

HISTORICAL ASPECTS ON MYSTICS AND METAPHYSICS OF METALS

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RESUMEN

Se presenta una visión panorámica sobre la evolución histórica de la mística y metafísica de los metales considerando su concepto, génesis y constitución desde la Antigüedad hasta la época de Lavoisier en relación con concepciones astro-lógicas, animistas, hilozoistas, vitalistas y metafísicas características de los sistemas alquímicos orientales y occidentales.

ABSTRACT

An overview is presented on the historical evolution of the mystics and metaphysics of metals taking into consideration their concept, geneses and constitution from Antiquity up to Lavoisier's time, considering main views and concepts related to astrology, animistic, hylozoistic and metaphysical thought both in oriental and western systems of the alchemical tradition.

Palabras clave: Metales, Alquimia, Elixires, Transmutación, Teorías de la materia

Introduction

The subject *metals* has been a most important, polyfacetic, complex and fascinating matter throughout history due to the determinant role played by metals in all civilizations and cultures not only from an utilitarian point of view but also in connection with their mystical, magic and metaphysical meaning. As a matter of fact one of the most important pillars of the Neolithic revolution is based on the knowledge and use of metals by mankind as related to most of its needs as well as to many of its beliefs. Social progress, commerce, richness, war and conquest, travels and expeditions, work and art, technologies, etc. are everywhere bound to the production and use of metals. In addition to their indisputable utilitarianism in connection with the technological

progress of mankind, the protagonism of metals extends both to religious mystics beliefs and metaphysical theories of matter sustained over millennia, thereby making the subject of metals a most inter- and pluridisciplinary matter involving a lot of both humanistic and technical aspects covering the fields of religion, philosophy, myths, crafts and techniques, science and technology. Of special interest is the subject of metals within the frame of such a syncretic holistic system as was *alchemy*, aiming at the establishment of a unifying cosmovision of mystics, metaphysics and science.

The subject of Metallurgy was in Paracelsus' s cosmovision one of the basic pillars on which the «Ars Medica» was based together with Philosophy, Astronomy and Physics. In more actual terms Ihde [23] assumes *Ars Chemica*, the actual scientific chemistry, to derive from three main historical sources, i.e, Medicine, Alchemy and Metallurgy.

In the present communication attention will be paid exclusively to a number of aspects on old theories on matter and metals within the frame of the traditional meaning of "Metallography" which actually has acquired quite a different meaning as related to the structure of metals and alloys at the beginning of the present century as dealt with in detail by Smith [76]. As a matter of fact very little progress was made on the structure of metals in the period covered by this paper, as derived both from the lack of suitable scientific theories as well as from the insufficiency of experimental means available.

Considering that one of the important derivations of the holistic concept of alchemy is protochemical experimentation as dealt with elsewhere by the author [61] whereby metals played an essential role and also considering the fact that chemical experimentalism did not achieve a real scientific dimension until the end of the 18th c. it becomes self evident that the history of metals is to a great extent a fundamental part of the history of chemistry. For this reason the keywords related to the history of metals are associated with most of the fundamental concepts in chemistry (matter theories, elements and principles, mixture and combination, affinity, calcinations and combustion, pneumatics, etc.) bound traditionally with mystical and magical concepts (planetary gods, cosmical energies, planets, rituals, myths, etc.) as well as with metaphysical alchemical connotations (elixirs, tinctures, quintaessentiae, matter ennoblement, metal transmutation, etc.).

A curious fact in this history is the paradoxical great protagonism played by metals as compared with their reduced number which amounted to seven in

antiquity and remained very limited (up to about one dozen) until the middle of the 18th c. [62] considering that about three quarters of the more than 110 actually known elements are metals.

The importance of specific metals has depended historically on their abundance and uses: four of them were essentially utilitarian (Cu, Sn, Pb, Fe), referred to in early alchemy as *tetrasomy* as *prima materia* to carry out metal transmutations; two of them (Ag, Au) scarce and of limited technical utility were greedily sought for and highly appreciated as symbols of dignity, richness and power, even of divinity, perfection and immortality as was the case of gold in pharaonic Egypt. Many aspects of metals in antiquity are reviewed elsewhere [19, 33, 35, 48, 57, 84].

Even the etymology of the term *metal*, is a subject of curiosity since it derives from the original greek term *metallon*, not related specifically to metals, passing through the aristotleian term *metalleuta*, finally becoming *metallum*, the latin word in the actual context [19]. A detailed study of many important terms related to metallurgy and alchemy, all derived from the root *metal* has been carried out by Zacharias [86] indicative of the complexity and generalised confusionism resulting from the translation and interpretation of a lot of «metallic» terms related to ancient metallurgy and alchemy.

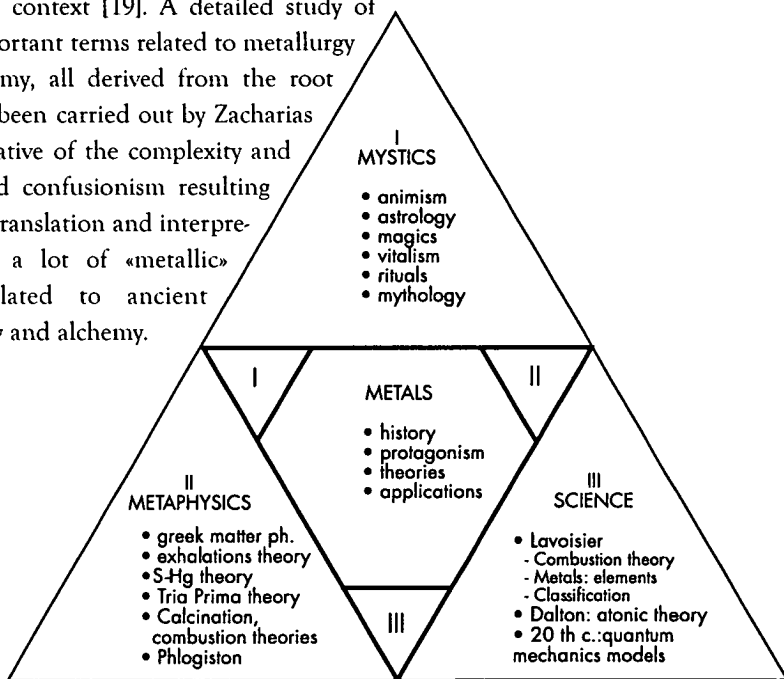


Fig. 1.- Stages of development of the science of metals within the frame of COMTE'S «three stadia law»

The pattern of the approach to metals in the present paper conform to the frame of Comte's «three stadia law» and to the author's holistic interpretation of alchemy [61] as depicted by Fig.1. In accordance to these guidelines a number of mystical and metaphysical aspects of metals will be dealt with considering the three main projections of the holistic concept of alchemy, namely :

- *hylic* (exoteric protochemical alchemy)
- *medicinal alchemy* (iatrochemistry)
- *mystical alchemy* (spiritual ; oriental macrobiotics)

The three projections of alchemy have in common the use and ennoblement of metals for achieving different purposes of complementary interest:

- *matter ennoblement* (metal transmutation)
- *body ennoblement* (pharmacological use of metals)
- *spiritual ennoblement* (use of metals for the preparation of elixirs of longevity and immortality in connection with macrobiotics and ascetical practices).

