



From Alchemy to Chemistry

A path of symbols and symbolism

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Summary - How can we define “Alchemy”? Is it a science or just a pseudoscience that deals with the demand of metal transmutation into gold or the formula for the elixir of eternal youth? Did Chemistry evolved from the Alchemist arts? We can say that alchemy and chemistry have a common origin, related to the study of matter structure and composition and the transformations that occurred, but in alchemy the explanations are connected with the spirituality, the philosophy, the magic. The alchemical texts were (and are) almost always cryptic, written using symbols and symbolisms that make them only perceptible to initiates, and magical spells and recitations are used to invoke gods and demons favourable to the processes. Close in experimental processes and techniques, alchemy and chemistry are separated in a way similar to what separates the sacred from the profane or the material from the spiritual. Alchemists always claimed a special magic-religious moment when dealing with any substance, as they are working with matter considered sacred, that they are striving to transform, improve and transmute, but using the same apparatus and processes as a chemist.

Keywords: alchemy / chemistry / symbols / magic

Riassunto - Come di definisce l’“Alchimia”? È una scienza o solo una pseudoscienza che si occupa della trasmutazione dei metalli in oro o della formula per l’elisir di eterna giovinezza? La Chimica si è evoluta dalle arti alchemiche? Possiamo dire che l’alchimia e la chimica hanno un’origine comune, entrambe studiano la struttura della materia, la sua composizione e i suoi processi di trasformazioni, ma l’alchimia lo fa con un approccio spirituale, filosofico e magico. I testi alchemici erano (e sono) quasi sempre criptici, scritti utilizzando simboli e simbolismi che li rendono percepibili solo agli iniziati, accompagnati da incantesimi magici e formule per invocare dei e demoni favorevoli ai processi. Diverse nell’approccio nell’uso di tecniche sperimentali, l’alchimia e la chimica sono separate dallo stesso confine che separa sacro e profano, materiale e spirituale. Gli alchimisti si muovono in una dimensione magico religiosa che considera e tratta come sacra qualsiasi sostanza sottoposta a processi di trasformazione, miglioramento o trasmutazione, ma lavorando con la stessa apparecchiatura e seguendo gli stessi principi di un chimico.

Parole chiave: alchimia / chimica / simboli / magia

DESCRIPTION

To most of us the word “alchemy” brings up the image of witches hanging over boiling cauldrons in smoky dusty rooms, or of a medieval and slightly sinister laboratory in which an aged wizard deals with alembics and other equipment with strange names, intending to prepare the Philosopher’s Stone, or discover the formula for the elixir of eternal youth. But despite these mystical images, it is now clear that alchemy played an important role in the evolution of modern science.



Fig. 1 - Alchemist in his Workshop David Teniers d.J.c.1650 Courtesy of Roy Eddleman, Chemical Heritage Foundation Collections. Photo by Will Brown in https://artblart.files.wordpress.com/2014/07/4_teniers-dj-web.jpg

ETYMOLOGY OF THE WORD "ALCHEMY"

There is no consensus about the etymological origin of the word Alchemy. It may have come from the Arabic word "al-khimiya" or "al-kimiya". The "al-" part of the Arabic word is the definitive article, like "the" in English, and according to the *Oxford English Dictionary*, "kimiya" comes from the Egyptian word "kem-it" or "kam-it" that means the colour black and also the fertile Nile lands of Egypt, known as the "black land". Others think that "kimiya" comes from the Greek word "khumeia" or "khemeia" that means the art of melting metals and producing alloys (Ferrario 2007). Another possibility is that alchemy derived from the Chinese word Chin-I or Chin-je that means "gold juice", used to denote elixirs (Haefner 2004). Still another possibility suggests that the word *al-kimiya* derives from the Hebrew *kim Yah*, meaning "divine science" (Ferrario 2007).

FROM THE FOUR ELEMENTS TO ELECTRONS AND PROTONS

Alchemical reports emerge in various ancient civilizations such as Egypt, Mesopotamia, Greece, Rome, India and China. It is, however, considered that the real genesis of alchemy oc-

curred around the 6th century B.C., with Thales of Miletus. Since the beginning until our days the main goals of alchemists were the transmutation of metal into gold, using the philosopher's stone, and to find the formula of the elixir of eternal youth. These first alchemists were essentially philosophers who wanted to know the world around them and with their quest they contributed to the development of fields of knowledge as different as astronomy, chemistry, medicine or physics.

