explorations of Central and South America, to the more recent series of gold rushes — California, Nevada, Colorado, Alaska, Canada's Yukon Territory, Siberia, Australia and

Fig. 3 'Pray, read, read, read again, work and you shall find'. (*Mutus Liber*, 1702)

South Africa — gold led to the extension of civilization and the opening up of new territories (4, pp. 113-149, 157-215). According to Columbus' son Fernando, the acquisition of Cathay's gold was his father's primary objective (4, p. 117), while King Ferdinand of Spain's directive of 1511 to his South American explorers ('Get gold, humanely if you can, but at all hazards get gold') (14) was probably typical of the advice of monarchs from the ancient Egyptian pharaohs to contemporary rulers. Today South Africa is the world's leading producer of gold, followed by the U.S.S.R. (4, p. 246).

Alchemy: Its Goals, Origins and Accomplishments

Gold was so precious that from earliest times man has left no stone unturned in searching for it in nature. It is not surprising, therefore, that man should have sought to convert other metals into gold. In view of alchemy's lengthy history and its near universal appearance in all places, cultures and times, there is no paucity of books or articles — scholastic, popular or mystical — on this venerable protoscience or pseudoscience (17-34). In fact, a recent bibliography of alchemy, limited to writings only in English (35), lists no fewer than 3 188 items. Nevertheless, it is not really clear what alchemy was or is (36). Isaac Asimov, the erstwhile biochemist and prolific science fiction writer, has dogmatically asserted that:

'Alchemy is simply chemistry. The name has been spoiled because of the follies and fates of the ancient alchemists'.

Liebig seems to echo this view:

'Alchemy was never at any time anything different from chemistry. It is utterly unjust to confound it, as is generally done, with the gold-making of the sixteenth and seventeenth centuries Alchemy was a science, and included all those processes in which chemistry was technically applied' (37).

Yet these are minority views, and many writers have interpreted alchemy in a restricted sense as 'the pretended art of transmuting so-called 'base' metals into the 'noble' metals, silver and gold, and in a broader sense as 'a system of philosophy which claimed to penetrate the mystery of life as well as the formation of inanimate

substances' (24, pp. 1-2). In Chinese alchemy, the prolonging of life and the attainment of immortality was a primary goal (5;33, Chap. 7;38). Some scholars make a distinction between

'...an esoteric alchemy, whose hidden secrets were revealed only to chosen adepts, and an exoteric pseudo-alchemy, which is depicted as the uninstructed craft of mercenary gold-seekers or 'puffers' ' (named after the noise of the bellows which they used to increase the heat of their furnaces) (24, p. 2).

There are many interpretations of alchemy. Weyer (39) has suggested three possibilities: (a) the American chemist Arthur John Hopkins' chemical interpretation (9, 40), (b) the Swiss psychiatrist Carl Gustav Jung's psychological interpretation (41), and (c) the Rumanian historian of religion Mircea Eliade's mythological interpretation (42). According to the psychological interpretation, man is the base metal which is refined and perfected by the process of psychotherapy (33, Chap. 6; 40; 43-49).

Alchemy emerged as a mixture of primitive science, metallurgy, mysticism, philosophy, religion (50), astrology and various occult sciences. In accordance with the alchemical fondness for correspondences and analogies, the Great Work of transmutation (*Ars Magna*) was likened to the creation of the world itself: ('The first chapter in *Genesis* is the greatest page in alchemy' (19, p. 350)), and alchemists were encouraged to 'pray, read, read, read again, work and you shall find' (*Ora, lege, lege, relege, labora et invenies*) (Figure 3). The Great Work was sometimes divided into twelve steps or operations, each associated with a different Zodiacal sign, *viz.*, calcination (Aries), congelation (Taurus), fixation (Gemini), solution (Cancer), digestion (Leo), distillation (Virgo), sublimation (Libra), separation (Scorpio), ceration (Sagittarius), fermentation (Capricorn), multiplication (Aquarius) and projection (Pisces) (24, p. 135; 51) (Figure 4).

