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Alchemy is an early protoscientific and philosophical discipline combining elements of chemistry, metallurgy, physics, medicine, astrology, semiotics, mysticism, spiritualism, and art. Alchemy has been practiced in ancient Egypt, India, and China, in Classical Greece and Rome, in the Islamic empire, and then in Europe up to the 19th century — in a complex network of schools and philosophical systems spanning at least 2500 years.

Western alchemy has always been closely connected with Hermeticism, a philosophical and spiritual system that traces its roots to Hermes Trismegistus, a syncretic Egyptian-Greek deity and legendary alchemist. These two disciplines influenced the birth of Rosicrucianism, an important esoteric movement of the 17th century. In the 19th century, as mainstream alchemy evolved into modern chemistry, its mystic and Hermetic aspects became the focus of a modern spiritual alchemy, where material manipulations are viewed as mere symbols of spiritual transformations.

The alchemists did not follow what is now known as the scientific method, and much of the "knowledge" they produced was later found to be banal, limited, wrong, or meaningless. Today, the discipline is of interest mainly to historians of science and philosophy, and for its mystic, esoteric, and artistic aspects. Nevertheless, alchemy was one of the main precursors of modern sciences, and we owe to the ancient alchemists the discovery of many substances and processes that are the mainstay of modern chemical and metallurgical industries.

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Overview

Alchemy as a proto-science

The common perception of alchemists is that they were pseudo-scientists, crackpots and charlatans, who attempted to turn lead into gold, believed that the universe was composed of the four elements of earth, air, fire, and water, and spent most of their time concocting miraculous remedies, poisons, and magic potions.

This picture is rather unfair. Although many alchemists were indeed crackpots and charlatans, many were well-meaning and intelligent scholars, who were simply struggling to make sense of a subject which, as we now know, was far beyond the reach of their tools. These people were basically "proto-scientists", who attempted to explore and investigate the nature of chemical substances and processes. They had to rely on unsystematic experimentation, traditional know-how, rules of thumb, — and plenty of speculative thought to fill in the wide gaps in existing knowledge.

Given these conditions, the mystic character of alchemy is quite understandable: to the early alchemist, chemical transformations could only seem magical phenomena governed by incomprehensible laws, whose potential and limitations he had no way of knowing. Having discovered that a specific procedure could turn an earth-like ore into glistening metal, it was only natural to speculate that some different procedure could turn a metal into another.

At the same time, it was clear to the alchemists that "something" was generally being conserved in chemical processes, even in the most dramatic changes of physical state and appearance; i.e. that substances contained some "principles" that could be hidden under many outer forms, and revealed by proper manipulation. Throughout the history of the discipline, alchemists struggled very hard to understand the nature of these principles, and find some order and sense in the results of their chemical experiments — which were often undermined by impure or poorly characterized reagents, the lack of quantitative measurements, and confusing and inconsistent nomenclature.

In spite of those difficulties, and of many false turns and loops, the alchemists managed to make steady progress in the understanding of the natural world. To them we owe the discovery of many important substances and chemical processes, which paved the way for the modern science of chemistry, and are still the mainstay of today's chemical and metallurgical industries.

The changing goals of alchemy

The best known goals of the alchemists were the transmutation of common metals into gold or silver, and the creation of a "panacea", a remedy that supposedly would cure all diseases and prolong life indefinitely. Starting with the Middle Ages, European alchemists invested much effort on the search for the "philosopher's stone", a mythical substance that was believed to be an essential ingredient for either or both of those goals. Alchemists enjoyed prestige and support through the centuries, though not for their pursuit of those unattainable goals, nor the mystic and philosophical speculation that dominates their literature. Rather it was for their mundane contributions to the "chemical" industries of the day — ore testing and refining, metalworking, production of ink, dyes, paints, and cosmetics, leather tanning, ceramics and glass manufacture, preparation of extracts and liquors, and so on. (It seems that the preparation of *aqua vitae*, the "water of life", was a fairly popular "experiment" among European alchemists.)

On the other hand, alchemists never had the intellectual tools nor the motivation to separate the physical (chemical) aspects of their craft from the metaphysical interpretations. Indeed, from antiquity until well into the Modern Age, a physics devoid of metaphysical insight would have been as unsatisfying as a metaphysics devoid of physical manifestation. For one thing, the lack of common words for chemical concepts and processes, as well as the need for secrecy, led alchemists to borrow the terms and symbols of biblical and pagan mythology, astrology, kabbalah, and other mystic and esoteric fields; so that even the plainest chemical recipe ended up reading like an abstruse magic incantation. Moreover, alchemists sought in those fields the theoretical frameworks into which they could fit their growing collection of disjointed experimental facts.

Starting with the middle ages, alchemists increasingly came to view these metaphysical aspects as the true foundation of alchemy; and chemical substances, physical states, and material processes as mere metaphors for spiritual entities, states and transformations. Thus, both the transmutation of common metals into gold and the universal panacea symbolized evolution from an imperfect, diseased, corruptible and ephemeral state towards a perfect, healthy, incorruptible and everlasting state; and the philosopher's stone then represented some mystic key that would make this evolution possible. Applied to the alchemist himself, the twin goal symbolized his evolution from ignorance to enlightenment, and the stone represented some hidden spiritual truth or power that would lead to that goal. In texts that are written according to this view, the cryptic alchemical symbols, diagrams, and textual imagery of late alchemical works typically contain multiple layers of meanings, allegories, and references to other equally cryptic works; and must be laborously "decoded" in order to discover their true meaning.

Some humanistic scholars now see these spiritual and metaphysical allegories as the truest and most valuable aspect of alchemy, and even claim that the development of chemistry out of alchemy was a "corruption" of the original Hermetic tradition. Most scientists, on the other hand, tend to take quite the opposite view: to them, the path from the material side of alchemy to modern chemistry was the "straight road" in the evolution of the discipline, while the metaphysically oriented brand of alchemy was a "wrong turn" that led to nowhere. In any case, the naïve interpretations of some alchemists or the

fraudulent hopes fostered by others should not diminish the undertakings of the more sincere practitioners.

Alchemy and astrology

Since its earliest times, alchemy has been closely connected to astrology — which, in Islam and Europe, generally meant the traditional Babylonian-Greek school of astrology. Alchemical systems often postulated that each of the seven planets known to the ancients "ruled" or was associated with a certain metal. See the separate article on astrology and alchemy for further details.

Alchemy in the age of science

Up to the 18th century, alchemy was actually considered serious science in Europe; for instance, Isaac Newton devoted considerably more of his time and writing to the study of alchemy than he did to either optics or physics, for which he is famous, (see Isaac Newton's occult studies). Other eminent alchemists of the Western world are Roger Bacon, Saint Thomas Aquinas, Tycho Brahe, Thomas Browne, and Parmigianino. The decline of alchemy began in the 18th century with the birth of modern chemistry, which provided a more precise and reliable framework for matter transmutations and medicine, within a new grand design of the universe based on rational materialism.

In the first half of the nineteenth century, one established chemist, Baron Carl Reichenbach, researched on concepts similar to the old alchemy, such as the Odic force, but his research did not enter the mainstream of scientific discussion.

Matter transmutation, the old goal of alchemy, enjoyed a moment in the sun in the 20th century when physicists were able to convert lead atoms into gold atoms via a nuclear reaction. However, the new gold atoms, being unstable isotopes, lasted for under five seconds before they broke apart. More recently, reports of table-top element transmutation — by means of electrolysis or sonic cavitation — were the pivot of the cold fusion controversy of 1989. None of those claims have yet been reliably duplicated.

Alchemical symbolism has been occasionally used in the 20th century by psychologists and philosophers. Carl Jung reexamined alchemical symbolism and theory and began to show the inner meaning of alchemical work as a spiritual path. Alchemical philosophy, symbols and methods have enjoyed something of a renaissance in post-modern contexts, such as the New Age movement. Even some physicists have played with alchemical ideas in books such as *The Tao of Physics* and *The Dancing Wu Li Masters*.

Alchemy as a subject of historical research

The history of alchemy has become a vigorous academic field. As the obscure—*hermetic*, of course—language of the alchemists is gradually being "deciphered", historians are becoming more aware of the intellectual connections between that discipline and other facets of Western cultural history, such as the sociology and psychology of the

intellectual communities, kabbalism, spiritualism, Rosicrucianism, and other mystic movements, cryptography, witchcraft—and, of course, the evolution of science and philosophy.

Etymology

The word *alchemy* comes from the Arabic *al-kīmiya* or *al-khīmiya* (الكيمياء or الخيمياء), which might be formed from the article *al-* and the Greek word *chumeia* (χυμεία) meaning "cast together", "pour together", "weld", "alloy", etc. (from *khumatos*, "that which is poured out, an ingot", or from Persian *Kimia* meaning "gold." A decree of Diocletian, written about 300 CE in Greek, speaks against "the ancient writings of the Egyptians, which treat of the *khēmia* [transmutation] of gold and silver".

It has been suggested that the Arabic word *al-kīmiya* actually means "the Egyptian [science]", borrowing from the Coptic word for "Egypt", *kēme* (or its equivalent in the Mediaeval Bohairic dialect of Coptic, *khēme*). The Coptic word derives from Demotic *kmi*, itself from ancient Egyptian *kmt*. The ancient Egyptian word referred to both the country and the colour "black" (Egypt was the "Black Land", by contrast with the "Red Land", the surrounding desert); so this etymology could also explain the nickname "Egyptian black arts". However, this theory may be just an example of folk etymology.

History

Extract and symbol key from a 17th century book on alchemy. The symbols used have a one-to-one correspondence with symbols used in astrology at the time.

Alchemy encompasses several philosophical traditions spanning some four millennia and three continents. These traditions' general penchant for cryptic and symbolic language makes it hard to trace their mutual influences and "genetic" relationships.

One can distinguish at least two major strands, which appear to be largely independent, at least in their earlier stages: Chinese alchemy, centered in China and its zone of cultural influence; and Western alchemy, whose center has shifted over the millennia between Egypt, Greece and Rome, the Islamic world, and finally back to Europe. Chinese alchemy was closely connected to Taoism, whereas Western alchemy developed its own philosophical system, with only superficial connections to the major Western religions. It is still an open question whether these two strands share a common origin, or to what extent they influenced each other.

Alchemy in Ancient Egypt

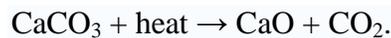
The origin of western alchemy may generally be traced to ancient (pharaonic) Egypt. Metallurgy and mysticism were inexorably tied together in the ancient world, as the transformation of drab ore into shining metal must have seemed to be an act of magic

governed by mysterious rules. It is claimed therefore that Alchemy in ancient Egypt was the domain of the priestly class.

Egyptian alchemy is known mostly through the writings of ancient (Hellenic) Greek philosophers, which in turn have often survived only in Islamic translations. Practically no original Egyptian documents on alchemy have survived. Those writings, if they existed, were likely lost when the emperor Diocletian ordered the burning of alchemical books after suppressing a revolt in Alexandria (292), which had been a center of Egyptian alchemy.