In his pursuit to explain the world around him, Thales of Miletus considered water as the essence of all matter. Empedocles of Agrigentum (460-370 BC), one of his followers, proposed that all matter is composed by four primary elements: Fire, Air, Water and Earth. But none of these elements can be identified with what is found in nature. Empedocles identified them with the mythical names: Zeus, Hera, Nestis, and Aidoneus. Each of the elements, or "root" as he designated them, would be formed by a blend of the other elements. Thus, a rock always had some water and the water a bit of earth element, as would be demonstrated by the evaporation of water and observing the solids precipitated. (Kingsley, 1995)

"Now hear the fourfold roots of everything: enlivening Hera, Hades, shining Zeus, and Nestis, moistening mortal springs with tears" (Kingsley 1995).

Plato (ca 428-348 BC) was a Greek philosopher and mathematician, that contributed to the four elements theory describing nature as being ruled by five perfect solids (the platonic solids), figure 2, whose faces are regular polygons (equilateral triangles, squares, or regular pentagons).

He associated four of those perfect solids with the four primary elements (table 1) and the fifth one, the dodecahedron (with more interesting mathematical features) with 12 faces (the number of the Zodiac signs) with the shape of regular pentagons (one of the most important symbols of alchemy) representing the universe as a whole.

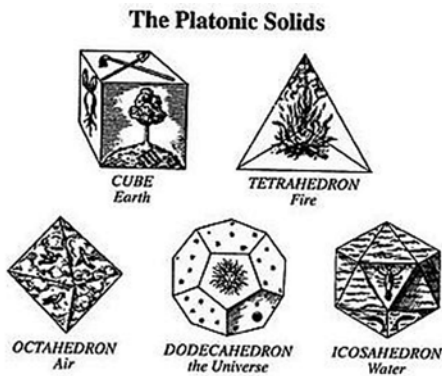


Fig. 2 - The Platonic Solids. Photo in <https://www.buzzfeed.com/>

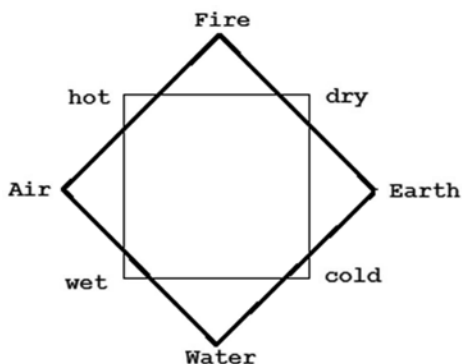


Fig. 3 - The Four Elements of Aristotle, based on a diagram from Isidore of Seville, *Liber de responsione mundi*, 1472 (in: <http://newmediaabington.pbworks.com/w/page/26052773/ART%20201%20-%20Vector%20%20-%20Geometry,%20Color,%20Meaning>)



Solid	n. of faces	Shape of faces	Faces at a vertex	Properties	Element
Tetrahedron	4	Triangle	3	Sharp, pointed	Fire
Cube	6	Square	3	lumpish, packable	Earth
Octahedron	8	Triangle	4	Smooth, sliding	Air
Icosahedron	20	Triangle	5	droplet	Water
Dodecahedron	12	Pentagon	3		Universe as a whole

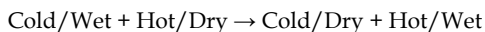
Table 1



Aristotle (384-322 BC), pupil of Plato and one of the great thinkers of antiquity, followed the theory of the four elements (Fire, Air, Water and Earth) but proposed the existence of a primordial element, the "ether" that would occupy the space between the four elements (Fig. 3).

He assigned four opposite forces (hot, cold, dry, wet) acting between the elements, disposed in the vertices of a square, one of the key figures of alchemy, as depicted below.

Hot is the principle of energy and movement; cold the principle of inertia; wet the unifying principle; and dry the separation principle. Thus, fire is associated to hot and dry; air to warm and wet; water to cold and wet; and earth to cold and dry. The fire was neither solid nor liquid or gaseous but an internal energy form (the same concept will be, in the 18th century, designated as calorie by Lavoisier). The elements can be transformed into each other by a change in their opposite constituents. Thus, Water becomes Earth when wet leaves and dry comes in the system and a mixture of Fire and Water can become Earth and Air by a double decomposition reaction. (Keyser 1990).



While the theory of the four elements passed through the process of evolution, Democritus (ca 460-370 BC) introduces the first "modern" theory of the structure of matter. He states that all matter consists of atoms that are surrounded by void, considered as real as the atoms. The atoms were defined as the smallest particle that could be obtained. There would be an infinite number of atoms that differ in size, shape and temperature, were always moving, and were invisible. But this theory will be forgotten until the seventh century.