If the goals and nature of alchemy are obscure, its origins are even more uncertain (18, Chapter 1; 51). Ancient Egypt is traditionally considered the birthplace of alchemy (*Khem*, being the hieroglyphic name for Egypt) (52), and Hermes Trismegistos

Fig. 4 (Left)
Chymia: an illustration of the 'Great Work' by Libavius (1660)

Fig. 5 (Right) A depiction of Hermes Trismegistos, the Egyptian Thot, regarded as the patron saint of alchemists, and from whom the expression of hermetically sealing a vessel is named. After T.L. Davis, 88th Am. Chem. Soc. Meeting, Cleveland, 1934

(Hermes, the Thrice Great), the Greek version of the ibis-headed Egyptian moon god Thoth (Figure 5), is generally considered the legendary founder of the 'Hermetic Art' and the patron saint of alchemists (7, p. 73; 18, p. 11; 24, p. 5; 30, p. 25; 52-57). His name is immortalized in the philosopher's egg or Hermetic Vase (Figure 6), the sealed alchemical vessel *par excellence*, in which the Great Work of transmutation was consummated (24, p. 149). Even today we speak of a vessel as being hermetically sealed.

Hermes is also sometimes identified with Canaan (or Chanaan), the son of Ham, Noah's youngest son (*Genesis*, 5:22-27). The Scottish chemist Thomas Thomson credits Canaan with the founding of alchemy, to which 'he affixed his own name' (54). Of the 36 000 original alchemical writings attributed to the legendary Hermes (24, p. 9), the best known is 'The Emerald Table' (Tabula

Smaragdina) (Figure 7), a brief, primitive doctrine of cosmogony, astrology and metaphysics that is regarded as the fundamental document of transmutation (20, pp. 17-19; 27, p. 2; 58-60). Its famous dictum

'That which is above is like that which is below: and that which is below is like that which is above to accomplish the miracles of one thing' (27, p. 2)

is the cryptic watchword of alchemical transmutation which establishes the correspondence between the universe (the macrocosm) and man (the microcosm) (Figure 8).

There are other contenders for the title of founder of alchemy. For example, Moses is sometimes considered the first adept, for he was familiar with drinkable gold (*aurum potabile*), which we will discuss later in more detail (20, p. 16). When Moses descended from

Fig. 6 The philosopher's egg or Hermetic Vase in which the 'Great Work' of transmutation was to be consummated

Mount Sinai and beheld the Israelites dancing around the golden calf which his brother Aaron had made, he broke the tables of the law,

'And he took the calf which they had made, and burnt it in the fire, and ground it to powder, and strewed it upon the water, and made the children of Israel drink of it' (*Exodus*, 32:20).

Another semilegendary early alchemist, Maria the Jewess (Figure 9), is sometimes identified with Miriam, the sister of Moses, while others consider her a contemporary of the Jewish alchemist Theophilus (20, pp. 21-22). Her name is immortalized in the water bath (in French, *bain marie*), that simple but indispensable heating device, which has survived almost unchanged from ancient times (Figure 10). She is also credited with inventing the *kerotakis*, a reflux apparatus or sublimatory (Figure 11).

Alchemy flourished in China (5; 23, pp. 108-117; 25, Chap. 3; 33, Chap. 7), India (23, p. 112), the Graeco-Roman world (23, pp. 113-117; 25, Chap. 2; 61), the Arabic world (23, pp. 118-127; 25, Chap. 5), and Europe (25, Chap. 6). Western alchemy may go back to the beginnings of the Hellenistic period (*ca.* 300 B.C.-*ca.* A.D. 300), and Multhauf regards Zosimos of Panopolis (upper Egypt) (*ca.* 350-420) (9, pp. 69-77; 62; 63), who taught in Alexandria, as 'the earliest writer known to us with certainty to have been an alchemist' (26, p. 85; 36). The alchemist known in the West as Geber (64, 65) and sometimes identified with the Arab Jabir ibn Hayyan (*ca.* 720-800) (Figure 12), has been rated as the greatest alchemist (61), and Multhauf considers his works to be 'the most famous alchemical writings in the Latin West' (26, p. 171). Yet Geber may have been

a pen name of a group resembling a secret sect of natural philosophers, the Brethren of Purity (21, p. 78), and even his existence as a distinct individual has been questioned.