Nevertheless archaeological expeditions in recent times have unearthed evidence of chemical analysis during the Naqada periods. For example, a copper tool dating to the Naqada era bears evidence of having been used in such a way (reference: artifact 5437 on display at [1]). Also, the process of tanning animal skins was already known in Predynastic Egypt as early as the 6th millennium BC [2]; although it possibly was discovered haphazardly.

Other evidence indicates early alchemists in ancient Egypt had invented mortar by 4000 BC and glass by 1500 BC. The chemical reaction involved in the production of Calcium Oxide is one of the oldest known (references: Calcium Oxide, limekiln):



Ancient Egypt additionally produced cosmetics, cement, faience and also pitch for shipbuilding. Papyrus had also been invented by 3000 BC.

Legend has it that the founder of Egyptian alchemy was the god Thoth, called Hermes-Thoth or Thrice-Great Hermes (*Hermes Trismegistus*) by the Greek. According to legend, he wrote what were called the forty-two Books of Knowledge, covering all fields of knowledge—including alchemy. Hermes's symbol was the caduceus or serpent-staff, which became one of many of alchemy's principal symbols. The "Emerald Tablet" or *Hermetica* of Thrice-Great Hermes, which is known only through Greek and Arabic translations, is generally understood to form the basis for Western alchemical philosophy and practice, called the hermetic philosophy by its early practitioners.

The first point of the "Emerald Tablet" tells the purpose of hermetical science: "in truth certainly and without doubt, whatever is below is like that which is above, and whatever is above is like that which is below, to accomplish the miracles of one thing." (Burckhardt, p. 196-7) This is the macrocosm-microcosm belief central to the hermetic philosophy. In other words, the human body (the microcosm) is affected by the exterior world (the macrocosm), which includes the heavens through astrology, and the earth through the elements. (Burckhardt, p. 34-42)

It has been speculated that a riddle from the Emerald Tablet—"it was carried in the womb by the wind"—refers to the distillation of oxygen from saltpeter—a process that was unknown in Europe until its (re)discovery by Sendivogius in the 17th century.

In the 4th century BC, the Greek-speaking Macedonians conquered Egypt and founded the city of Alexandria in 332. This brought them into contact with Egyptian ideas. See Alchemy in the Greek World below.

Chinese alchemy

Whereas Western alchemy eventually centered on the transmutation of base metals into noble ones, Chinese alchemy had a more obvious connection to medicine. The philosopher's stone of European alchemists can be compared to the Grand Elixir of Immortality sought by Chinese alchemists. However, in the hermetic view, these two goals were not unconnected, and the philosopher's stone was often equated with the universal panacea; therefore, the two traditions may have had more in common than it initially appears.

Black powder may have been an important invention of Chinese alchemists. Described in 9th century texts and used in fireworks by the 10th Century, it was used in cannons by 1290. From China, the use of gunpowder spread to Japan, the Mongols, the Arab world and Europe. Gunpowder was used by the Mongols against the Hungarians in 1241, and in Europe starting with the 14th century.

Black powder was most likely invented in the middle east before it found its way to China. Saltpeter, the critical oxidising component, was found naturally in India and along the Salt trade routes in the Middle East.

Chinese alchemy was closely connected to Taoist forms of medicine, such as Acupuncture and Moxibustion, and to martial arts such as Tai Chi Chuan and Kung Fu (although some Tai Chi schools believe that their art derives from the Hygienic or Philosophical branches of Taoism, not the Alchemical).

Indian alchemy

Little is known in the West about the character and history of Indian alchemy. An 11th century Persian alchemist named al-Biruni reported that they "have a science similar to alchemy which is quite peculiar to them, which is called Rasavātam. It means the art which is restricted to certain operations, drugs, compounds, and medicines, most of which are taken from plants. Its principles restored the health of those who were ill beyond hope and gave back youth to fading old age." The best example of a text based on this science is *The Vaishashik Darshana* of Kanada (fl. 600 BC), who described an atomic theory over a century before Democritus.

The texts of Ayurvedic Medicine and Science have aspects related to alchemy, such having cures for all known diseases. The similarities in Ayurveda and alchemy are that both had methods used to treat people by putting oils over them.

Some people have also noted certain similarities between the metaphysics of the Samkhya philosophical tradition of Hinduism and the metaphysics of alchemy. Whether there is any direct connection between the two systems is an open question.

The Rasavadam was understood by very few people at the time. Two famous examples were Nagarjunacharya and Nityanadhiya. Nagarjunacharya was a buddhist monk who, in ancient times, ran the great university of Nagarjuna Sagar. His famous book, Rasaratanakaram, is a famous example of early Indian medicine. In traditional Indian medicinal terminology 'rasa' translates as 'mercury' and Nagarjunacharya was said to have developed a method to convert the mercury into gold. Much of his original writings are lost to us, but his teachings still have strong influence on traditional Indian medicine (Ayurveda) to this day.

Alchemy in the Greek world

The Greek city of Alexandria in Egypt was a center of Greek alchemical knowledge, and retained its preeminence through most of the Greek and Roman periods. The Greeks appropriated the hermetical beliefs of the Egyptians and melded with them the philosophies of Pythagoreanism, ionianism, and gnosticism. Pythagorean philosophy is, essentially, the belief that numbers rule the universe, originating from the observations of sound, stars, and geometric shapes like triangles, or anything from which a ratio could be derived. Ionian thought was based on the belief that the universe could be explained through concentration on natural phenomena; this philosophy is believed to have originated with Thales and his pupil Anaximander, and later developed by Plato and Aristotle, whose works came to be an integral part of alchemy. According to this belief, the universe can be described by a few unified natural laws that can be determined only through careful, thorough, and exacting philosophical explorations. The third component introduced to hermetical philosophy by the Greeks was gnosticism, a belief prevalent in the Christian and early post-Christian Roman empire, that the world is imperfect because it was created in a flawed manner, and that learning about the nature of spiritual matter would lead to salvation. They further believed that God did not "create" the universe in the classic sense, but that the universe was created "from" him, but was corrupted in the process (rather than becoming corrupted by the transgressions of Adam and Eve, i.e. original sin). According to Gnostic belief, by worshipping the cosmos, nature, or the creatures of the world, one worships the True God. Gnostics do not seek salvation from sin, but instead seek to escape ignorance, believing that sin is merely a consequence of ignorance. Platonic and neo-Platonic theories about universals and the omnipotence of God were also absorbed.

One very important concept introduced at this time, originated by Empedocles and developed by Aristotle, was that all things in the universe were formed from only four elements: *earth*, *air*, *water*, and *fire*. According to Aristotle, each element had a sphere to which it belonged and to which it would return if left undisturbed. (Lindsay, p. 16)

The four elements of the Greek were mostly qualitative aspects of matter, not quantitative, as our modern elements are. "...True alchemy never regarded earth, air,

water, and fire as corporeal or chemical substances in the present-day sense of the word. The four elements are simply the primary, and most general, qualities by means of which the amorphous and purely quantitative substance of all bodies first reveals itself in differentiated form." (Hitchcock, p. 66) Later alchemists (if Plato and Aristotle can be called alchemists) extensively developed the mystical aspects of this concept.

Alchemy in the Roman Empire

The Romans adopted Greek alchemy and metaphysics, just as they adopted much of Greek knowledge and philosophy. By the end of the Roman empire the Greek alchemical philosophy had been joined to the philosophies of the Egyptians to create the cult of Hermeticism. (Lindsay)

However, the development of Christianity in the Empire brought a contrary line of thinking, stemming from Augustine (354-430 AD), an early Christian philosopher who wrote of his beliefs shortly before the fall of the Roman Empire. In essence, he felt that reason and faith could be used to understand God, but experimental philosophy was evil: "There is also present in the soul, by means of these same bodily sense, a kind of empty longing and curiosity which aims not at taking pleasure in the flesh but at acquiring experience through the flesh, and this empty curiosity he is dignified by the names of learning and science." (Augustine, p. 245)

Augustinian ideas were decidedly anti-experimental, yet when Aristotelian experimental techniques were made available to the West they were not shunned. Still, Augustinian thought was well ingrained in medieval society and was used to show alchemy as being un-Godly.

Much of the Roman knowledge of Alchemy, like that of the Greeks and Egyptians, is now lost. In Alexandria, the centre of alchemical studies in the Roman Empire, the art was mainly oral and in the interests of secrecy little was committed to paper. (Whence the use of "hermetic" to mean "secretive".) (Lindsay, p. 155) It is possible that some writing was done in Alexandria, and that it was subsequently lost or destroyed in fires and the turbulent periods that followed.

Alchemy in the Islamic world

After the fall of the Roman Empire, the focus of alchemical development moved to the Middle East. Much more is known about Islamic alchemy because it was better documented: indeed, most of the earlier writings that have come down through the years were preserved as Islamic translations. (Burckhardt p. 46)

The Islamic world was a melting pot for alchemy. Platonic and Aristotelian thought, which had already been somewhat appropriated into hermetical science, continued to be assimilated. Islamic alchemists such as al-Razi (Latin Rasis or Rhazes) contributed key chemical discoveries of their own, such as the technique of distillation (the words *alembic* and *alcohol* are of Arabic origin), the muriatic, sulfuric, and nitric acids, soda,

potash, and more. (From the Arabic names of the last two substances, *al-natron* and *al-qaly*, Latinized into *Natrium* and *Kalium*, come the modern symbols for sodium and potassium.) The discovery that aqua regia, a mixture of nitric and muriatic acids, could dissolve the noblest metal; gold, was to fuel the imagination of alchemists for the next millennium.

Islamic philosophers also made great contributions to alchemical hermeticism. The most influential author in this regard was arguably Jabir Ibn Hayyan (Arabic جابر ابن حيان, Latin Geberus; usually rendered in English as Geber). Jabir's ultimate goal was takwin, the artificial creation of life in the alchemical laboratory, up to and including human life. He analyzed each Aristotelian element in terms of four basic qualities of *hotness*, *coldness*, *dryness*, and *moistness*. (Burckhardt, p. 29) According to Geber, in each metal two of these qualities were interior and two were exterior. For example, lead was externally cold and dry, while gold was hot and moist. Thus, Jabir theorized, by rearranging the qualities of one metal, a different metal would result. (Burckhardt, p. 29) By this reasoning, the search for the philosopher's stone was introduced to Western alchemy. Jabir developed an elaborate numerology whereby the root letters of a substance's name in Arabic, when treated with various transformations, held correspondences to the element's physical properties.

It is now commonly accepted that Chinese alchemy influenced Arabic alchemists (Edwardes pp. 33-59)(Burckhardt, p. 10-22), although the extent of that influence is still a matter of debate. Likewise, Hindu learning was assimilated into Islamic alchemy, but again the extent and effects of this are not well known.