Paracelsus (1493-1531) was one of the most important European alchemists, considered to be the true founder of the Rosicrucianism, which combined religious, occult, and alchemical beliefs. He believed that the body's organ worked alchemically, separating the impure from the pure. He proposed that matter was formed by a balance between mercury (characterized as female) and sulfur (characterized as male) and salt, as the third principle. The relationship is

depicted as a triangle (Kingsley 1995), as we can see below.

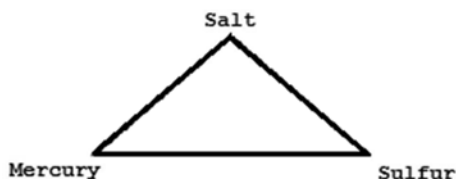
To Paracelsus this scheme reflects the cosmos and the human microcosm. But in fact this scheme reflects the Trinity: it represents God, and has a single essence formed by the three entities; whilst the human being consists of three essences: Spirit (Mercury), Soul (Sulfur) and Body (Salt). Paracelsus treated the plague and other diseases giving salts, mineral and metals to patients (Greenberg 2007).

Descartes (1596-1650) was an anti-atomistic, rejected the four qualities of Aristotle considering only two principles in matter: extent and movement, what led him to reject the idea of finite atoms and void (Greenberg 2007).

The philosopher Robert Boyle (1627-1691) was an atomist and assumed that matter is constituted by corpuscles or atoms joining to form all the elements and compounds that are known. He was an alchemist and believed in metal transmutation and he carried out experiments to achieve it. Maybe it was one of such attempts that led him to the formulation of Boyle's law an experimental gas law that describes how the pressure of a gas tends to increase as the volume of said gas decreases (Greenberg 2007).

Thus, in the seventeenth and the eighteenth centuries the conflict between the two schools: the Cartesian and the corpuscular, which includes Robert Boyle and Isaac Newton, remained.

In the modern concept, the atom is composed by three fundamental particles: protons (positive charge); neutrons (no charge) and electrons (negative charge). Electrons are the fundamental particles of infinite lifetime and are actually one of six subatomic particles called leptons. Protons and neutrons are not considered fundamental and are two of a very complex class of subatomic particles called hadrons. Outside of the nucleus, a neutron has a half-life of only 17 minutes and decays into a proton, a β particle and an antineutrino. Based upon this modern view, we can draw a triangle that connects the 3 particles, like in Paracelsus theory (Greenberg 2007).

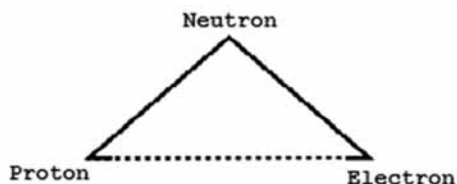


ALCHEMIST SYMBOLS

Alchemy is the domain of symbols. For a time the astronomical symbols of the planets were used to denote the elements. However, as alchemists came to be persecuted, particularly in medieval times, secret symbols were invented for the same elements. This led to a great deal of confusion, but those symbols were in common use through the 17th century and some are still in use today.

The symbols alchemy for the four primary elements (below) were used until the late 18th century.

On figure 4 we can identify the alchemists symbols used for Paracelsus principles (sulfur, mercury and salt), the planets and some of the alchemic operations (that are often represented by the zodiac symbols).