While the origins of alchemy are obscure, its practitioners, in their illusory attempts to transmute base metals into gold and to prolong life indefinitely, contributed much to modern chemistry in the form of chemical substances (e.g., arsenic, antimony, bismuth, phosphorus, zinc, salt, sal ammoniac, saltpetre, alum, vitriols, aqua regia (Figure 13) and sulfuric, nitric and hydrochloric acids), laboratory techniques (e.g., heating, refluxing, extraction, sublimation and distillation)

Fig. 7 The Emerald Table of Hermes, regarded as the fundamental document of transmutation. The thirteen precepts are set out in Latin and German. From *Amphibeatrum Sapientiae Aeternae*, H. Khunrath, Hanau, 1609

Fig. 8 The Alchemical Microcosm and the Macrocosm. From *Musaeum Hermeticum*, 1678

Fig. 10 The alchemist's water bath (*bain-marie*), from a 1519 wood cut. The furnace below the bath gave only gradual warming of the material in the glass vessels in the water

Fig. 9 17th-century portrait of Mary the Jewess (or Prophetess) credited with the invention of the water bath named after her (the *bain-marie*). Traditional belief has it that she was Miriam, the sister of Moses

Gold Bull., 1985, 18, (1)

and scientific apparatus (e.g., sand, water and air baths; furnace (athanor); still; sublimatory (*kerotakis*); and balance) (66, 67a). There is no doubt that the alchemists' attempts to obtain gold by transmutation were misguided; Charles Mackay, in 'Extraordinary Popular Delusions and the Madness of Crowds' (68), devotes 159 pages to the 'divine art' of alchemy, far more than to any of the other topics in his now classic book. Yet, in the words of the English lawyer, courtier, statesman and philosopher Francis Bacon (1561-1626),

'Alchemy may be compared to the man who told his sons that he had left them gold buried somewhere in his vineyard; where they, by digging found no gold, but by turning up the mould about the roots of the vines, procured a plentiful vintage. So the search and endeavours to make gold have brought many useful inventions and instructive experiments to light' (20, p. 46; 69).

Fig. 12 The Arab alchemist Jabir ibn Hayyan

The Idea of Transmutation

Transmutation is the primary goal of alchemy, and in this article we are concerned with the process in its exoteric or chemical sense, i.e., the conversion of base metals into gold, rather than in its esoteric or medical-psychological sense, i.e., the search for prolonging life, conferring immortality on man, or integrating man's fragmented psyche. Today we scoff at the alchemists' attempts at transmutation, but we must realise that they plumbed the unknown with their intuitive as much as with their rational faculties. They did not feel our present-day need to prove hypotheses through rigid experimentation, but instead they made extensive use of analogies and correspondences.

Primitive man, as even today's primitive tribes and very young children, made little distinction between animate and inanimate matter, i.e., they believed in the doctrine of hylozoism — that 'all Nature is like man, alive and sensitive' (24, p. 12). Since many alchemists were miners and metallurgists who could apparently turn rock and sand into metals, they believed that they were actually transmuting rock into metal — sometimes dull lead, sometimes reddish copper, sometimes whitish silver, and sometimes even yellow gold. They believed that metals grew in the earth, changing colour as they ripened, an idea persisting today in the Philippines

where miners still leave seeds of gold in the mine so that more gold will grow from them. As late as the 16th century, Calbus of Freiberg, a famous mining centre, described the growth and weathering (*Witterung*) of metals, which were believed to be generated by the exhalations from their respective planets — gold (the Sun), silver (the Moon), iron (Mars), mercury (Mercury), tin (Jupiter), copper (Venus) and lead (Saturn) — and ripened through continued exhalations into gold — the 'perfect' metal (Figure 14). However, if the gold was not harvested like fruit at the proper time, further planetary influences would cause it to wither into a reddish earthy residue, thus accounting for the scarcity of gold (4, p. 72).