Alchemy in Medieval Europe

Because of its strong connections to the Greek and Roman cultures, alchemy was rather easily accepted into Christian philosophy, and Medieval European alchemists extensively absorbed Islamic alchemical knowledge. Gerbert of Aurillac, who was later to become Pope Sylvester II, (d. 1003) was among the first to bring Islamic science to Europe from Spain. Later men such as Adelard of Bath, who lived in the 12th century, brought additional learning. But until the 13th century the moves were mainly assimilative. (Hollister p. 124, 294)

In this period there appeared some deviations from the Augustinian principles of earlier Christian thinkers. Saint Anselm (1033–1109) was a Benedictine who believed faith must precede rationalism, as Augustine and most theologians prior to Anselm had believed, but Anselm put forth the opinion that faith and rationalism were compatible and encouraged rationalism in a Christian context. His views set the stage for the philosophical explosion to occur. Peter Abelard followed Anselm's work, laying the foundation for acceptance of Aristotelian thought before the first works of Aristotle reached the West. His major influence on alchemy was his belief that Platonic universals did not have a separate existence outside of man's consciousness. Abelard also systematized the analysis of philosophical contradictions. (Hollister, p. 287-8)

Robert Grosseteste (1170–1253) was a pioneer of the scientific theory that would later be used and refined by the alchemists. He took Abelard's methods of analysis and added the use of observations, experimentation, and conclusions in making scientific evaluations. Grosseteste also did much work to bridge Platonic and Aristotelian thinking. (Hollister pp. 294-5)

Albertus Magnus (1193–1280) and Thomas Aquinas (1225–1274) were both Dominicans who studied Aristotle and worked at reconciling the differences between philosophy and Christianity. Aquinas also did a great deal of work in developing the scientific method. He even went as far as claiming that universals could be discovered only through logical reasoning, and, since reason could not run in opposition to God, reason must be compatible with theology. (Hollister p. 290-4, 355). This ran contrary to the commonly held Platonic belief that universals were found through divine illumination alone. Magnus and Aquinas were among the first to take up the examination of alchemical theory, and could be considered to be alchemists themselves, except that these two did little in the way of experimentation.

The first true alchemist in Medieval Europe was Roger Bacon. His work did as much for alchemy as Robert Boyle's was to do for chemistry and Galileo's for astronomy and physics. Bacon (1214–1294) was an Oxford Franciscan who explored optics and languages in addition to alchemy. The Franciscan ideals of taking on the world rather than rejecting the world led to his conviction that experimentation was more important than reasoning: "Of the three ways in which men think that they acquire knowledge of things: authority, reasoning, and experience; only the last is effective and able to bring peace to the intellect." (Bacon p. 367) "Experimental Science controls the conclusions of all other sciences. It reveals truths which reasoning from general principles would never have discovered." (Hollister p. 294-5) Roger Bacon has also been attributed with originating the search for the philosopher's stone and the elixir of life: "That medicine which will remove all impurities and corruptibilities from the lesser metals will also, in the opinion of the wise, take off so much of the corruptibility of the body that human life may be prolonged for many centuries." The idea of immortality was replaced with the notion of long life; after all, man's time on Earth was simply to wait and prepare for immortality in the world of God. Immortality on Earth did not mesh with Christian theology. (Edwardes p. 37-8)

Bacon was not the only alchemist of the high middle ages, but he was the most significant. His works were used by countless alchemists of the fifteenth through nineteenth centuries. Other alchemists of Bacon's time shared several traits. First, and most obviously, nearly all were members of the clergy. This was simply because few people outside the parochial schools had the education to examine the Arabic-derived works. Also, alchemy at this time was sanctioned by the church as a good method of exploring and developing theology. Alchemy was interesting to the wide variety of churchmen because it offered a rationalistic view of the universe when men were just beginning to learn about rationalism. (Edwardes p. 24-7)

So by the end of the thirteenth century, alchemy had developed into a fairly structured system of belief. Adepts believed in the macrocosm-microcosm theories of Hermes, that is to say, they believed that processes that affect minerals and other substances could have an effect on the human body (e.g., if one could learn the secret of purifying gold, one could use the technique to purify the human soul.) They believed in the four elements and the four qualities as described above, and they had a strong tradition of cloaking their written ideas in a labyrinth of coded jargon set with traps to mislead the uninitiated. Finally, the alchemists practiced their art: they actively experimented with chemicals and made observations and theories about how the universe operated. Their entire philosophy revolved around their belief that man's soul was divided within himself after the fall of Adam. By purifying the two parts of man's soul, man could be reunited with God. (Burckhardt p. 149)

In the fourteenth century, these views underwent a major change. William of Ockham, an Oxford Franciscan who died in 1349, attacked the Thomist view of compatibility between faith and reason. His view, widely accepted today, was that God must be accepted on faith alone; He could not be limited by human reason. Of course this view was not incorrect if one accepted the postulate of a limitless God versus limited human reasoning capability, but it virtually erased alchemy from practice in the fourteenth and fifteenth centuries. (Hollister p. 335) Pope John XXII in the early 1300s issued an edict against alchemy, which effectively removed all church personnel from the practice of the Art. (Edwardes, p.49) The climate changes, Black plague, and increase in warfare and famine that characterized this century no doubt also served to hamper philosophical pursuits in general.

Nicholas Flamel had these mysterious alchemical symbols carved on his tomb in the Church of the Holy Innocents in Paris.

Alchemy was kept alive by men such as Nicolas Flamel, who was noteworthy only because he was one of the few alchemists writing in those troubled times. Flamel lived from 1330 to 1417 and would serve as the archetype for the next phase of alchemy. He was not a religious scholar as were many of his predecessors, and his entire interest in the subject revolved around the pursuit of the philosopher's stone, which he is reputed to have found; his work spends a great deal of time describing the processes and reactions, but never actually gives the formula for carrying out the transmutations. Most of his work was aimed at gathering alchemical knowledge that had existed before him, especially as regarded the philosophers' stone. (Burckhardt pp.170-181)

Through the high middle ages (1300-1500) alchemists were much like Flamel: they concentrated on looking for the philosophers' stone and the elixir of youth, now believed to be separate things. Their cryptic allusions and symbolism led to wide variations in interpretation of the art. For example, many alchemists during this period interpreted the purification of the soul to mean the transmutation of lead into gold (in which they believed elemental mercury, or 'quicksilver', played a crucial role). These men were viewed as magicians and sorcerers by many, and were often persecuted for their practices. (Edwardes pp. 50-75)(Norton pp lxiii-lxvii)

One of these men who emerged at the beginning of the sixteenth century was named Heinrich Cornelius Agrippa. This alchemist believed himself to be a wizard and actually thought himself capable of summoning spirits. His influence was negligible, but like Flamel, he produced writings which were referred to by alchemists of later years. Again like Flamel, he did much to change alchemy from a mystical philosophy to an occultist magic. He did keep alive the philosophies of the earlier alchemists, including experimental science, numerology, etc., but he added magic theory, which reinforced the idea of alchemy as an occultist belief. In spite of all this, Agrippa still considered himself a Christian, though his views often came into conflict with the church. (Edwardes p.56-9)(Wilson p.23-9)

Alchemy in the Modern Age and Renaissance

European alchemy continued in this way through the dawning of the Renaissance. The era also saw a flourishing of con artists who would use chemical tricks and sleight of hand to "demonstrate" the transmutation of common metals into gold, or claim to possess secret knowledge that — with a "small" initial investment — would surely lead to that goal.

The most important name in this period is Philippus Aureolus Paracelsus, (Theophrastus Bombastus von Hohenheim, 1493–1541) who cast alchemy into a new form, rejecting some of the occultism that had accumulated over the years and promoting the use of observations and experiments to learn about the human body. He rejected Gnostic traditions, but kept much of the Hermetical, neo-Platonic, and Pythagorean philosophies; however, Hermetical science had so much Aristotelian theory that his rejection of Gnosticism was practically meaningless. In particular, Paracelsus rejected the magic theories of Agrippa and Flamel. He did not think of himself as a magician, and scorned those who did. (Williams p.239-45)

Paracelsus pioneered the use of chemicals and minerals in medicine, and wrote "Many have said of Alchemy, that it is for the making of gold and silver. For me such is not the aim, but to consider only what virtue and power may lie in medicines." (Edwardes, p.47) His hermetical views were that sickness and health in the body relied on the harmony of man the microcosm and Nature the macrocosm. He took an approach different from those before him, using this analogy not in the manner of soul-purification but in the manner that humans must have certain balances of minerals in their bodies, and that certain illnesses of the body had chemical remedies that could cure them. (Debus & Multhauf, p.6-12) While his attempts of treating diseases with such remedies as Mercury might seem ill-advised from a modern point of view, his basic idea of chemically produced medicines has stood time surprisingly well.

In England, the topic of alchemy in that time frame is often associated with Doctor John Dee (13 July 1527 – December, 1608), better known for his role as astrologer, cryptographer, and general "scientific consultant" to Queen Elizabeth I. Dee was considered an authority on the works of Roger Bacon, and was interested enough in alchemy to write a book on that subject (*Monas Hieroglyphica*, 1564) influenced by the

Kabbala. Dee's associate Edward Kelley — who claimed to converse with angels through a crystal ball and to own a powder that would turn mercury into gold — may have been the source of the popular image of the alchemist-charlatan.

Another lesser known alchemist was Michael Sendivogius (*Michał Sędziwój*, 1566 - 1636), a Polish alchemist, philosopher, medical doctor and pioneer of chemistry. According to some accounts, he distilled oxygen in a lab sometime around 1600, 170 years before Scheele and Priestley, by warming nitre (saltpetre). He thought of the gas given off as "the elixir of life". Shortly after discovering this method, it is believed that Sendivogius taught his technique to Cornelius Drebbel. In 1621, Drebbel practically applied this in a submarine.

Tycho Brahe (1546–1601), better known for his astronomical and astrological investigations, was also an alchemist. He had a laboratory built for that purpose at his Uraniborg observatory/research institute.

The decline of Western alchemy

The demise of Western alchemy was brought about by the rise of modern science with its emphasis on rigorous quantitative experimentation and its disdain for "ancient wisdom". Although the seeds of these events were planted as early as the 17th century, alchemy still flourished for some two hundred years, and in fact may have reached its apogee in the 18th century.

Robert Boyle (1627–1691), better known for his studies of gases (cf. Boyle's law) pioneered the scientific method in chemical investigations. He assumed nothing in his experiments and compiled every piece of relevant data; in a typical experiment, Boyle would note the place in which the experiment was carried out, the wind characteristics, the position of the Sun and Moon, and the barometer reading, all just in case they proved to be relevant. (Pilkington p.11) This approach eventually led to the founding of modern chemistry in the 18th and 19th centuries, based on revolutionary discoveries of Lavoisier and John Dalton — which finally provided a logical, quantitative and reliable framework for understanding matter transmutations, and revealed the futility of longstanding alchemical goals such as the philosopher's stone.

Meanwhile, Paracelsian alchemy led to the development of modern medicine. Experimentalists gradually uncovered the workings of the human body, such as blood circulation (Harvey, 1616), and eventually traced many diseases to infections with germs (Koch and Pasteur, 19th century) or lack of *natural* nutrients and vitamins (Lind, Eijkman, Funk, et al.). Supported by parallel developments in organic chemistry, the new science easily displaced alchemy from its medical roles, interpretive and prescriptive, while deflating its hopes of miraculous elixirs and exposing the ineffectiveness or even toxicity of its remedies.