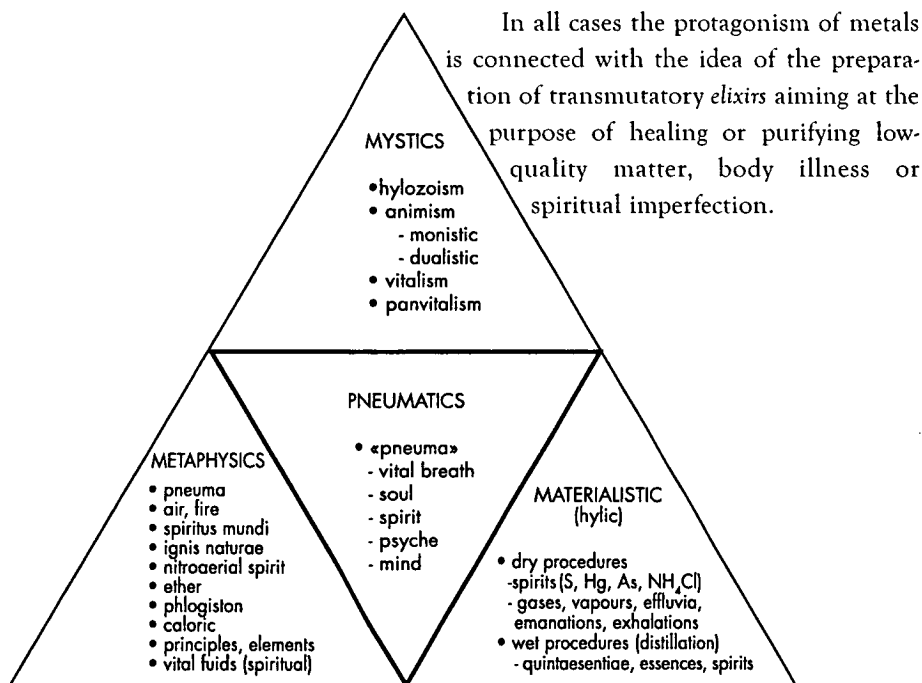


Fig. 2.- Overview on the projections of «pneumatics» of special incidence in alchemy and chemistry

A very important link bridging mysticism, metaphysics, alchemy and chemistry is *pneumatics*, a term with plenty of conceptual connotations related to activity, subtlety and thinness, both in figurative and actual sense, as summed up in Fig. 2, considering and differentiating mystical implications, some metaphysical aspects of the greek term *pneuma*, active alchemical *spirits* (volatile reactive substances) and distillates (*quintaessentiae*) ending with the materialistic chemical concept of gases and vapours which were the typical *airs* of pneumatic chemistry along the 18th c. the study of which led to such a fundamental chemical milestone as was the «chemical revolution» which meant the end of chemical metaphysics based on the phlogiston theory paving the way towards scientific modern chemistry. As a matter of fact, the decisive step for experimental chemistry to get rid of alchemical mystical and metaphysical connotations to become a new experimental science took place during the 18th c. on the basis of the development and interpretation of the so-called pneumatic chemistry, centered around gases, combustion and calcination of metals leading to such important conclusions as the identity (Van Helmont) and the chemical reactivity of gases (Black) ; the elucidation of the composition of air and water, the oxygen combustion theory and the definition and classification of simple bodies or elements, among them the known metals (Lavoisier).

Mystics, magics and metals

Without disregarding specific differences typical of old oriental and occidental civilisations metals have been historically associated with a lot of correspondences: gods and planetary deities, planets, numbers, symbols, geometric figures and magic squares and seals, sexuality, body organs, colours, plants and stones, etc. The art of metals has often been referred to in alchemical terms as «lower astronomy» and the protagonism of metals has been omnipresent in the traditional alchemical and chemical nomenclature plenty of chemical substances arbitrarily named after the seven planets, pictorial allegories and intriguing symbolisms up to the end of the 18th c. when it was rationalised and systematised by prominent french chemists [6, 46]. Two good



Fig. 3.- The chorus of the seven metals [Stolcius, «*Viridianum chemicum*», Frankfurt, 1749]



Fig. 4.- Astrological · metallic allegory of the alchemical «Magnus Opus» [Michelspacher, «Cabala», Augsburg, 1616]

representative examples of alchemical allegories for metals are depicted in Figs. 3 and 4.

Metals were considered alternatively in antiquity as telluric corporifications of cosmic principles, as solidified cosmic energies, as planetary elements, as astral spirits or effluviae condensed in the telluric matrix, as Shiva's semen (mercury), as condensed solar energy, etc. Extended hylozoistic thought gave rise to a generalised embryological concept on the genesis of metals whereby the earth plays the role of a telluric nurse or matrix where the seeds of metals grew, ripened and got gradually ennobled over very long periods of time to become finally precious metals (Ag, Au). Metallurgy exhibited a fundamental obstetric character, plenty of initiatic rites, aiming at the accelerated birth or

metal delivery in the crucible in substitution of the slow telluric matrix natural process, as dealt with by ELIADE [12]. In essence the work of the miner, metallurgist or alchemist aimed at the imitation and acceleration of natural slow metal maturation (ennoblement) processes. This idea was explicitly formulated in comparatively recent time by Paracelsus stating that «the purpose of alchemy is the finishing off of Nature, by chemical means and operations».

Extensive attention has been devoted to the bibliography of metal mysticism, mythology and hermetism in connection with the deciphering and interpretation of planetary correspondences [4, 33, 48, 57, 58, 71, 78], numerological associations and magic squares [11, 21, 26, 79, 80].