Similarly, Eirenaeus Philalethes, an alleged 16th-century alchemist, wrote

'All metallic seed is the seed of gold: for gold is the intention of nature with regard to all metals. If the base metals are not gold, it is only through some accidental hindrance: they are all potentially gold' (70).

According to the English alchemist Thomas Norton (24, pp. 174-182), author of the famous 'Ordinall of Alkimie' (1477),

'Metals are generated in the Earth, for above ground they are subject to Rust; hence above ground is the Place of Corruption of Metals and of their gradual Destruction. The cause which we assign to this fact is that above ground they are not in their proper Element, and an unnatural position is destructive to natural objects as we see, for instance, that Fishes die when they are taken out of the Water' (20, p. 69).

Norton concluded that since metals grow at particular places, exhausted minefields need only to be closed for a sufficient time for a new crop to be obtained from subsequent growth of the metal.

Even Sir Isaac Newton (1642-1727), one of the greatest scientific geniuses of all time, whom most laymen consider the epitome of the totally rational thinker, was intensely interested in alchemy and the 'vegetation' of metals (71). He believed that metals were the only part of the mineral kingdom that vegetated, while other minerals were formed mechanically (72). In keeping with the vegetation theory of metals, alchemists attempted to imitate the transmutation of metals that they believed was occurring within the earth, hence the alchemical saying, 'Man must finish the work which Nature has left incomplete'.

Because of their lack of knowledge of the composition of common substances alchemists viewed many ordinary chemical reactions as transmutations. As a case in point, the deposition of copper on iron metal placed in a solution of copper sulphate, a redox reaction known since the time of Pliny the Elder (A.D. 23?-79) was assumed to be a transmutation of iron into copper until the late Renaissance (67b) because blue vitriol or bluestone ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) was not known to contain copper (2). Similarly, other changes in nature, especially those involving changes in colour to which the alchemists attached a great significance, lend credence to the idea of transmutation. For example, the mineral galena (PbS), on heating, liberates sulphur dioxide and is transformed into lead. Since silver is often present as an impurity in galena, silver is sometimes obtained by this process. The art of 'colouring' metals or producing various gold-coloured alloys of base metals was well

Fig. 13 Ancient depiction of aqua regia — the lion eating the sun (gold)

Fig. 14 Miners in medieval times thought that seeds of gold sowed in the ground would grow and ripen into more gold. From M. Maier, *Secretioris Naturae*, The New York Public Library, Rare Book Division

known and easily accomplished from ancient times (73), and to many an unsophisticated mind, if a substance was the colour of gold, it was believed to be gold. Hopkins thought that the theory of transmutation, at least in its origin, was entirely due to misinterpretation of such colours (74). It is true that various tests for gold, e.g., colour, malleability, density ('weightiness' as in the familiar 'Eureka' story of Archimedes in the bathtub and the crown of Hieron II, tyrant of Syracuse) and resistance to atmospheric oxidation on fusion ('trial by fire'), were common knowledge in the ancient world. In his 'Moral Essays' ('On Providence', 5:9), Seneca the Younger (ca. 4 B.C.-A.D. 65), the leading intellectual figure of mid-1st-century Rome, wrote, 'Fire is the test of gold; adversity of strong men'. Furthermore, additional tests, e.g., the touchstone (well reviewed by Wälichli recently in this journal, *Gold Bull.*, 1981, 14, (4), 154-158), touch-needles, cupellation (resistance to the oxidizing power of litharge, PbO), cementation (resistance to the attack of acid fumes) and resistance to mineral acids ('wet-way' analysis, 'parting' from silver by *aqua fortis*, HNO₃), were available to medieval and Renaissance alchemists. Yet technical imperfections in these procedures, especially if only one test was applied, may have provided apparent confirmation of transmutation:

'The technical equipment of the alchemical period was capable of invalidating any serious claim for successful transmutation of base metals, but numerous factors, especially the application of mineral acids of uncertain composition, probably led to "augmentations" in which even experts could not detect the added constituent, or to inexplicable residues of gold which had been unwittingly introduced by the operator himself. Fraudulent dexterity, false philosophy, public credulity and Royal rapacity all played their due part in the perpetuation of the transmutation theory' (75).