Thus, as science steadily continued to uncover and rationalize the clockwork of the universe, founded on its own materialistic metaphysics, Alchemy was left deprived of its

chemical and medical connections — but still incurably burdened by them. Reduced to an arcane philosophical system, poorly connected to the material world, it suffered the common fate of other esoteric disciplines such as astrology and Kabbalah: excluded from university curricula, shunned by its former patrons, ostracized by scientists, and commonly viewed as the epitome of charlatanism and superstition.

These developments could be interpreted as part of a broader reaction in European intellectualism against the Romantic movement of the preceding century. Be as it may, it is sobering to observe how a discipline that held so much intellectual and material prestige, for more than two thousand years, could disappear so easily from the universe of Western thought.

Modern 'alchemy'

In modern times, progress has been made toward achieving the goals of alchemy using scientific, rather than alchemic, means. These developments may on occasion be called "alchemy" for rhetorical reasons.

In 1919, Ernest Rutherford used artificial disintegration to convert nitrogen into oxygen. This process of bombarding the atomic nucleus with high energy particles is the principle behind modern particle accelerators, in which transmutations of elements are common. Indeed, in 1980, Glenn Seaborg transmuted lead into gold, though the amount of energy used and the microscopic quantities created negated any possible financial benefit.

In 1964, George Ohsawa and Michio Kushi, based on the claims of Louis Kervran, reportedly successfully transmuted sodium into potassium, by use of an electric arc, and later of carbon and oxygen into iron. In 1994, R. Sundaresan and J. Bockris reported that they had observed fusion reactions in electrical discharges between carbon rods immersed in water. However, none of these claims have been replicated by other scientists, and the idea is now thoroughly discredited.

As of 2005, a universal panacea remains elusive, though futurists such as Ray Kurzweil believe sufficiently advanced nanotechnology may prolong life indefinitely. Some say the third goal of alchemy has been fulfilled by IVF and the cloning of a human embryo, although these technologies fall far short of creating a human life from scratch.

The aim of artificial intelligence research could be said to be creating a life from scratch, and those philosophically opposed to the possibility of AI have compared it with alchemy, such as Herbert and Stuart Dreyfus in their 1960 paper *Alchemy and AI*.

Alchemy in art and entertainment

References to alchemy in art and entertainment are far too numerous to list. Here we give only a few indicative samples. More titles can be found in the philosopher's stone article.

Novels and plays

Many writers lampooned alchemists and used them as the butt of satirical attacks. Two early and well-known examples are

- Geoffrey Chaucer, *Canon's Yeoman's Tale* (ca. 1380). The main character, an alchemist on the way to Canterbury, claims that he will "pave it all of silver and of gold".
- Ben Jonson, *The Alchemist* (ca 1610). In this five-act play, the characters set up an alchemy workshop to swindle people.

An Alchemical Laboratory, from *The Story of Alchemy and the Beginnings of Chemistry*

In more recent works, alchemists are generally presented in a more romantic or mystic light, and often little distinction is made between alchemy, magic, and witchcraft:

- Mary Shelley, *Frankenstein* (1818). Victor Frankenstein uses both alchemy and modern science to create Frankenstein's monster.
- Goethe, *Faust, Part 2* (1832). Faust's servant Wagner uses alchemy to create a homunculus.
- Gabriel García Márquez, *One Hundred Years of Solitude* (1967). An alchemist named Melquíades adds to the novel's surreal atmosphere.
- Paulo Coelho, *The Alchemist* (1988).
- J. K. Rowling, *Harry Potter and the Philosopher's Stone* (1997). Features Nicholas Flamel as a character.
- Neal Stephenson, *The Baroque Cycle* (2003–2004). Features real and imaginary alchemists such as Isaac Newton, de Duillier, and Enoch Root.
- Martin Booth, *Doctor Illuminatus: The Alchemist's Son* (2003).
- Margaret Mahy, *Alchemy* (2004).
- John Fasman, *The Geographer's Library*, whose plot revolves around thirteen alchemical artifacts.
- Gregory Keyes, *Age of Unreason*. Features Isaac Newton and de Duillier.
- Cornelia Funke, *Dragon Rider* (2004). Twigleg the homonculus was created by an alchemist.

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Hermeticism

This article is about the magical and religious movement stemming from the teachings of Hermes Trismegistus.

Hermes Trismegistus depicted as Caucasian in a medieval rendering. However, some believe that if Hermes was from Ancient Egypt, he is more likely to have had African characteristics.

Hermeticism is a set of philosophical and religious beliefs based primarily upon the writings of Hermetism. Sometimes it isn't even differentiated from Hermetism, as in the *Kybalion*. (Three Initiates p. 12) These beliefs have had the impact of effecting magic traditions and further, the impact of serving as a set of religious beliefs. Whatever the impact of the beliefs, they stem from teachings and books accredited to Hermes Trismegistus, who is put forth as a wise sage and Egyptian priest, commonly seen as synonymous with the Egyptian god Thoth.

Hermeticism is closely related to occultism: avoiding persecution through secrecy (Hall *The Hermetic Marriage* p. 227), focusing on the concept of God, astrology, alchemy, and theurgy. The traditional secrecy surrounding Hermetic philosophy gave rise to the term

"hermetically sealed" (Hall *The Secret Teachings of All Ages* p. 95) and many Hermeticists still feel uncomfortable throwing their *pearls to swine*. (Three Initiates p. 18)

The roots of Hermeticism come from Hermetism, but Hermetism's roots are debated. Some scholars feel that Hermetism is a Greek movement which developed around the time of Christianity. Other scholars, primarily from occult circles, trace Hermetism's roots to Egypt and its mystery schools. There are a few others who go further and trace Hermetism to Atlantis, in which some survivors handed their wisdom down to the people of Egypt.

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Etymology

The word Hermeticism is derived from "Hermetism" which is in turn derived from "Hermes". Hermes is taken from an ancient Greek root, "Herm" which means "vitality" or "the active, positive, radiant principle of Nature" (Hall *The Hermetic Marriage* p. 223) In essence, the masculine principle.

History

Enter the Corpus Hermeticum

According to tradition, Hermetism arose in Ancient Egypt several millennia ago, as the religion of the Egyptian philosophical elite. (Hall *The Secret Teachings of All Ages* pp. 39-40) After centuries of falling out of favor, as did all pagan religions, Hermetism was reintroduced to the West when, in 1460 CE, a man named Leonardo brought the Corpus Hermeticum to Pistoia. He was one of many agents sent out by Pistoia's ruler, Cosimo de'Medici, to scour European monasteries for lost ancient writings. (*The Way of Hermes* p. 9) Though Hermetism had been reintroduced, the time lapse was cause for the new movement to be *Hermeticism*, suggesting that it was based not necessarily off of Hermes' teachings, but based off of the texts that were based off of those teachings.

Believed originally to predate Plato and Moses, much of the facination disappeared with the analysis in 1614 CE by Isaac Casaubon, a Swiss Calvinist. Casaubon analyzed the Hermetic texts for linguistic style and concluded that they were written after the start of the Christian Era. (*The Way of Hermes* p. 9) Other scholars analyzing the Greek texts for linguistics came to similar conclusions. Walter Scott places their date shortly after 200 CE, while Sir W. Flinders Petrie places them between 200 and 500 BCE. (Abel and Hare p. 7) Plutarch's mention of Hermes Trismegistus dates back to the first century CE (1-100 CE) suggesting that Scott dated the work after its true date. (Hoeller)

However, the wise thought along the same lines as E.A. Wallis Budge, the most prominent Egyptologist of his day. Budge, in discussing the Egyptian text, *The Book of the Dead*, clearly stated that the earliest version of *The Book of the Dead* found was not necessarily mean that it is the earliest version that existed. One cannot claim that an earlier version does not exist simply because it has not been found. (Budge p. xiii) *The Book of the Dead* itself was drastically rewritten, reorganized, and amended several times in Egypt, creating 4 distinct versions which have been found. These versions stretch over a millennium, from the Fifth Dynasty (2498 BCE - 2345 BCE) to the Twentieth Dynasty (1186 BCE - 1073 BCE). (Budge pp. ix-x)

In 1945 CE, Hermetic writings were among those found near Nag Hammadi, in the form of one of the conversations between Hermes and Asclepius from the Corpus Hermeticum, and a text about the Hermetic mystery schools, *On the Ogdoad and Ennead*, written in the Coptic language, the last form of the Egyptian writing style. (*Way of Hermes* pp. 9-10) An older version was indeed found, and still may not be the earliest. It is claimed that many of the older versions that would be found in the Great Library of Alexandria, were destroyed in 391 CE when the Romans burnt the library down. (Hall *The Secret Teachings of All Ages* p. 96)

The concepts discussed within the Corpus Hermeticum, even if the Coptic book was from the earliest version, are distinctly ancient Egyptian. This includes the concept, "All is one, all is from the One". (*Way of Hermes* p. 10)

Hermeticism as a Religion

Most Hermeticists do not consider their beliefs a religion. Many alloy the beliefs of their own Christianity, Buddhism, Judaism, or Islam with their mystical ideas. Others hold that all great religions have a few mystical truths at their core, and all religions point to the esoteric tenants of Hermetism.

However, according to the American Heritage Dictionary, 4th edition, one definition of religion is "A set of beliefs, values, and practices based on the teachings of a spiritual leader." [1] Literal belief in a historical Thoth-Hermes meets this criterion.

Religious Texts

Though many more have been falsely attributed to the work of Hermes Trismegistus, Hermeticists commonly accept there to have been 42 books to his credit. However, most of these books are reported to have been destroyed in 391 CE when the Romans burnt down the Library of Alexandria. It is further reported that the volumes saved from the flames were buried in the desert, the locations known only to the few initiates of mystery schools. (Hall *The Secret Teachings of All Ages* p. 96)

There are three major works which are widely known texts for Hermetic beliefs:

The Corpus Hermeticum is the body of work most widely known and is the aforementioned Greek texts. These sixteen books are set up as dialogues between Hermes and a series of others. The first book involves a discussion between Poimandres (also known as *Nous* and God) and Hermes, supposedly resulting from a meditative state, and is the first time that Hermes is in contact with God. Poimandres teaches the secrets of the Universe to Hermes, and later books are generally of Hermes teaching others such as Asclepius and his son Tat.

The Emerald Tablet of Hermes Trismegistus is a short work which coins the well known term in occult circles "As above, so below." The actual text of that maxim, as translated by Dennis W. Hauck is "That which is Below corresponds to that which is

Above, and that which is Above corresponds to that which is Below, to accomplish the miracle of the One Thing." (Scully p. 321) The tablet also references the three parts of the wisdom of the whole universe, to which Hermes claims his knowledge of these three parts is why he received the name Trismegistus (thrice great, or Ao-Ao-Ao meaning "greatest").

As the story is told, this tablet was found by Alexander the Great at Hebron supposedly in the tomb of Hermes. (Abel & Hare p. 12) Such a story assumes a mortal Hermes, whether or not the name is correct.

The Kybalion is a book published in 1912 anonymously by three Freemasons, whose identities are suspected to be now known, as an introduction to Hermeticism. Though their claims that the Kybalion is a book that ever actually existed are probably false, many of the Hermetic principles are explained in the book. Online versions of the book can be found [2].