As mentioned above the influence of the tradition of mystic and magic aspects as related to metals lasted up to the 18th c. through a number of inherited beliefs maintaining many ancestral ideas such as the feeding and growth of metals in the bowels of the earth; the regeneration of exhausted mines by letting them rest sufficiently; ideas of sickness and healing of metals and minerals; the transmutation of air into ore; the revivification of metal seeds by sprinkling the mines with water; the sowing of metal filings to become metal seeds; the concept of metal fecundity, etc. [1]. Curious vitalistic conceptions arose in the 16-17th c. related to palingenesis and the so-called «metal vegetations»

[39, 69] such as the growing of «Diana's and Saturn's trees», typical crystallisation phenomena rightly interpreted by Homberg and Lémery.

A curious aspect of the 16th c., essentially reactionary against the stagnation of scholasticism, is to be found in the increased interest in magics and hermeticism quite compatible with new trends towards knowledge and science, a century where many important development in chemistry and metallurgy took place.

Renewed attention was paid by Ficino, Agrippa, Paracelsus and others to numerology and metals developing a system of magic squares and seals for metals, the antecedents of which can be traced back to chinese, arabic and llullian alchemical traditions. In addition, a pioneer attempt was made by Pantheus («*Voarchidumia*», Venedig, 1518) to connect alchemy and metal trasmutation with jewish thought aiming at the establishment of a cabbalistic science of metals, a trend which was followed in the 17th c. by Knorr and Rosenroth who developed a curious metal transmutational scheme based on cabbalist jewish sephirotical trees aiming at the obtention of a «metal medicine» allowing for the transmutation of bass metals into silver and gold [56, 70].

Special interest for the western civilization presents the Renaissance period in connection with the progress of metallurgy both as derived from inherited traditional sources as well as concerning new developments in technology, assay of metals and alloys and mining techniques. However, most of the ancient views on the constitution of metals, their genesis, matter theories, beliefs associated with elixirs and metal transmutation, etc. remained. A realistic picture of the state of the matter concerning ideas and facts about minerals, ores and metals during the 16-17th c. period is very well reflected in the classical books of Webster [84] and Rulandus (67). This period is summed up concisely and accurately by Suhling [82].

The progress of scientific knowledge has been historically hampered by the weight and extension of mystical and metaphysical conceptions which are two of the main obstacles to be overcome in the development of science. Bachelard [1] has paid special attention to the analysis of epistemological obstacles opposing the progress of science, some of them specifically affecting the understanding of metals which very clearly exemplify the weight of such obstacles together with a holistic hermetic cosmivision as was the case with alchemy, of direct impact on the metaphysics of matter, essentially qualitative and lacking any trend towards a metrological quantification of the protochemical experimentation associated with exoteric alchemical laboratory

work. However, as dealt with by Joly [24], alchemy can not be considered as irrational placed in its time considering the corresponding general status of science. The supposed irrationality of alchemy, a widely generalised concept lasting up to recent time, is but a short-sighted oversimplification entailing ignorance and misconceptions of past facts and attitudes in science as focused on our actual state of knowledge. Such a misconception was seemingly and purposely initiated in France by Lemery [63] in his own interest but can nowadays be easily superated by proper understanding of the holistic concept of alchemy [61].

As a matter of fact the world of metals is full of phantasies and legends which extended well up to the end of the 18th c. which is reflected for example, in the names given to some metals like nickel, related to «Old Nick» (Satan, devil) and cobalt, derived from «Kobold» (gnome, goblin) associated with metallurgical difficulties or mining dangers associated with their obtention and superstitious beliefs. A number of highly qualified scientists, among them Glauber, Boerhaave, Boyle and even Newton sustained quite phantastic beliefs on metals, as disclosed in the past few years by different authors, i.e., Dobs [10], Figala [14], Newman [52 - 54] and Principe [64].

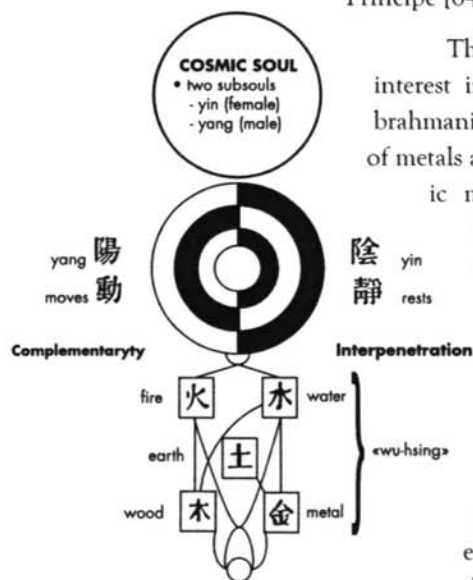


Fig. 5.- The derivation of metals as elements in the dualistic «yin-yang» chinese system

The mystics of metals also presents special interest in eastern civilisations [13, 65] relating brahmanic and tantric conceptions to the genesis of metals assumed to derive from divine hierogamic marriages (i.e., Agni-Apa; Hara-Gauri; Shiva-Parvati, etc.) each divinity representing some element or principle. Thus the generalised embryological concept of the genesis of metals closely resembles many beliefs sustained by most of the old mythical western civilisations.

However a distinctive feature of the use of metals lies in the strong emphasis relating metals and elixirs in the Chinese and Indian alchemical systems with mystical beliefs and macrobiotic practices whereby the role played by

animistic conceptions, the protagonism of cinnabar, herbometallic calcinations, etc. were essential aspects in connection with metal transmutation [37, 38]. A very curious feature of brahmanic alchemy lies in the fact of metal transmutation interdiction based on religious and social tenets directly related to the indian caste system which precludes ennoblement from original status be it persons or metals [65].

Very interesting animistic theories on the genesis and ennoblement of metals are put forward by Mahdihassan [36] based on the mystical significance of the red colour as related both to blood and life from which the author suggested three theories for metals as deriving from minium, cinnabar and minium and finally from cinnabar alone as a chronological development.

As regards to chinese mystics of metals the dualistic *yin-yang* system of oppositions is omnipresent as depicted by Fig.5 wherefrom the typical five-element *wuxing* theory derives, one of the elements being generically *metal*. A very typical feature of the chinese ideographic nomenclature for metals [83] as depicted by Fig. 6 lies in the fact that all metal ideograms are built by the combination of a generic root meaning metal or gold (second acception) with a second specific ideogram applying to each particular metal. The japanese ideographic system of representing metals is essentially identical with the Chinese one.