Theories of Matter

The primary theoretical basis for the idea of transmutation, however, lay in the various theories of matter, which reduced the perplexing diversity of material substances to several fundamental 'elements', which, in varying proportions, constituted the material universe. Considering their wide divergence in geography and culture (ancient Chinese, ancient Greek, medieval Islamic and early Renaissance European), these theories exhibit remarkable similarities (20, p. 91; 22, Chap. 3; 29, p. 17; 33, p. 58; 52; 55; 76-79).

The Chinese: The Two Contraries and the Five Elements (52)

China nurtured alchemical philosophy as early as the 4th century B.C. (5, p. 11; 80). Taoism, the Chinese philosophical and religious system embodied in 'The Way of Life' (Tao Te Ching) by Lao Tzu (604? B.C.-531? B.C.) (81-84), conceived the world in terms of two concepts — the doctrine of the two contraries (*yin-yang*) and five elements (*Wu-Hsing*) — water, fire, wood, metal and earth. *Yang* denotes the male, positive, light, fiery, hot, dry, even principle of the universe. *Yin* denotes the female, negative, cold, humid, heavy, earthy, odd principle. According to Wei-Po-Yang in a 2nd-century quote from 'Ts'an T'ing Ch'i', the oldest known treatise devoted

entirely to alchemy, *yang* donates, while *yin* receives. *Yang*, the perfect, may be quenched by *yin*, the imperfect.

The *T'ai-chi*, the first matter of the universe, is composed of *yin* and *yang*. It is a 'mathematical model of the universe' and 'a fruitful conventional representation of reality, as are the equations of physics and chemistry' (85). Relativity theory, the binary system of computers, the proton and electron, concepts of chemical valence and the wave-particle nature of light are modern illustrations of *T'ai-chi*. 'The organizing principle of *T'ai-chi* served very much the same function in Chinese culture and science as has mathematics in Western science since the Renaissance' (85, p. 6).

From its beginning Chinese alchemy emphasized a search for immortality. Hence the idea of a transmutation drug (*Lien tan*) or elixir may have been introduced to Western alchemy from China by way of Islam. This immortalizing elixir would bring the body into perfect harmony with the way of the universe. It was to be made from substances rich in *yang* — particularly cinnabar (red mercuric sulphide), which possesses the colour of vital blood, and, on heating, yields mercury, the 'living' metal (quicksilver) (86).

Alchemists considered combustion a symbol of death, and they regarded cinnabar's conversion to mercury a regeneration through death. Gold was second only to cinnabar in its potency as a life impartor. For this reason, as well as its material worth, it was highly valued.

Tsou Yen (305-240 B.C.) is generally credited with making a systematic world view by uniting *yin* and *yang* with the five elements. The elements were an intimate expression of *T'ai-chi* because they were constituents of earth. One cannot exaggerate the extent to which the two contraries and five elements were applied. In the West the seven metals known to the ancients were associated with the seven heavenly bodies (Table I).

The Greeks: The Four Elements (52)

Most chemistry texts begin their discussion of atomic theory with Leucippus and his student, Democritus (460-370? B.C.), the first atomists. Their theories — of innumerable elements in perpetual motion, changing through an infinite number of phases, of full and void, being and not being — sound almost Chinese when discussed by Simplicius, a 6th-century Neoplatonist.