Thoth, the ibis-headed god of Knowledge, closely related, if not equivalent, to Hermes Trismegistus.

In addition, there is **The Book of Thoth**, written by Hermes Trismegistus, said to be the key to immortality. To those acquainted to its use, it is said to give them power over the spirits of the air and subterranean divinities. Within it lies the One spiritual path. Some have claimed that this is the Tarot that has been in possession of the gypsies for centuries. (Hall *The Secret Teachings of All Ages* pp. 96-7)

The Three Parts of the Wisdom of the Whole Universe

Hermes Trismegistus is accredited with the name Trismegistus, meaning the "Thrice Great" or "Thrice Greatest" because, as he claims in *The Emerald Tablet of Hermes Trismegistus*, he knows the three parts of the wisdom of the whole universe. (Scully p. 322) The three parts of the wisdom are alchemy, astrology, and theurgy.

Alchemy - The Operation of the Sun - For Hermeticism, Alchemy is not the changing of physical lead into physical gold. (Hall *The Hermetic Marriage* p. 227) Rather, one attempts to turn themselves from a base person (symbolized by lead) into an adept master (symbolized by gold). The various stages of chemical distillation and fermentation, among them, are metaphorical for the Magnum Opus (Latin for Great Work) performed on the soul. (Scully p. 11)

Astrology - The Operation of the Moon - Hermes claims that Zoroaster discovered this part of the wisdom of the whole universe, astrology, and taught it to man. (Powell pp. 19-20) In Hermetic thought, it is likely that the movements of the planets have meaning beyond the laws of physics and actually holding metaphorical value as symbols in the mind of The All, or God. Astrology has influences upon the Earth, but does not dictate

our actions, and wisdom is gained when we know what these influences are and how to deal with them.

Theurgy - The Operation of the Stars - There are two different types of magic, according to Giovanni Pico della Mirandola's *Apology*, there are two types of magic, completely opposite of one another. The first is γοητεία, Goëtia, black magic reliant upon an alliance with evil spirits (i.e. demons). In complete opposition is Theurgy, divine magic reliant upon an alliance with divine spirits (i.e. angels, archangels, God). (Garstin p. v)

Theurgy translates to "The Science or art of Divine Works" and is the practical aspect of the Hermetic art of alchemy. (Garstin p. 6) Furthermore, alchemy is seen as the "key" to theurgy (Garstin p. vi), the ultimate goal is to become united with higher counterparts, leading to the attainment of Divine Consciousness. (Garstin p. 6)

Hermetic Beliefs

Hermeticism is a pantheist belief system which teaches that there is One God, or one "Cause", of which we are all a part. These beliefs are claimed to have come from Egypt and have strong philosophical ties to that land. Also it often subscribes to the notion that other beings such as angels, demons, ascended masters and elementals exist in the Universe.

However, it should be stressed that Hermeticists greatly differ in their belief systems because there is no central organization per se. Manly P. Hall, 33rd degree Mason and Hermetic scholar, however, claims that Hermeticism has foremost inspired three movements, The Illuminati, The Order of Freemasons, and The Rosicrucians. (Hall *The Hermetic Marriage* p. 226) There has also been The Hermetic Order of the Golden Dawn which has fallen into ruin. Outside of these three orders, at least, Hermeticism is a personal spiritual path which rewards open mindedness and personal logical deduction.

Ideally, a Hermeticist should be completely openminded, thinking for themselves, and bring the spiritual truths into physical manifestation in their own way. The good teachings, from any teacher, should be weeded out by the false ones. (Hall *The Hermetic Marriage* p. 248)

God and Reality

In the Hermetic view, all is in the mind of The All, the Hermetic conception of God, as expressed in the *Kybalion*: "We have given you the Hermetic Teaching in regarding the Mental Nature of the Universe - the truth that 'the Universe is Mental - held in the Mind of THE ALL.'" (Three Initiates p. 96)

Everybody and Everything in the universe is part of this entity. As everything is mental, it is also a vibration (Three Initiates p. 137). This is very similar to what one would come up with if they conjoined the quantum mechanics principles of wave-particle duality and nonlocality. Everything being (when not observed for location) a wave and in the same

place, we have a wave without dimensions, best described as a vibration. All vibrations vibrate from the densest of physical particles, through mental states, to the highest spiritual vibrations. In Hermeticism, the only difference between different states of physical matter, mentality, and spirituality is the frequency of their vibration. The higher the vibration, the further it is from base matter. (Three Initiates pp. 138-47)

Classical Elements

The four classical elements of earth, water, air, and fire are used often in alchemy, and are alluded to several times in the Corpus Hermeticum. However, it should be noted that these elements represent ideas rather than physical elements. Fire is the ascending, active, masculine principle, which is kept from going too far with air, which represents rational thought. Water is the descending, reflective, emotional feminine principle, which is kept from going too far by earth, which represents a solid, practical foundation in the real world.

Mental Gender, Polarity, and Duality

Hermeticists take to heart one of the primary ideas of Taoism, yin and yang. The implementation of this Taoist principle, which may or may not have been discovered independently, has been split across many teachings.

Yin and Yang, the shared concept between Hermeticism and Taoism

The primary place where it has had an impact is in the principle of duality. Duality states that everything has two sides, two opposing attributes which make up the same thing. This idea is sucked up into the concept of polarity almost immediately:

"Everything is dual; everything has poles; everything has its pair of opposites; like and unlike are the same; opposites are identical in nature, but different in degree; extremes meet; all truths are but half-truths; all paradoxes may be reconciled." (Three Initiates p. 149)

Polarity takes duality and moves a few steps further, saying that there are an infinite number of degrees between one side of a duality, and the other side. If you pick two things of different temperature, something else can be hotter than one of them, and colder than the other. (Three Initiates p. 151) Likewise you can turn one side of a duality into another, but not into a different thing. For example, hot and cold being opposites, you can turn hot into cold, and cold into hot, but you cannot turn hot into sharp, or sharp into cold; nor can hot be turned into courage or fear. (Three Initiates p. 154)

Mental Gender is the part of yin and yang that polarity and duality do not deal with. Gender. Yin is feminine and yang is masculine, and these principles which are viewed as

a special case of polarity, are put into the masculine (action) and feminine (thought) principles. (Three Initiates p. 203)

As Above, So Below

The Magician displaying the Hermetic concept of "as above, so below." It is thought that the modern Tarot may be based off of *The Book of Thoth*.

These words circulate throughout occult and magical circles, and they come from Hermetic texts. The concept was first laid out in *The Emerald Tablet of Hermes Trismegistus*, in the words "That which is Below corresponds to that which is Above, and that which is Above, corresponds to that which is Below, to accomplish the miracles of the One Thing." (Scully p. 321)

In accordance with the various levels of reality: physical, mental, and spiritual, this relates that what happens on any level happens on every other. This is however more often used in the sense of the microcosm and the macrocosm. The microcosm is oneself, and the macrocosm is the universe. The macrocosm is as the microcosm, and vice versa; within each lies the other, and through understanding one (usually the microcosm) you can understand the other. (Garstin p. 35)

Reincarnation

There are mentions in Hermeticism about reincarnation. As Hermes states:

"O son, how many bodies we have to pass through, how many bands of demons, through how many series of repetitions and cycles of the stars, before we hasten to the One alone?" (*Way of Hermes* p. 33)

Manly P. Hall also claims that there is a general acceptance among Hermeticists for constant reincarnation between both sexes, as in some way integral, but not absolutely vital, within Hermeticism. (Hall *The Hermetic Marriage* p. 234)

Causation

One tenet of Hermeticism, which may be the sole work of *The Kybalion* is the tenet of causation. Causation is in a simplified form, simply cause and effect. Each cause has its effect and each effect has its cause. However, when brought up to *Kybalion* levels, this principle states that there is no such thing as chance, but rather that chance is undiscovered law, organization in the chaos. (Three Initiates p. 171) (see Chaos Theory)

The argument *The Kybalion* makes on this issue, is that The All is the Law, and as nothing can be outside of The All, nothing can be outside of the Law. The idea of

something happening by chance would be, in their opinion, outside of the Law. (Three Initiates p. 173)

Some Hermeticists who do not agree with everything that *The Kybalion* states, would say that free will is part of the Law, and it requires the uncertainty called chance. If we are to make choices freely, any omnipotence must be limited to not include the result of our choices. Therefore, though it may be derived from all other information what we are likely to choose, there must be that chance that we will choose something else if free will is to exist. This view is closely related to the idea that The All acts to gain something.

Morality, Good and Evil

There is no strict moral code in Hermeticism resembling the Ten Commandments. In fact, there are some Hermeticists who deny the existence of good and evil altogether. What is right and wrong is generally left to each person to discover for themselves, though the Hermetic texts do speak somewhat on good and evil.

Hermes explains in Book 9 of the *Corpus Hermeticum* that *Nous* brings forth both good and evil, depending on if he receives input from God or from the demons. God brings good, while the demons bring evil. Among those things brought by demons are:

"adultery, murder, violence to one's father, sacrilege, ungodliness, strangling, suicide from a cliff and all such other demonic actions." (*Way of Hermes* p. 42)

This provides a clearcut view that Hermeticism does indeed include a sense of morality. However, the word good is used very strictly, to be restricted to use to the *Supreme Good*, God. (*Way of Hermes* p. 28) It is only God (in the sense of the Supreme Good, not The All) who is completely free of evil to be considered good. Men are exempt of having the chance of being good, for they have a body, consumed in the physical nature, ignorant of the *Supreme Good*. (*Way of Hermes* p. 47)

Among those things which are considered extremely sinful, is the focus on the material life, said to be the only thing that offends God:

"As processions passing in the road cannot achieve anything themselves yet still obstruct others, so these men merely process through the universe, led by the pleasures of the body." (*Way of Hermes* pp. 32-3)

It is troublesome to oneself to have no "children". This is a symbolic description, not to mean physical, biological children, but rather creations. Immediately before this claim, it is explained that God is "the Father" because it has authored all things, it creates. Whether father or mother, one must create, do something positive in their life, as the Supreme Good is a "generative power". The curse for not having "children" is to be imprisoned to a body, neither male (active) nor female (thoughtful), leaving that person with a type of sterility, that of being unable to accomplish anything. (*Way of Hermes* p. 29)

Creation Legend

The Hermetic creation legend is not meant to be taken literally, it is completely symbolic. Aside from Christianity, generally all faiths of the world have long ago accepted an evolutionary creation. (Hall *The Hermetic Marriage* p. 228)

Possible Perversion by Christianity

For centuries, Hermetism had to survive where Christianity flourished. During much of this time, outright persecution and bookburning was a common way for dealing with pagan practices. In order for Hermetists to keep themselves and their texts from burning, they had to not only be veiled in secrecy, but also in Christianity, so that any texts found would be mistaken for obscure Christian ones. Some Hermeticists believe that the texts of Hermetism were brought to them already partially corrupted by Christianity, though the inner meaning may still be intact under the metaphors.