Another philological curiosity is the chinese ideogram for mercury built up by two ideograms associating a composed one (silver) with the simple ideogram for water, wherefrom it can be stated that the association of the ideas of liquidity, water,



Fig. 6.- Chinese ideograms for the metals and water

silver, metallicity and mercury is a striking common feature both in oriental and western alchemical and language systems. As a matter of fact, such an association becomes evident from the following names for mercury in different languages: *idrargiros* (greek), *hydrargyrum* (latin), *vive argent* (french), *kesef hay* (hebrew; «living silver»), *simab* (persian; «silver water»). The fact that mercury is also related to «life» in germanic, scandinavian and other languages is evident from the indogermanic root *jiv* or *giv* wherefrom

the following terms for mercury derive: *Quecksilber* (german), *quicksilver* (English), *quiksoelv* (scandinavian languages), whereby all *queck*, *quick* and *kvik* prefixes mean «life» thus associating the liquidity property with the *alive* metal mercury. The same conceptual association can easily be detected in other words for mercury both in islamic and slavonic languages: *zibak* (Persian), *zawuk* (Arabian), *zhivak* (Bulgarian), *dzhiva* (Azerbaijan) terms deriving all from the root *zhit* meaning the verb to live. There are of course exceptions to this general philological association (*life-silver=water-mercury*) as it happens for example in Russian which uses the term *rtut* for mercury totally devinulated from the above- mentioned derivations [18].

Another interesting feature of mercury —a metal of utmost importance in alchemical context as related to metal constitution and transmutatory elixirs— can be found in astronomic-astrological context due to the fact that the planet mercury is closest to the sun and therefore moving quickest from all planets, traditionally associated to specific metals, in this case to the mercury metal. A third important root for mercury derives from the Arabian *al-zauq*, *az-zauq* or *as-soc* roots [18] giving rise to the spanish latinised term *azogue*, synonymous of mercury still in use occasionally. This last term is of special interest in the alchemy of Renaissance since it is the mother-term of *azoth* meaning the metal transmutatory elixir, coined by Paracelsus and used frequently by Van Helmont. Special attention to many questions related to the *azoth* and to the closely related hypothetical universal solvent *alkahest* has been paid by Joly [25].

Mercury is a singular liquid metal bridging particularly well astronomy, astrology, mythology and alchemy in connection with the classical problem of metal transmutation where the proximity of mercury and gold is taken for granted in conceptual association with the proximity of the planet mercury to the sun, metaphorically associated with the gold metal, both within mythical and astrological-alchemical contexts. As will be discussed in coming lines mercury was considered for many centuries to be a fundamental constituent of metals which led to the coining of the *philosophical mercury* term, sinonimous with *elixir*, *azoth*, *philosophical stone*, etc.

Speaking now in pure scientific terms it is not without interest to consider the striking proximity of 80-Hg to 79-Au in the periodical classification system, a fact certainly recalling the traditional alchemical intuition upon which the transmutatory myth and dream of the *crysopeia* belief was based lasting for many centuries. Actual scientific knowledge accounts for the striking differences of the aggregation states and

general physical and chemical properties of both metals—despite their similar atomic structure and closest neighbourhood in the Periodical System of the elements—in mechano-quantical terms as derived from relativistic phenomena resulting from their high nuclear charges and electronic structures as discussed by Norrby «Why is mercury liquid?», [1991, *J.Chem. Ed.* 110-113]. As stated in the preceding lines philological examination can lead to very interesting conclusions concerning the general idea that all metals have something in common and very substantial. In this respect a further example is furnished by vedic hinduism which associated metals generically with the root *aya* suitably combined to refer to specific metals considering their colour [2], as illustrated by the names *krishaya* (black metal) for iron, *loitayas* (red metal) for copper, etc. evidencing that the property of *colour* has played a determining role in alchemy throughout the centuries in all cultures for any type of materials.

Metaphysics and metals

Historically the philosophy of matter is essentially qualitative metaphysics until Lavoisier's pragmatic definition based on chemical analytical criteria, concretion and classification of simple bodies, or chemical elements. It is out of the scope of this paper to review in depth the historical evolution of the theories of matter from the point of view of actual chemistry; however a few historical aspects of the theme deserve to be discussed briefly at this place.

Here we will recall on passing the monistic matter theories of ancient presocratic greek philosophers, the four or five element theories bound to the names of Empedocles, Plato and Aristotle; the five elements of the indian *panchatouan* and of the *wu-hsing* chinese theories; the dualistic sulphur-mercury arabian theory for metals deriving from the aristotleian *two-exhalations* theory or, perhaps from the chinese *yin-yang* dualistic system, to arrive later on to the paracelsian trichotomy of the *tria prima* to end finally with the *five-principle* theory of general adoption in the 17-18th c. as related to the interpretation of observations made on the products resulting from distillation and fire-analysis of any type of matter [9, 22].

Metaphysical principles played a determinant role in alchemy and chemistry up to the end of the 18th c. expressed in a variety of forms (*spirits, airs, effluviae, exhalations, fluids*, etc.) which were consubstantial to pneumatic chemistry, initiated by Van Helmont extending for over one and half centuries up to the end of the 18th c.

However, even after the abolition of the phlogiston theory quite a number of metaphysical theories on matter appeared during the 19th c. reaching even the beginning of the 20th c., some of them extremely phantasmagoric held even by very prestigious chemists [27, 77] clearly demonstrative of the conceptual problems posed by the constitution of matter before the irruption of atomic physics in modern science.

Brief attention will be paid in the following lines to a few of the most important theories on the constitution of metals which have played an important role in alchemy and chemistry up to Lavoisier's time.

Plato considered in his «Timaeus» that metals were built by forms of solidified water thus accounting for their fusibility distinguishing two types of water, liquid and fusible (heavier) the later accounting for the nature of metals. With the exception of gold as a perfect metal, all metals should contain varying amounts of water mixed with earth, the later separating as rust or dregs on ageing. The metal content of earth should account for the stability and hardness of the metals while the structural compression of the geometric building elements would determine the metal density (compactness).

Aristotle adhered essentially to his master's concept as regards the connection of the metal property of liquidity with the presence of water as an element thereby distinguishing between potential water which on melting becomes actual water. The permanent liquidity of mercury was considered by him to derive from the presence of air in the metal, in addition to water and earth. Contrary to his master however, Aristotle did not consider gold to be a perfect metal.