A school of Greeks living ca. 550 B.C. thought that water, fire, air, and an indefinite matter called *apeiron* were the elements from which all other things were made. Strangely, although Thales (640-546 B.C.) thought that earth evolved from water, he did not assume earth's matter to be composed of it (21, p. 93). Anaximander's (626?-546? B.C.) concept of *apeiron* was not, as Aristotle thought, an intermediate between fire and air (21, p. 111). Although his fire and air were contesting and yet supportive opposites, *apeiron* was greater — an infinite, ever-moving substance which caused the two opposites to move away (21, p. 131). From this theory evolved Anaximander's notion that life emerged from a reaction between slime and sun, taking the form of fish with prickly

Table I
Equivalents of the Five Alchemical Elements and Two Contraries
Equivalents

T'ai-Chi	Metals	Heavenly bodies
Elements		
Water	Mercury	Mercury
Fire	Iron	Mars
Wood	Tin	Jupiter
Metal	Copper	Venus
Earth	Lead	Saturn
Contraries		
Yin	Silver	Moon
Yang	Gold	Sun

Other Alchemical Quintets

Places	Colours	Tastes
North	Black	Salty
South	Red	Bitter
East	Green	Sour
West	White	Astringent
Centre of world	Yellow	Sweet

Fig. 15 The four elements combined with the four qualities as envisaged by the ancient Greeks

bark instead of skin.

Later alchemists undoubtedly derived some ideas of transmutation from these theories. All was in a state of flux in both the West and East. A notable refinement in the theory of opposites occurred between Anaximander and Heraclitus: 'The way up and the way down are one and the same'. Aristotle found this absurd because he could not see how opposites were the same. Just as the *T'ai-chi* contained both *yin* and *yang*, so Heraclitus' *Logos* included life's opposing forces, even its most ethereal fire (87).

Empedocles of Agrigentum (492-432 B.C.) also postulated two fundamental forces — love and hate. Life could be ruled by either, depending upon how the four elements — earth, fire, air and water — combined.

'During the reign of hate the elements are separated; during the transformation of hate into love the elements draw together and begin to combine; during the rule of love, harmony is established to produce a perfect world — and a subsequent return to hate through repulsion, decomposition.... The four "roots" are indivisible, immutable and eternal. This aspect of Empedocles' doctrine foreshadows the atomic theory' (21, p. 190).

Aristotle believed that the four elements were combinations of four fundamental qualities — heat, cold, dryness and moistness. The four formed six possible pairs; however, opposites — heat and cold, moistness and dryness — could not couple (Figure 15). These elements were thought to change into each other as the qualities uncoupled and recoupled.

As the Chinese used the balance between *yin* and *yang* in

medicine, so Galen of Pergamos (A.D. 129-199) applied Aristotle's theory to Western physiology and medicine. In the body the four elements and their four qualities formed an equilibrium as the four humours — blood, phlegm, yellow bile and black bile. Disease occurred when one element predominated and was cured by adding its opposite element.

The Arabs: The Sulphur-Mercury Theory (52)

The first alchemist to mention explicitly the sulphur-mercury theory was Geber. Geber's sulphur-mercury theory derived from Aristotle's idea of exhalations. The earth gives off two kinds of exhalations when heated by the sun — one vapourous, cool and moist, the other windy and smoky. The vapourous produces metals from water in and on the earth. The smoky produces minerals from the earth itself.

Geber believed simmering exhalations under the earth produced sulphur and mercury, two elements that, in combination, formed other metals:

'Metals are all, in essence, composed of mercury combined and solidified with sulphur. They differ from one another only because of the difference of their accidental qualities, and this difference is due to the difference of their varieties of sulphur, which again is caused by a variation in the soils and in their situations with respect to the heat of the Sun' (4, pp. 72-73).

Since sulphur was frequently found with gold in mines and since mercury would extract gold from crushed ore, this may have led Geber and alchemists before him to postulate that metals were a

combination of these two substances (4, p. 72).

This theory held sway until the 18th century. Gold was the purest, most equally combined metal (25, p. 58). Geber's sulphur and mercury were not the ordinary substances that, when combined by heating, formed cinnabar (HgS). They were hypothetical substances, sometimes called sophic or philosophical, to which ordinary sulphur and mercury were close approximations. Before the advent of modern chemistry, the term sulphur (brimstone) commonly referred to any fusible, volatile and combustible substance. In fact, sulphur was often referred to as 'the stone that burns'.