Hermeticism as Magic

Hermeticism, being opposed by the Church, became a part of the occult underworld, intermingling with other occult movements and practices. The infusion of Hermeticism into occultism has given it great influence in Western magical traditions. Hermeticism's spiritual practices were found very useful in magical work, especially in Theurgic (divine) practices as opposed to Goëtic (profane) practices, due to the religious context from which Hermeticism sprang forth.

Using the teachings and imagery of the Jewish Kabbalah and Christian Mysticism, Hermetic Theurgy was used effectively and in a context more easily understood by Europeans in the Middle Ages and Renaissance.

A few primarily Hermetic occult orders were founded in the late Middle Ages and early Renaissance. Hermetic magic underwent a 19th century revival in Western Europe (Regardie p. 17), where it was practiced by people such as the Hermetic Order of the Golden Dawn, Aurum Solis, Ragon, Kenneth M. Mackenzie, Eliphas Lévi, Frederick Hockley, William Butler Yeats, and Arthur Machen. (Regardie pp. 15-6)

Rosicrucianism

Rosicrucianism was a Hermetic/Christian movement dating back to the 15th century. It has officially fallen out of existence in the 19th century, though some claim it merely fell into complete secrecy. It consisted of a secretive inner body, and a more public outer body under the direction of the inner body.

This movement was symbolized by the rose (feminine) and the cross (masculine) which came together to symbolize God or rebirth. This is very similar to the Egyptian use of the ankh. However, these also led to false accusation that the order practiced grotesque orgy rituals.

The Rosicrucian Order consisted of a graded system (similar to The Order of Freemasons) in which members moved up in rank and gained access to more knowledge, for which there was no fee. Once a member was deemed able to understand the knowledge, they moved on to the next grade.

There were three steps to their spiritual path: philosophy, qabalah, and divine magic. In turn, there were three goals to the order: 1) the abolition of monarchy and the institution of rule by a philosophical elect, 2) reformation of science, philosophy, and ethics, and 3) discovery of the Panacea.

The order claimed that secrecy was needed because "powerful people" opposed, and hindered, them. They promised that the time was coming when all their knowledge would, by mandate of God, be revealed to all. They already accepted any person who was seeking their enlightenment. They also claimed that the "Christian Church" wielded great power, but misused it, and thus were doomed to destruction. Furthermore, they condemned what they deemed "pseudo-chemists and philosophers" whom strayed from God's path.

Amazing claims were made of these men, including that they worked miracles, could shapeshift, and teleport where they wished, among them. (Hall *The Secret Teachings of All Ages* pp. 455-66)

The only source dating the existence of the Rosicrucians as far back as the 17th century are a pair of German pamphlets: the *Fama* and the *Confessio Fraternitatis*. Many scholars believe these to be hoaxes, and that antedating Rosicrucian organisations are the first appearance of any real Rosicrucian fraternity. Modern R.C. organisations such as the AMORC claim to possess documents dating their existence as far back as classical Greece and Egypt, but these sources are not available to non-members.

Hermetic Order of the Golden Dawn

The Hermetic Order of the Golden Dawn claims descent from the Rosicrucians, officially instituted in 1887 CE. Unlike the Order of the Freemasons, the Golden Dawn was open to both sexes, and treated both as equal. The order was a specifically Hermetic society, teaching the arts of alchemy, qabalah, and the magic of Hermes along with the principles of occult science. Israel Regardie claims that there are many, many orders who know what they do of magic from what has been leaked out of the Golden Dawn by what he deems "renegade members."

The order maintained the tightest of secrecy, maintained by severe penalties for loose lips. Overall, the general public was left oblivious to the actions and even existence of the Golden Dawn, making the policies a success. (Regardie pp. 15-7) This secrecy was broken first by Aleister Crowley, in 1905 CE, and later by Israel Regardie himself in 1940 CE, giving a detailed account of the order's teachings to the general public. (Regardie p. ix)

Hermeticism's Relationship with other Systems

Buddhism

Buddhism shares some essential concepts with Hermetic thought. Buddhism is a personal journey that brings personal revelation, as Hermeticism is highly individualistic as well. Buddhists try to understand God through understanding themselves, searching in quiet meditation. This is in accordance with the Hermetic principle of "as below, so above," searching the microcosm to understand the macrocosm. Both also believe in an illusionary world, where the physical is only an illusion.

Christianity

Hermeticism Effecting Christianity

Hermeticism had influenced the Christian religion, with Hermes being seen often as a virtuous and prophetic man living at about the same time as Moses, some even thinking that the two were one and the same. It was suggested in 1593 CE, by a Cardinal Patrizzi, that Hermeticism replace Aristotle's teachings as the basis for Catholic thought. However, those wishing to continue the reign of Thomas Aquinas's Aristotelian philosophy won the battle and Hermeticism became a heresy. In 1600 CE, the friar Giordano Bruno, a primary supporter of Hermetic thought in Christianity, was burned at the stake for heresy. (Hoeller)

Hermes, unlike other pagan (i.e. non-Christian) philosopher-priests, was not condemned by early Christians, but rather found to be enlightened. They, however, felt that he could be much greater with their teachings. (Hall *The Secret Teachings of All Ages* p. 95)

Christianity Effecting Hermeticism

In medieval Europe, where Christianity was the dominant political and religious force, many Hermeticists incorporated Christian symbols into the Hermetic art of Alchemy. Some Hermeticists hold that the true meaning of Christianity lies in the symbolic view of Christianity as opposed to the dogmatic. Such a theory goes against orthodox Christian teaching, and thus many Hermeticists were put to death for heresy, as well as witchcraft relating to their magical practices. On the other hand, many Hermeticists were employed by Kings and other nobles, as court magicians, astrologers and scholars. Many Catholic priests were also involved in Hermetic study. Henrich Cornelius Agrippa's teacher was Johannes Trithemius, a German abbot. To this day many European Churches are decorated with Hermetic symbolism. A mosaic of Hermes Trismegistus is in the Cathedral of Siena, in Sienna Italy, is one such example.

St. Augustine thought Hermes lived later than Moses. Whilst Augustine opposed Hermeticism, some Renaissance scholars claimed that Hermetic thought was closer to Christianity than those of Ancient Greece.

Many Hermeticists seem to write from a Christian perspective. This may have been sincere, or may have simply been a way to get their books published, avoiding censorship, and a way to avoid persecution; especially during the Inquisition. Rosicrucianism employs many Christian symbols. Some regard this as Christian mysticism, though such Hermetic orders and texts are generally labeled "demi-Christian" since they do not usually subscribe to a literal interpretation of the New Testament, using the death and resurrection of Jesus Christ as metaphors for spiritual attainment and enlightenment. Orthodox Christianity does not generally accept any form of Hermeticism, Alchemy, Rosicrucianism or Occultism, though from a Hermetic point of view, one could possibly be both Christian and Hermetic.

Gnosticism

Gnosticism and Hermeticism are often seen as being sister religions, both flourishing in the same period, sharing the goal of the soul escaping from the material realm through true understanding, and emphatizing personal knowledge of God (Hoeller). Gnostics, however, felt that there was something seriously wrong with *Nous* a part of The All (Horgan p. 41). This could be stretched so far as to say that by bringing the world into existence, God had to remove himself from it at the same time (Horgan pp. 39-40). In essence, the primary difference between the philosophy of Hermeticism and Gnosticism is that Hermeticism is optimistic about God, while Gnosticism is pessimistic (Hoeller). Other differences persist, such as the views on Jesus of Nazareth. The Gnostic Bible is often read by Hermeticists and the Hermetic works are often read by Gnostics, though each puts more credibility on their own works.

Islam

Of the three movements primarily influenced by Hermeticism, the Illuminati involves Islam. The prophet Mohammed is one of three people that is said to represent the Illuminati, along with Roger Bacon and Paracelsus (Hall *The Hermetic Marriage* p. 226)

Judaism

Medieval Hermeticism was heavily blended with the Jewish Kabbalah, (Regardie p. 15) and it is not uncommon to see Greek philosophers mentioned side by side with Biblical figures and with the same esteem. In some cases Hermes Trismegistus is even equated to be the Biblical Enoch (Hall *The Secret Teachings of All Ages* p. 94) or Moses (Hall *The Hermetic Marriage* p. 223). However, it is unlikely that Moses could be equated as Hermes, as it is also said that he was initiated into the Hermetic arts, suggesting that Hermes predated him. (Regardie p. 16)

It is considered highly possible that the Pentateuch comes from the Hermetic Mystery schools' teachings. (Hall *The Secret Teachings of All Ages* p. 427) Moses, claimed to be the writer of these five books, has a name that is an anagram for the sun. מֹשֶׁה, the Hebrew spelling of Moses, is easily changed to מִשֶׁה, a name of the Sun. Initiates were often given a name that was equivalent to the Sun to show their own redemption and regeneration. In

fact, the stories of Moses prior to the Exodus match ceremonies in the Hermetic Mystery schools exactly. (Hall *The Secret Teachings of All Ages* p. 428)

The Tabernacle was also of Egyptian origin, being a copy of one in Egypt. The inside held deep symbolism in the Hermetic Mysteries. (Hall *The Secret Teachings of All Ages* p. 429) The Ark of the Covenant also matches depictions of an Egyptian ark, down to the kneeling figures on the lid. (Hall *The Secret Teachings of All Ages* p. 430) The common use of the number twelve in Jewish and Christian texts also refers to the Zodiac and astrology, an art taught to the Jews by the Egyptians. (Hall *The Secret Teachings of All Ages* p. 439)

The Occult

Much of the Western Esoteric tradition is based off of a blend of Hermeticism and the Kabbalah Ma'asit, so called magical or practical Kabbalah. Occultism uses the Hermetic and Kabbalistic theory of creation and angelic/demonic forces, as a basis for ritual magic, and theurgy. Most magic theory involves the manipulation of Yetzirah, the world of Formation, and letting the effect trickle down to the physical universe (in accordance to the Hermetic concept of "as above, so below"). This includes the communication and manipulation of inhabitants of Yetzirah, angelic or demonic forces. The spelling of "Qabbalah", is generally referred to as the Hermetic Qabbalah, often having a magical or occult slant. While "Kabbalah" refers to the traditional Jewish branch.

These beliefs were influential in European occult lore, especially from the Renaissance forward. During the middle ages and Renaissance, magicians wrote grimoires which show a major influence from both Hermeticism and Kabbalah and have since become a basis for most practical occultism. In more recent times, magical orders such as The Golden Dawn revived and revised these traditions.

Taoism

The Taoists have a concept called *shoong*. It is the state in which you stop perceiving yourself as separate from the Universe, but rather perceiving yourself as one with everything else. (Liao pp. 30-31) This is the same as the state of mind cultivated prior to Theurgy.

Trancendentalism

Trancendentalism's concept of a spark of God in everyone, which can eventually consume a person if properly treated is very similar to the Hermetic conception that God is everything, and the ultimate goal is to rejoin with God. Hermeticism and Trancendentalism also share the view that the physical can be trancended individually by sentient beings.