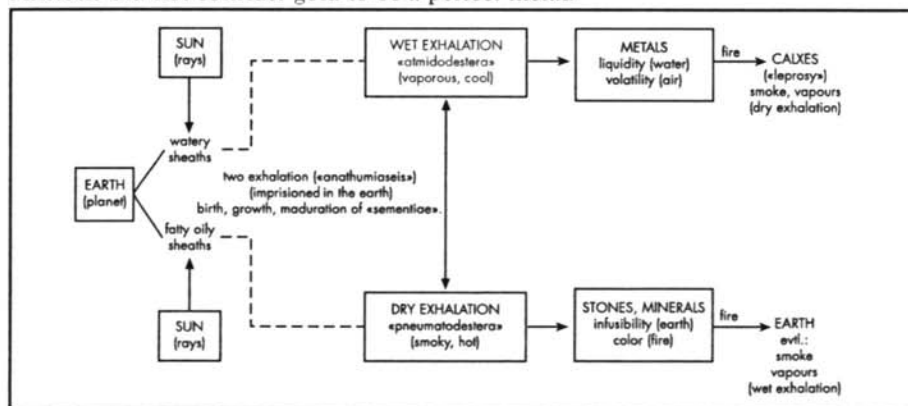


Fig. 7.- Conceptual interpretation of ARISTOTLE's two-exhalations theory for the genesis of the metals in the earth

Special interest on the genesis of metals presents Aristotle's *two-exhalations* theory briefly outlined in Fig.7.

The *gebberian corpus* (8-9th c.) introduced the sulphur-mercury theory in islamic alchemy to explain the constitution of metals probably as a syncretic derivation of Aristotle's *two-exhalations* theory and pneumatic stoic philosophy or, alternatively, related to the Chinese *yin-yang* system [7, 8]. This theory was based on the presence of two principles in metals, one of combustibility (*sulphur*: active, male, father, soul) and one of liquidity (*mercury*: female, mother, alternatively spirit or body in different contexts) the later being coagulated by the first one. This model of metals played a fundamental role in alchemy for many centuries, both in islamic and scholastic time until it was displaced by a new matter theory in the 16th c., the paracelsian *tria prima*, the originality of which has been contested occasionally, although after a careful and critical analysis of the question Hooykaas [«Chemical trichotomy before Paracelsus», *Arch.Int.d'Hist. des Sci.*, 28, 1063-74] has arrived to the conclusion that it was really a new original theory advanced by Paracelsus. Geber's matter philosophy is dispersed along a vast *corpus* of more than 70 books based on aristotleian hylemorfism although with some important modifications placing special emphasis on opposed qualities or «natures» of metals both internal and external [20, 28] assuming metals to be formed by the two mentioned principles: sulphur and mercury. The type and proportions of such qualities were considered to determine the physical properties of metals (purity, colour, weight, etc.). Metallic perfection was related to «balances» of qualities or natures, weights, ethymologies and numbers in a peculiar way focusing on the magic number 17, sinonimous of the *elixir*, metal perfection, etc. According to Geber all metals exhibit two natures, internal (occult) and external (manifest) each possessing a pair of opposing qualities which can be inverted by alchemical means thereby allowing for the transmutation of bass metals into noble ones, for example lead into gold.

Theories on the composition of metals based on opposition dialectics are a common very important aspect both in oriental and western alchemical systems [7, 8] where by metals are assumed to originate from the alchemical marriage of two opposing principles: *sulphur* (solar seed, *yang*, father, combustibility principle) and *mercury* (lunar seed, *yin*, mother, metallicity or liquidity principle). The alchemical marriage of fire and water, sulphur and mercury, etc. is therefore the basis of metal genesis as the result of the union of two fundamental complementary oppositions.

In oriental alchemy the union of sulphur and mercury materialised in *cinnabar* plays a very important protagonism for the preparation of elixirs suitable for metal, human body or spiritual ennoblement after a preliminary activation or «animation» of the two *subsouls* of cinnabar, *yang* (sulphur) and *yin* (mercury) by resorting to alchemical procedures based on controlled herboreal calcinations of selected starting metals or cinnabar [37, 38, 85]. Unity of oppositions as well as sexuality are fundamental aspects in connection with the genesis of metals within the alchemical context [60].

The connection between Aristotle's «two-exhalations» theory and the dualistic sulphur-mercury theory of the «Gebberian Corpus» is interpreted conceptually by the author

as depicted by Fig. 8 in line with Read's approach [66]. According to Cardano [47] the origin of this theory may well have derived from empirical old metallurgy based on observations that many ores submitted to roasting by fire and reduction by coal evolve sulphureous fumes (association sulphur-combustibility) yielding finally silvery liquids (association mercury-liquidity-metallicity).

The «Faithful Brother's Corpus» (10-th c.) adopted an aristotelic-neoplatonic pattern assuming metals to consist of body, spirit and soul—a theory adopted occasionally by different authors assumed erroneously to have been precursors of

Paracelsus's «tria prima» as discussed by Hooykaas—whereby their colour should be related to fire (sulphur), their purity and luster to air, metal softness and cohesion to some unctuous or *radical humidity* and metal weight to earthy components or *terrosity* [81].

Of special relevance for future metal theories is the concept of *unctuous humidity* in the constitution of metals to explain both their cohesion and relative lack of

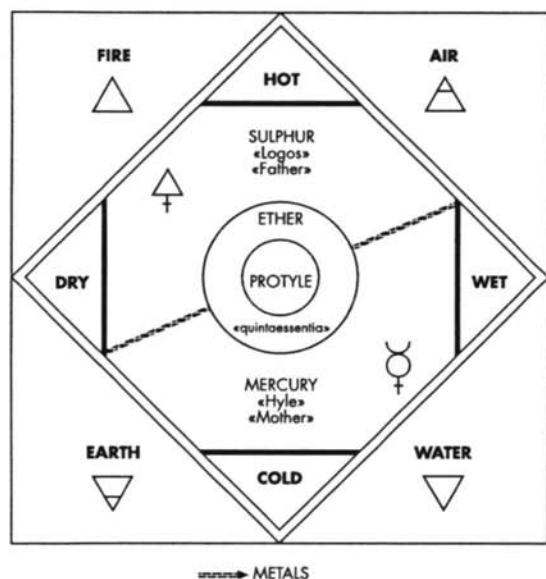


Fig. 8.- Derivation of the sulphur-mercury theory from the aristotelian elements to account for the composition of metals based on the two-exhalations theory