l'explication des caracteres		chymiques.	Feuillet 153.
Acier, fer ou mars.....♁	signe celeste.....☿	Gomme.....☿	Saffran de fer ou crocus de mars.....♁
Aimant.....♁	Cancer ou leserueisse.....♋	Haue.....♁	Sagittaire signe celeste.....♐
Air.....♁	signe celeste.....♋	Huille.....♁	Sauon.....♁
Alambic.....☒	Cendres.....☒	Iour.....♁	Scorpion signe celeste.....♏
Alun.....☉	Cendres graueles.....☒	Limeaux signe celeste.....♏	Sel alkali.....☒
Amalgame.....☿	Chaux.....☿	Lion signe celeste.....♌	Sel armoniac.....☿
Antimoine.....♁	Chaux viue.....☿	Lit sur lit ou stratum super stratum.....☿	Sel comun.....☿
Aquarius ou verseau.....♁	Cinnabre ou vermillon.....☿	Marcassite.....☿	Sel gemme.....☿
Signe Celeste.....☿	Cire.....☿	Mercur precipite.....☿	Soulfre.....☿
Argent ou lune.....☾	Croiset.....☿	Mercur sublimé.....☿	Soulfre noir.....☿
Argent vif ou mercure.....☿	Cuivre calciné.....☿	Mois.....☿	Soulfre desphilosophes.....☿
Aries, ou le belier signe celeste.....♈	as restum ou crocus de venis.....☿	Nitre ou salpêtre.....☿	Sublimer.....☿
Arsenic.....☿	Distiller.....☿	Nuit.....☿	Tal:K.....☿
Bain.....B	Eau.....☿	Or ou soleil.....☉	Tartre.....☿
Bain marie ou bain marin.....MB	Eau forte.....☿	Opment.....☿	Taureau signe celeste.....♉
Bain vaporeux ou bain de rose.....VB	Eau regale.....☿	Plomb ou saturne.....☿	Terre.....☿
Balance signe celeste.....☿	Esprit.....☿	Poissons signe celeste.....♋	Teste morte.....☿
Borax.....☿	Esprit de vin.....☿	Poudre.....☿	Tutie.....☿
Briques.....☿	Esprit de iupiter.....☿	Precipiter.....☿	Verre.....☿
Capre ou Capricorne.....♁	Farine de briques.....☿	Purifier.....☿	Verdet ou vert de gris.....☿
	Feu.....☿	Quinte essence.....☿	Vinaigre.....☿
		Realnar.....☿	Vinaigre distille.....☿
		Retorte, Cornue.....☿	Vitriol.....☿
		Sable.....☿	Vrine.....☿

Fig. 4 - Alchemical Symbols, in: http://www.alchemywebsite.com/fevre_symbols.html

By the end of the 18th century, chemistry had parted from alchemy. Among the most significant first chemists there was Lavoisier, who wrote the first true chemistry book.

Dimitri Mendeleev (1834–1907) was a Russian chemist that formulated the Period Law of the elements.

Based on the properties of the known elements, he predicted the proprieties of the missing ones, which lead to the discovery of several new elements. From the 118 elements confirmed by IUPAC on December 2015 only 94 exist in nature, the elements with atomic number from 94 to 118 have been synthesized in laboratories or nuclear reactors by researchers that were looking for them based on Mendeleev Periodic Table (IUPAC 2016).

Ueber die Beziehungen der Eigenschaften zu den Atomgewichten der Elemente. Von D. Mendelejeff. — Ordnet man Elemente nach zunehmenden Atomgewichten in verticale Reihen so, dass die Horizontalreihen analoge Elemente enthalten, wieder nach zunehmendem Atomgewicht geordnet, so erhält man folgende Zusammenstellung, aus der sich einige allgemeinere Folgerungen ableiten lassen.

			Ti = 50	Zr = 90	? = 180
			V = 51	Nb = 94	Ta = 182
			Cr = 52	Mo = 96	W = 186
			Mn = 55	Rh = 104,4	Pt = 197,4
			Fe = 56	Ru = 104,4	Ir = 198
		Ni =	Co = 59	Pd = 106,6	Os = 199
H = 1			Cu = 63,4	Ag = 108	Hg = 200
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79,4	Te = 128?	
	F = 19	Cl = 35,5	Br = 80	J = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75,6	Th = 118?		

1. Die nach der Grösse des Atomgewichts geordneten Elemente zeigen eine stufenweise Abänderung in den Eigenschaften.

2. Chemisch-analoge Elemente haben entweder übereinstimmende Atomgewichte (Pt, Ir, Os), oder letztere nehmen gleichviel zu (K, Rb, Cs).

3. Das Anordnen nach den Atomgewichten entspricht der *Werthigkeit* der Elemente und bis zu einem gewissen Grade der Verschiedenheit im chemischen Verhalten, z. B. Li, Be, B, C, N, O, F.

4. Die in der Natur verbreitetsten Elemente haben *kleine* Atomgewichte

Fig. 5 - The first view of Mendeleev's periodic Table - an extract from *Zeitschrift für Chemie*, 1869 in: <http://www.rsc.org/education/teachers/resources/periodictable/pre16/develop/mendeleev.htm>

Chemists all around the world are working on the development of new techniques and inventions, and like alchemists, sometimes they isolate or purify specific components; other findings may come from developing new compounds. Philosophers of chemistry discuss issues like symmetry and chirality in nature. Chemists, biochemists and biologists still debate the origins of those properties and some speculate that the answer can only be found in comparison with extra-terrestrial life (if they can ever find it!). Maybe the chemistry of the 21st century is not so far away from alchemy, as we might have thought...



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