Wicca and Paganism

A depiction by Edward Coley Burne-Jones of the God and Goddess. These are personifications of the Masculine and Feminine aspects of The All

Wicca and Paganism, though not exactly the same, have the same relation to Hermeticism. Silver Ravenwolf explains Wicca, in part:

"Down we go then, to the first two branches of the tree, right below the All. Each branch is exactly the same, one on the right side of the tree and one on the left. Totally balanced in every respect to each other. They represent the God and the Goddess, or the Lord and the Lady. Separate yet equal, together they combine into the essence of the All." (Ravenwolf p. 44)

Ravenwolf reveals an acceptance of the Hermetic concept of The All, and that the God and Goddess are merely the masculine and feminine aspects of The All. Wiccans and Pagans break the God and Goddess into the pantheons of gods and goddesses (Ravenwolf p. 45) much as Hermeticists may break The All into archangels, angels, and demons, or even follow the Wiccan/Pagan path. As far as the view of God is concerned, the major difference between Hermeticism, Paganism, and Wicca is that Pagans and Wiccans personify the masculine and feminine aspects of The All.

These three also share a sense that all things in nature are in some sense sentient, possessing intelligence, consciousness, and feeling, however weak. (Hall *The Hermetic Marriage* p. 230)

Zoroastrianism

Zoroastrianism plays a large role in influencing Hermeticism. In 525 BCE, Egypt was conquered by the Persian Empire, bringing Zoroastrian ideas along with it. (Able & Hare p. 8) In obscure texts, Hermes claims to look to Zoroaster as a spiritual father, having learned much of the zodiac from him. It is further said that Zoroaster had penetrated the mystery of the zodiac more than any other. (Powell pp. 15-6) Alternatively, it has been suggested that Zoroaster (like so many others) and Hermes are one and the same. (Hall *The Secret Teachings of All Ages* p. 516) It is possible that this was from a faked Zoroastrian text however. Theurgy is often called Zoroastrian Magic as well. (Garstin pp. 9-10)

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Hermes Trismegistus

Hermes Trismegistus (Greek for "Hermes the thrice-greatest", Greek: *Ερμης ο Τρισμεγιστος*) or **Mercurius ter Maximus** in Latin, is the syncretism of the Greek god Hermes and the Egyptian Thoth. In Hellenistic Egypt, the god Hermes was given as epithet the Greek name of Thoth. He has also been identified with Enoch. Other similar syncretized gods include Serapis and Hermanubis.

Hermes Trismegistus might also be explained in Euhemerist fashion as a man who was the son of the god, and in the Kabbalistic tradition that was inherited by the Renaissance, it could be imagined that such a personage had been contemporary with Moses, communicating to a line of adepts a parallel wisdom. (Occultist etymology has connected the two, making of Moses a truncated name and positing a full name, Thothmoses. This is presented in the *royal hostage* thesis below.) A historian, however, would leave such speculation to the history of alchemy and the 19th-century history of occultism.

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Origin

Both Thoth and Hermes were gods of writing and of magic in their respective cultures. Thus the Greek god of interpretive communication was combined with the Egyptian god of wisdom as a patron of astrology and alchemy. In addition, both gods were psychopomps, guiding souls to the afterlife.

The majority of Greeks, and later Romans, did not accept Hermes Trismegistus in the place of Hermes. The two gods remained distinct from one another. Cicero noted several individuals referred to as "Hermes":

the fifth, who is worshipped by the people of Pheneus [in Arcadia?], is said to have killed Argus, and for this reason to have fled to Egypt, and to have given the Egyptians their laws and alphabet: he it is whom the Egyptians call Theyn [Thoth].

The Hermetic literature added to the Egyptian concerns with conjuring spirits and animating statues that inform the oldest texts, Hellenistic writings of Greco-Babylonian astrology and the newly developed practice of alchemy (Fowden 1993: pp65–68). In a parallel tradition, Hermetic philosophy rationalized and systematized religious cult practices and offered the adept a method of personal ascension from the constraints of physical being, which has led to confusion of Hermeticism with Gnosticism, which was developing contemporaneously Dan Merkur, "Stages of Ascension in Hermetic Rebirth".

As a divine fountain of writing, Hermes Trismegistus was credited with tens of thousands of writings, of immense antiquity and high standing. Plato's *Timaeus* and *Critias* state that in the temple of Neith at Sais, there were secret halls containing historical records which had been kept for 9,000 years. Clement of Alexandria was under the impression that the Egyptians had forty-two sacred writings by Hermes, encapsulating all the training of Egyptian priests. Siegfried Morenz has suggested (*Egyptian Religion*) "The reference to Thoth's authorship...is based on ancient tradition; the figure forty-two probably stems

from the number of Egyptian nomes, and thus conveys the notion of completeness." The Neo-Platonic writers took up Clement's "forty-two essential texts".

The so-called "Hermetic literature", the *Hermetica*, is a category of papyri containing spells and induction procedures. In the dialogue called the *Asclepius* (after the Greek god of healing) the art of imprisoning the souls of demons or of angels in statues with the help of herbs, gems and odors, is described, such that the statue could speak and prophesy. In other papyri, there are other recipes for constructing such images and animating them, such as when images are to be hollow so as to enclose a magic name inscribed on gold leaf.

Hermetic revival

For the main article, see Hermeticism. For the career of the Corpus Hermeticum, see Hermetica.

During the Middle Ages and the Renaissance, the writings attributed to Hermes Trismegistus known as the *Hermetica* enjoyed great credit and were popular among alchemists. The "hermetic tradition" therefore refers to alchemy, magic, astrology and related subjects. The texts are usually distinguished in two categories the "philosophical" and "technical" hermetica. The former deals mainly with issues of philosophy, and the latter with magic, potions and alchemy. Among other things there are spells to magically protect objects, hence the origin of the term "Hermetically sealed".

The texts that were traditionally written at the dawn of time, the classical scholar Isaac Casaubon in *De Rebus sacris et ecclesiasticis exercitationes XVI* (1614) showed, by the character of the Greek, to be more recent: most of the "philosophical" *Corpus Hermeticum* can be dated to around AD 300.

New Age revival

Modern occultists continue to suggest that some of these texts may be of Pharaonic origin, and that "the forty two essential texts" that contained the core work of his religious beliefs and his life philosophy remain hidden away in a secret library.

In some of the readings of Edgar Cayce, Hermes or Thoth was an engineer from the submerging Atlantis and that he built or designed or directed the construction of the Pyramids of Egypt. Hermes Trismegistus is said to be an incarnation of Jesus.

Within the occult tradition, Hermes Trismegistus is credited with several wives, and more than one son who took his name, as well as more than one grandson. This repetition of given name and surname throughout the generations may at least partially account for the legend of his longevity, especially as it is believed that many of his children pursued careers as priests in the religion he started.

Fictional references

In White Wolf's World of Darkness, Hermes Trismegistus is held to be the founder of the faction of mages known as the Order of Hermes.

Tristram Shandy, the famous protagonist of Laurence Sterne, was to be named "Trismegistus" to counter the negative circumstances of his birth. He was instead named "Tristram", meaning "sad", further damaging his future.

Rosicrucian



 "The Temple of the Rose Cross," Teophilus Schweighardt Constantiens, 1618.

The **Rosicrucian Order** is a legendary and secretive Order dating from the 15th or 17th century. It generally is associated with the symbol of the Rose Cross, which is also found in certain rituals beyond "Craft" or "Blue Lodge" Freemasonry. The Rosicrucian Order is viewed among earlier and many modern Rosicrucianists as an inner worlds Order, comprised of great "Adepts." When compared to human beings, the consciousness of these Adepts is said to be like that of *demi-gods*. This "College of Invisibles" is regarded as the source permanently behind the development of the Rosicrucian movement.

Several modern societies have been formed for the study of Rosicrucianism and allied subjects. However, many researchers on the history of Rosicrucianism argue that modern Rosicrucianists are in no sense directly derived from the "Brethren of the Rose Cross" of the 17th century. Instead, they are considered to be keen followers. Moreover, some have viewed the 17th century order as a literary hoax or prank, rather than an operative society. Others contend that history shows them to be the genesis of later operative and functional societies.

The Rosicrucian greeting is, "May the Roses bloom upon your Cross."

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Origins

According to a legend published in the 17th century Rosicrucian manifestos, the Rosicrucian Order was founded in 1407 (the early 15th century) by a German pilgrim named Christian Rosenkreuz (1378 - 1484), who studied in the Middle East under various occult masters. During his lifetime, the Order was alleged to be small, consisting of no more than eight members. When Rosenkreuz died in 1484, the Order disappeared, only to be "reborn" in the early 17th century. Most modern Rosicrucianists accept this legend to varying degrees. Some accept it as literal truth, others see it as a parable, and yet others believe Rosenkreuz to be a pseudonym for a more famous historical figure, usually Francis Bacon.

According to a lesser known legend found in Masonic literature, the Rosicrucian Order was created in year 46 when an Alexandrian Gnostic sage named Ormus and his six followers were converted by one of Jesus' disciples, Mark. From this conversion, Rosicrucianism was born by fusing early Christianity with Egyptian mysteries. By this account, rather than being its founder, Rosenkreuz would have been initiated into and become the Grand Master of an already existing Order.

According to Émile Dantinne (1884-1969), the origins of the Rosicrucians may have an Islamic connection. As told in their first manifesto *Fama Fraternitatis* (1614) (early 17th century) Christian Rosenkreuz started his pilgrimage at the age of sixteen. This led him to Arabia, Egypt and Morocco, where he was put into contact with the sages of the East, who revealed to him the universal harmonic science. After learning Arabic philosophy in Jerusalem, he was led to *Damcar*. This place remains a mystery – it did not become

Damascus, but it is somewhere not too far from Jerusalem. Then he went to Egypt , where he did not stay for long. Soon afterwards he embarked to Fes, a center of philosophical and occultist studies, such as the alchemy of Abu-Abdallah, Gabir ben Hayan, and Imam Jafar al Sadiq, the astrology and magic of Ali-ash-Shabramallishi, and the esoteric science of Abdarrahan ben Abdallah al Iskari. However, Dantine states that Rosenkreuz may have found his secrets amongst the "Brethren of Purity," a society of philosophers that had formed in Basra (Iraq) during the first half of the fourth century. Their doctrine had its source in the study of the ancient Greek philosophers, but it became more pronounced in a neo-Pythagorean direction. They adopted the Pythagorean tradition of envisioning objects and ideas in terms of their numeric aspects. Their theurgy taught the divine and angelic names, conjurations, the Kabbalah, exorcisms, and other related subjects.

The "Brethren of Purity" and the Sufis were united in many points of doctrine. They both were mystical orders deriving from Koranic theology, where dogma is supplanted by faith in the "Divine Reality." Many similarities with the Rosicrucian way were expressed in the manifestos and the "Brethren of Purity" ways of life as well. Neither group wore special clothing, both practiced abstinence, they healed the sick, and they offered their teachings free of charge. Similarities also were evident in the doctrinal elements of their theurgy and the story of Creation in terms of emanationism.

The curious legend in which the fabulous origin of the so-called society was established was so improbable, though ingenious, that the genesis of the Rosicrucians was generally overlooked or ignored in the writings of the time. Christian Rosenkreuz had discovered and learned the Secret Wisdom on a pilgrimage to the East in the 15th century. The metaphorical quality of these legends lends to the nebulous nature of the origins of Rosicrucianism. For example, the opening of Rosenkreuz's tomb is thought to be only a way of referring to the cycles in nature and to cosmic events.