volatility upon melting, contrary to the behaviour exhibited by common water. To account for such a difference Aristotle postulated the existence of two types of humidity (fix and volatile) while the stoics accounted for the problem of cohesion and volatility of matter by introducing the *tonos* concept [68] associated with the interpenetrating *pneuma*. Albert Magnus paid special attention to the «unctuous humidity» of metals within Aristotle's way of thought, as dealt with by Freudenthal [15, 16] who concludes that such a question is directly related to the sulphur («fatty») component of metals acting both as a combustible and cohesive principle throughout the alchemical literature. Besides, the author assumes that such a principle can be considered a distant precedent of the *phlogiston* principle, passing historically through the *soul* principle of combustibility in the paracelsian *tria prima*, Becher's *terra pinguis*, Geoffroy's *principe huileux* to become finally *phlogiston* with Stahl along the 18th c. up to Lavoisier's introduction of the oxygen combustion theory.

Particular attention deserves a benedictine monk in the middle ages, known as pseudo-Geber, identified in all probability by Newman [49] as Paul of Taranto, who marks the culmination of mediaeval corpuscularianism in the 13-14th c. through the publication of the very important book «*Summa Perfectionis*» (13th c.) translated and critically commented by said scholar [49]. No doubt this is by far the most noticeable contribution to metals in the scholastic period thereby introducing a stoichiometric metal model deriving qualitative criteria relating the properties of metals to their composition based on similarity principles consecrated by tradition, as dealt with by Kubbinga [29]. Pseudo-Geber's «*Summa*» though including aspects based on Aristotle and the islamic alchemical and medical tradition presents a great number of important original innovations, to such an extent that it strongly influenced a great deal of important authors during the 13-14th c., being even adopted with corresponding modifications in the 17th c. by Van Helmont, Philaethes, Boyle and even Newton as a result of the revival of corpuscularianism and atomism in this century [6, 50-54].

Pseudo-Geber's metal theory is based on the sulphur-mercury pattern and explains in corpuscular terms many important properties of metals such as nobility, purity, activity, volatility, compacity, combustibility, malleability, amalgamability, etc. as related both to the relative composition, neighborhood of the two principles enhanced by *coction* or *concoction* and purity of the two principles considered and to the physical and structural characteristics of their corpuscles (size, packing, porosity, homogeneity, earthiness, etc.). In pseudo-Geber's view the four aristotleian elements are

corpuscular and from their union *per minima* arise the two metallic principles (sulphur and mercury) which by homeomeric juxtaposition (true mixture) by coction originate the metals. In this theory sulphur is related to impurity («earthiness»), porosity and metal corrosiveness while abundance of mercury of medium particle size («subtilis substantia», obtained by fractional distillation of mercury) is associated with metal nobility and perfection. The author differentiates between «essential sulphur» and «external sulphur», the first bound indissolubly to mercury while the latter acts as impurity or dreg hindering amalgamation of the base metal with mercury and considers two types of metal imperfections: accidental (superficial) and essential (profound) in connection with their eventual elimination by means of three types of elixirs or «metal medicines» of increasing ennoblement power. He further develops a metal theory based exclusively on mercury—based on the dualistic behaviour of mercury exhibiting both pneumatic and somatic properties— closely related to the preparation of the transmutatory elixir for metals, which was adopted by different authors in the 14th c.

However, attention should be paid to the fact that pseudo-Geber's theory is corpuscular, not atomistic in the classical sense, since no consideration whatsoever is given to such aspects as matter indivisibility, vacuum voids, atom shapes and movement. As a matter of fact his ideas represent a personal syncretism of aristotleian, platonic, stoic and corpuscular approaches to matter.

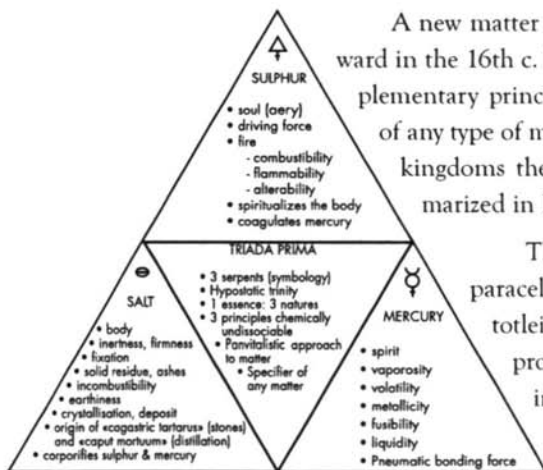


Fig. 9.- Conceptual implications of PARACELSUS's «tria prima» theory accounting for the constitution of any type of matter

A new matter theory, the *tria prima*, was put forward in the 16th c. by Paracelsus, based on three complementary principles extensive to the constitution of any type of matter within the frame of the three kingdoms the main aspects of which are summarized in Fig. 9.

The connection between the paracelsian three principles and the aristotleian four-element theory is a rather problematic question since the meaning of the paracelsian «element» concept is quite different from that of Aristotle [55] a fact that has originated a lot of misunderstandings and has led to

many misinterpretations, among them according to Hooykaas to the appearance of the five-principle theory, first formulated by Quercetanus in 1584 which was widely adopted along the 17th c. by most alchemists and physicians. Given the panvitalistic paracelsian cosmovision approach, metals were considered by him as animated matter [55] following extended old classical hylozoistic patterns. In Paracelsus's views a calcinated metal was but a *corpse* which had lost its *soul* escaping from the metal as a result of combustion although such a corpse could be enlivened again by suitable treatment with a soul-donating substance.

Most of Paracelsus's views on metals can be found in Webster's classical «Metallographia» [84], which deals with a lot of both sound and phantasiois views of metals within a frame of typical hermetism considering metal sexuality, the distinction of genuine metals from derivated «bastard» metals (i.e., Bi and Zn as related to the genuine Cu and Sn metals, respectively), the description of different types of «golds» and «mercuries», the conception that mercury was weak (as liquid) due to its constitution lacking enough coagulating sulphur and corporifying salt though he assumed the possibility of «strengthening» (solidifying) this metal by alchemical transmutatory practices, etc. On the other hand, a most positive aspect of Paracelsus's achievements is related to his ideas put into practice of using metals and their salts to heal body diseases thereby unfettering the *iatrochemical revolution* which led to the development of such an important medical field as is actually that of pharmacological chemistry.