Union of sulphur and mercury has been depicted as androgyny, sexual union, marriage and as combat. Singly, sulphur and mercury have been depicted as the sun and moon, respectively. Thus the sun and moon in the following passage from Hermes' Emerald Table are not the *Sol* (gold) and *Luna* (silver) of the medieval Latins but rather Geber's two principles of sulphur and mercury (55):

'As all things came into being by the contemplation of one so all things arose from this one thing, by a single act of creative adaptation. The Father thereof is the Sun. The Mother thereof is the Moon'.

The idea of a flammable principle, sulphur, in metals led to Johann Joachim Becher's (1635-1682) concept of *terra pinguis* (fatty or flammable earth), on which Georg Ernst Stahl's (1660-1734) phlogiston theory was based (88).

Geber also believed that metals ultimately consisted of the Aristotelian elements. A metal had one pair of qualities externally, another internally. For example, gold was hot and moist externally but cold and dry internally, whereas silver was cold and dry externally but hot and moist internally. Therefore, to prepare gold from silver required turning its nature inside out. Such transmutations were effected by the proper proportion of heat, moisture, cold and dryness.

Paracelsus: The Tria Prima (52)

In the early 16th century Philippus Aureolus Theophrastus Bombastus von Hohenheim (1493-1541), a Swiss physician and alchemist who called himself Paracelsus (89-94), added a third element — salt. This controversial figure believed alchemy's goal should be medicine, similar to the goals of the Chinese alchemists. Hence he is regarded as the founder of iatro- (or medical) chemistry. Paracelsus denounced Galenic medicine and its basis in the Aristotelian elements, without denying the elements. Instead, he thought them more remote than the *Tria Prima* (Figure 16). A Christian motif thus replaced pagan elements.

Paracelsus' *Tria Prima* was an explicit expression of the older alchemical trio of spirit, soul and body, or in more material terms, gas, liquid and solid. Sulphur represented fire or the soul (*anima*), and mercury symbolized water or the spirit (*spiritus*). To these Paracelsus added salt for the earthly body (*corpus*). Because this concept supported observations made in dry distillation, then a common method of analysis, the *Tria Prima* almost completely superseded the sulphur-mercury theory.

Paracelsus believed man also was made of these three substances — a trinity in unity. Man was healthy when the elements were in

Fig. 16 The celestial tree, a 15th-century work embodying the Paracelsus concept *Tria Prima* (spirit, soul and body or, in material terms, gas, liquid and solid)

Fig. 17 Attempts were made to link the *Tria Prima* with the philosopher's stone 'Make a circle out of a man and a woman, out of this a square, out of this a triangle. Make a circle and you will have the Philosopher's Stone.' (Atlanta Fugiens, 1617)

harmony. Again, Paracelsus' *Tria Prima* were not the common substances but their more abstract, sophic forms.

Many alchemists explained differences between metals as due to the proportions of sulphur, mercury and salt which they contained. Thus copper, because of its colour, was thought to contain excess sulphur, and iron excess salt. Transmutation should occur, then, when proper amounts of sophic sulphur, mercury or salt were added to a given metal. The much sought after philosopher's stone, capable of effecting such transmutations, was thought to be a combination of the *Tria Prima* in their pure forms (Figure 17).

Paracelsus' ideas thrived until the publication of Robert Boyle's (1627-1691) (95, 96) book 'The Sceptical Chymist' (1661) (97). Boyle, in contrast to general belief, was a firm believer in the concept of transmutation (98, 99). In his work on 'The Origin of Formes and Qualities of Substances' (1666) he tells alchemists,

'I will freely tell you, That supposing all Metals, as well as other Bodies, to be made of one Catholick Matter common to them all, and to differ but in the Shape, Size, Motion or Rest, and Texture of the small parts they consist of, from which Affections of Matter, the Qualities, that different particular Bodies result, I could not see any Impossibility in the Nature of the Thing, that one kind of Metal should be transmuted into another' (20, p. 165).

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Parts II and III of this review will appear in the April and July 1985 issues of *Gold Bulletin* and will discuss the relationship of transmutation and the philosopher's stone, potable gold and official attitudes towards alchemy. The review concludes with an account of alchemy in modern times, in which radioactive transmutation is discussed.

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