It is also of interest to recall that Paracelsus established a criterion for metal classification based on their malleability which lasted for about two centuries. On the other hand Paracelsus's «tria prima» theory was adopted by most physicians, alchemists and chemist along the 17th c.

From iatrochemistry to phlogiston

While the «tria prima» theory protagonized most of the matter theory views during the 17th c. significant changes occurred in this century due to the coexistence of iatrochemists, atomistics and corpuscularians. The *tria prima* became progressively displaced in the 17-18th c. by the *five principles* conception introduced by Quercetanus and Basso [22] and was adopted by Lémery and other french physicians and chemists (Beguín, Glaser, Lefèvre, Willis, etc.) as derived from experimental observations made in connection with the different fractions obtained by distillation and fire-analysis

processes of many substances [9, 22]. As a matter of fact, corpuscular matter theories and the five-principles approach were perfectly compatible for most scientists in this period whereby atomism remained a metaphysical theory as imposed by unavoidable experimental limitations in contrast with the five-principle theory based on sensorial experimental evidence [40].

Metals acquired special protagonism during the 18th c. in connection with their direct implication in pneumatic chemistry which, although initiated by Van Helmont in the middle of the 17th, did not reach a real chemical dimension until the following century due to the discovery and investigations of new gases carried out by Cavendish, Scheele, Priestley, Black, Lavoisier, Bayen, etc., focused on the calcination of metals and their attack by mineral acids whereby all the investigations were concerned with the evolution, identification and isolation of important gases (hydrogen, nitrogen, carbon dioxide and oxygen mainly) during the 17-18th c. specially along the latter one after the generalised adoption of Stahl's *phlogiston* theory the main problem of it lying in the scientific interpretation of the weight increase accompanying the transformation of the metals into their *cakes* (oxides). Two main interpretative lines emerged to explain such a phenomenon: either the metals absorbed «something» during the calcination process from the flame or present in the air or, alternatively, the metals emitted «something» to the air, some kind of metallic common combustion principle, supposedly *phlogiston*.

In either case the calcinations process implied the essential idea of the transference of «something».

The main obstacle opposing the correct interpretation of the calcination process of metals derived from a number of facts:

- the ignorance of the composition of the air
- eventual hypothesis considering the presence of certain species suspended in the air which were supposed to be active in the calcinations process
- problematic interpretation of experimental observations (evolution of fumes and vapours, colour and density changes, etc.)
- speculations about the nature of light, heat, fire and flames
- the weight of traditional metaphysical matter theories

- the traditional infravaloration of the quantitative aspects of the chemical reactions centered exclusively on a qualitative paradigm
- total absence of the energy concept

Extensive attention has been paid by many authors to reviewing and discussing the many theories on the question put forward during the 16-18th c. to account for the constitution of metals and the explanation of their combustion mechanism and accompanying weight changes involved in the process of metal calcinations [59].

Table I. Theories on the constitution of metals along the 16th and 17th centuries.

AUTHOR	METAL THEORY	REMARKS
CARDAN	Hylozoistic approach. Metals assumed to be congealed water.	Discarded the sulphur-mercury theory.
PARACELSUS	"Tria Prima" theory. Panvitalist approach.	Ambiguous connection with aristotellic "elements" (55).
BIRINGUCCIO	Metals assumed to originate from the 4 elements by fermentation-decoction.	Discarded the sulphur-mercury theory.
AGRICOLA	Similar views as Plato's (earth and water).	Metal nobility increases with decreasing earth content.
TACHENIUS	Dualist theory based on two acid and alkali principles (43, 45, 57).	Metals effervescence by acid attack assumed to derive from alkali content.
SENDIVOGIUS	Assumed metals to be composed by a principal component (philosophical mercury or radical humidity) and sulphur (dry, secondary component) (10, 14).	Embryological theory based on sublimation and subtilisation of seeds of the four elements in the earth as matrix under the influence of natural "Archeus".
SENNERT	Corpuscularian approach to matter. Metals assumed to be "prima mixta" (2 nd order corpuscles) of the four elements (elementary corpuscular "minima") (41).	Follower of the 16-17 th corpuscularian revival initiated by Scaliger, Gassendi, etc., continuators of the medieval pseudo-Geber tradition.
Van HELMONT	Synthetic corpuscular approach to metals (pseudo-Geber) and paracelsian Vitalism adhering to the "mineral tree" theory (51).	Mystic-vitalistic theory departing from water as primeval element acted upon by internal or external ferments under Archeus action bringing about fermentation.
GEOFFROY/HOMBERG	Metals supposed to be composed by an earth and a sulphur principle.	The combustibility principle was referred to by Geoffroy as "principe huileux".

AUTHOR	METAL THEORY	REMARKS
BOYLE	Following Epicurus and Sennert proposed a dynamic atomistic theory based on a unique "catholic" (universal) matter. Rejected classical elements and principles. He was a clear figure of transition between classical alchemy and chemistry.	Used the concepts of corpuscular "clusters", "textures" and structures to account for the chemical properties of the corpuscles (30, 41). Sustained many alchemical views related to metal transmutation, "Alkahest", "acidum peracutum", etc. (64).
NEWTON	Doubted about the simplicity of metals. Developed a "shell" metal theory influenced by STARKEY and SENDIVOGIUS considering a complex sulphur-mercury metal model (atomic) based on matrix conception and nobility considering attractive forces related to the "magneshalybs" phenomenon (10, 14).	Attempted by many means to resolve metals into mores simple elemental parts and prepared many alloys under careful control of metal proportions (3, 10). Like Boyle was very interested in metal transmutation (10, 64) and practical alchemy.
STARKEY ("Philalletes")	Developed a corpuscular theory for metals. Considered metals not to differ substantially but only accidentally (maturity, purity, etc.). Proposed a "shell" mercury-sulphur particle model (52, 53).	Related metal "baseness" to the presence of a telluric "residual Humidity" deriving from incomplete coction in the earth. Postulated two types of sulphur in 3 sheaths: External sulphur (corrosibility) and internal sulphur (metallicity).
GLASER	Thought "alkahest" to be able to reduce metals to their principles (25, 43).	Assumed Bi and Zn to be types of sulphureous-earthly marcasites.
LEMERY	Considered marcasites to be metal excrements (43).	Marcasites supposed to be earths impregnated with metallic particles.
BOERHAAVE	Adhered to the sulphur-mercury theory. Zn, Bi, Sb considered "semimetals".	Hg was not considered as a metal but as the basis for all metals (44).
BECHER	Theory of three earths: "lapis" (body), "pinguis" (sulphureous), "mercurialis" (metallic) (44).	Theory derived from Paracelsus's "tria prima" and hylemorfism. Metal amalgams explained by attraction between mercury and the metal "terra fluida, mercurialis".
STAHL	Metals assumed to be compounds of an earth with "phlogiston" (\emptyset) as a weightless combustion principle (44, 59).	"Phlogiston" was derived from Becher's "terra pinguis". Otherwise adopted Becher's metal theory as did as well Juncker.
LOMONOSOV	Metals are poor in \emptyset which determines their properties (32).	Metal ennoblement hypothetically possible by increasing the \emptyset content.

AUTHOR	METAL THEORY	REMARKS
BERGMANN	Assumed metals to be the result of coagulating acids by great amounts of \emptyset , alternatively to consider metals as elements built by calxes with \emptyset (43).	Suggested a quantitative method for the determination of \emptyset in metals (72) which was found in complete disagreement by Kirwan who recalculated his results.
G. de MORVEAU	Assumed metals to be compounds of an earth and \emptyset with "vital air" (O_2).	Complete removal of \emptyset should hypothetically originate acids from metals.
MACQUER	Adhered to the 4 element theory. Metals supposedly were related to specific calxes a theory adhered to as well by Berthollet and Fourcroy.	Considered metals to very similar substances their calxes being ultimately the same earthy element differing only by incomplete elimination of \emptyset (34, 75).
BRANDT	Following Paracelsus classified metals as malleable and non-malleable.	Considered non-malleable metals as "semimetals" (Hg, Sb, Bi, Co, As, Zn).
LAVOISIER	Classified and tabulated metals as simple bodies (elements) whereby the refractory earths were considered provisorily as a particular group of elements (31).	The limit of chemical analytical resolution power was adopted as a criterion of "chemical elementarity" thereby allowing for further analytical improvements as done by Davy (electrolytical decomposition of refractory "earths").
DAVY	Advanced a fugacious theory considering metals to be composed by hydrogen (for him the only true "undecomposed body") and unknown bases as "metallicity principles" (73, 74).	Involutionistic theory reminiscent of the sulphur-mercury and phlogiston dualistic theories.
KLAPROTH	Refused to classify as metals the alkaline elements obtained by Davy as derived from the striking unusual low density shown by them.	Erman and Simon (1803) suggested the term "metalloid" for the alkaline metals as an alternative, a term finally recommended by Berzelius (1811) for non-metals accepted for many years (17). IUPAC nomenclature distinguishes actually between metals, semimetals (metalloids) and non-metals.

The notation \emptyset will be used henceforth for phlogiston

Table I summarizes a number of the main aspects of the theories on the constitution of metals according to the views held by different authors during the 16-18th c. period.

The for chemistry crucial theme related to metal combustion and calcination, with particular consideration of the phlogiston theory, can not be considered in detail at this place given its complexity, extension and transcendence for the

development of scientific chemistry. Instead, here we will conclude simply, as an advance for an eventual future development of the question with a personal synthesis of the interpretation of the metal calcination process within the frame of Comte's «three stadia law», as outlined schematically in Fig.10, considering mystical, metaphysical and scientific approaches to the theme, implying animistic vitalism, the metaphysical combustion principle *phlogiston* and the actual scientific explanation based on the transference of *electrons*, respectively.

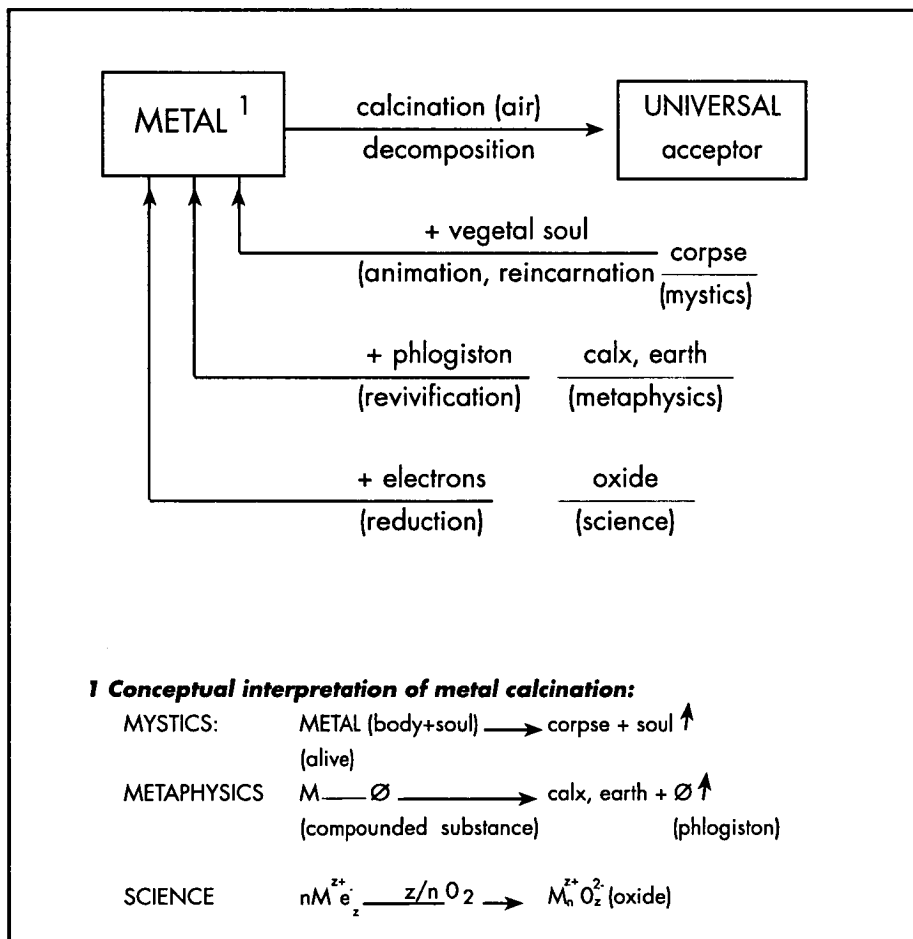


Fig. 10.- *Conceptual interpretation of metal calcination within the frame of COMTE'S «three stadia law»*

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