History

It is on the foundation of these teachings that Rosenkreuz conceived the plan for simultaneous and universal religious, philosophic, scientific, political, and artistic reform. For the realization of this plan, he united with several disciples (seven at first, according to *Fama Fraternitatis*), to whom he gave the name of Rose-Croix.

The founder of the Order of the Rose-Croix belonged, as affirmed by historians, to a noble family, but there is no document that allows us to affirm this peremptorily. However, it is certain that he was an orientalist and a great traveler.

What was known in the early 17th century as the "Fraternity of the Rose Cross" seems to have been a number of isolated individuals who held certain views in common, which apparently was their only bond of union. These views were regarding hermetic knowledge, related to the higher nature of man, and also with common philosophical conceptions towards the foundation of a more perfected human society. There is no trace of a Fraternity or secret society which held meetings, or had officers or leaders. So far, as

many works are concerned, it is evident that the writers who posed as Rosicrucians were moral and religious reformers, and utilized the technicalities of chemistry (alchemy), and the sciences generally, as media through which to publicize their opinions and beliefs. Their writings included a hint of mysticism or occultism, promoting inquiry and suggesting hidden meanings discernible or discoverable only by "Adepts."

The publications of *Fama Fraternalitatis Rosae Crucis* (1614), *Confessio Fraternalitatis* (1615), and *Chymical Wedding of Christian Rosenkreutz* (1616) caused immense excitement throughout Europe. These works declared the existence of a secret brotherhood of alchemists and sages who were interpreted as preparing to transform the arts, sciences, religion, political, and intellectual landscape of Europe while wars of politics and religion ravaged the continent. Not only did these works lead to many re-issues, but they were followed by numerous pamphlets, favourable and otherwise, whose authors generally knew little of the real aims of the original author and often amused themselves at the public's expense. According to historical records, it is probable that the first work was circulated in manuscript form about 1610, even though there was no mention of the order before that decade. In fact, research indicates that all three documents probably were the creation of Lutheran theologian Johann Valentin Andreae (1586-1654). However, his authorship only is confirmed for the *Chymical Wedding*, which he subsequently described as a Ludibrium. The authors of the Rosicrucian works generally favoured Lutheranism as opposed to Catholicism.

Around 1530, more than eighty years before the publication of the first manifesto, documented evidence of the *cross* and the *rose* already existed in Portugal in the Convent of the Order of Christ, home of the Knights Templar, which later was renamed Order of Christ. Three *bocetes* were, and still are, on the *abóboda* of the initiations' room. In these cases, the rose can clearly be seen at the center of the cross. At the same time, a minor writing by Paracelsus called *Prognosticatio Eximii Doctoris Paracelsi* (1530) contained the image of a double cross over an open rose, along with a written reference to it. The occultist Stanislas de Guaita, "Au seuil du Mystère" (1886), used Paracelsus' writing, and other examples, to prove the "Fraternity of the Rose Cross" existed far earlier than 1614.

It is evident that the first Rosicrucian manifesto, *Fama Fraternalitatis* (1614), was influenced by the work of the respected hermetic philosopher Heinrich Khunrath, of Hamburg. He was author of the *Amphitheatrum Sapientiae Aeternae* (1609), and was in turn strongly influenced by the work of the mysterious philosopher and alchemist John Dee, author of the *Monas Hieroglyphica* (1564).

The legend and ideas presented in the first two manifestos and in the "Chymical Wedding" originated a variety of controversial issues and works of Rosicrucianists inspiration. Among these, are the works of Michael Maier (1568-1622) of Germany, Robert Fludd (1574-1637) and Elias Ashmole (1617-1692) of England and many others, such as Teophilus Schweighardt Constantiens, Gotthardus Arthusius, Julius Sperber, Henricus Madathanus, Gabriel Naudé, Thomas Vaughan. Some later works with an impact on Rosicrucianism, were the *Opus magocabalisticum et theosophicum* by George

von Welling (1719), of alchemical and paracelsian inspiration, and the *Aureum Vellus oder Goldenes Vliess* by Hermann Fictuld in 1749.

Michael Maier (1568-1622), a philosopher, alchemist, practical chemist, and a doctor in medicine, was ennobled with the title *Pfalzgraf* (Count Palatine) by Rudolph II, Emperor and King of Hungary and King of Bohemia. He also was one of the most prominent apologists and defenders of the Rosicrucians, clearly transmitting details about the "Brothers of the Rose Cross" in his writings. Maier made the firm statement that the Brothers of R.C. actually exist to advance inspired arts and sciences, including Alchemy. The researchers of Maier's writings point out that he never stated, in an objective way, that he had produced gold. Neither Heinrich Khunrath nor any of the other Rosicrucianists ever said as well. Their writings point toward a highly symbolic and spiritual Alchemy, more than an operative one. In both direct and veiled styles, these writings conveyed the nine stages of the involutive-evolutive transmutation of the *threefold body* of the human being, the *threefold soul* and the *threefold spirit*, among other esoteric knowledge related to the "Path of Initiation".

Isaac Newton (1642-1727), one of the most important geniuses of mathematics, also possessed many famous and old treatises of Alchemy. He also made manuscript copies of alchemical works, found today at the Yale University's Library. One of these many works in his collection is the *Themis Aurea* by Michael Maier, to which he made references and comments about notes relating to hermetic philosophy.

In the 1618 manifesto, *Pia et Utilissima Admonitio de Fratibus Rosae Crucis*, Henrichus Neuhusius, presented the conception that the Rosicrucians left for the East, due to the instability in Europe at the time of the Thirty Years' War, 1618-1648. In 1710 Samuel Ritcher, and later on René Guénon, 1886-1951, also presented this idea in some of their works. However, another eminent author on the Rosicrucians, Arthur Edward Waite (1857-1942), presents motifs which contradict this idea. It was in this fertile field of discourse, and filling the vacuum left by the original Rosicrucians, that many societies said to be "Rosicrucianists" arose. They were based on the occult tradition and inspired by the mystery of this "College of Invisibles." However, it is possible only a few of them may have something in common with the true Rosicrucian Order, other than the name.

Influence on Freemasonry



"18° Knight of the Rose Croix" (Masonic's Scottish Rite)

According to Jean Pierre Bayard, two rites of Rosicrucian inspiration emerged from the end of 18th century. One was the Rectified Scottish Rite, which was widespread in Central Europe where there was a strong presence of the "Golden and Rosy Cross". The other was the Ancient and Accepted Scottish Rite, practiced in France. During the 18th century, there were several rites practiced in Freemasonry based on the Renaissance universe of hermeticism and alchemy, which was created by the Rosicrucians of 17th century or earlier.

Although many serious research attempts were made to learn about the change from the *operative Masonry* to the *speculative Masonry*, no concrete answer has yet been found, other than it occurred between the end of 16th century and the beginning of the 17th century. Two of the first speculative Masons were Sir Robert Moray (1600-1675) and Elias Ashmole (1617-1692), of a Masonic lodge meeting in Warrington, Lancashire.

There is no documented evidence for Christopher McIntosh's speculation that Robert Fludd (1574-1637) may have been a Mason. Neither is there any documented evidence to support Arthur Edward Waite (1857-1942) speculating that Fludd may have introduced a Rosicrucian influence into Freemasonry. However Robert Vanloo states that earlier 17th century Rosicrucianism had a considerable influence on Anglo-Saxon Masonry. Hans Schick sees in the Rosicrucian works of Comenius (1592-1670) the ideal of the newly born English Masonry before the foundation of the Grand Lodge in 1717. Comenius was in England during 1641.

A point of similarity between the two groups, in continental Europe, is found during the 18th century. The Masonic circle "Gold und Rosenkreuzer" (Golden and Rosy Cross), published the *Geheime Figuren* or "The Secret Symbols of the 16th and 17th century Rosicrucians" in 1785 and 1788. This circle, oriented by Hermann Fictuld from 1777 along Masonic lines, had important branches in Russia, which may have introduced Freemasonry and Martinism into that region.

Rose Cross: Alchemy and Divine Sciences of Healing & of the Stars

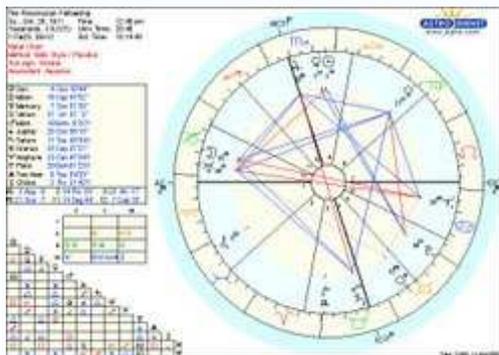
The alchemy in the laboratory (the ancestor of modern chemistry), where the ultimate goal was understanding of the laws of Nature in order to aid the individual's quest for perfection, recalls another type of alchemy, the one called *spiritual*. The true alchemists, or *philosophers of the fire*, often make reference in their works to the *blowers*, meaning all those who were just interested the creation of gold and the material aspects of alchemy.

In his laboratory, the alchemist works on the *materia prima* and surrounds himself, among other tools to accomplish the operations, of a furnace with a peculiar form, called athanor.

In the point of view of the *Spiritual Alchemy* [1], the materia prima is the human soul, and about the athanor, it is constituted by the physical body and the subtle bodies. These last ones maintain the life of the most dense one and assure the connection with the soul. The laboratory is the human existence during which the soul has the possibility of accomplishing the learning needed to perfect itself, operating the transmutation of the vices and defects of the vil metal into spiritual, that is, into related virtues and qualities.

The first Rosicrucians practiced the operative alchemy, in vogue at that epoch, of interest even to the higher ranks of popes and kings. The *Chymical Wedding of Christian Rosenkreutz* is a major written work which clearly makes reference, through its title, to this work on the matter, in the laboratory.

Current-day Rosicrucianists (like modern Freemasons, who do not construct cathedrals anymore) direct their concentration toward the work of spiritual alchemy.



3rd Natal Chart of The Rosicrucian Fellowship (1911)

According to the early Manifestoes, the Rosicrucians were a "secret" Order. Their members believed or could "demonstrate" healing powers that were believed to be a gift from God: *Spiritual Healing*. In the outer orders these powers were explained by Egyptian mysteries and again, differently in the hermetic Order. Members were admitted

on this basis alone and the "membership" was very selective. The writers, philosophers and people of the time became curious and infuriated because they were denied entrance into these secret meetings. Most of the writings of the time are biased or speculative for this reason. Many modern Rosicrucian organizations hold the belief that these God given powers may be used to help others.

Some interpretations are described as being Rosicrucian. They are used as an idea or icon by persons or groups either Gnostic Christian or simultaneously Christian and trans-Christian. An example would be a cult that centers around the Virgin Mary yet openly or secretly identifies her to the Virgo constellation of the Zodiac.

A large majority of modern Rosicrucians believe in the study of *Spiritual Astrology* as a key to the *Spirit*, designed toward spiritual development and self-knowledge, as well as an aid to healing through *Astro-Diagnosis*. [2]

A way through which the alchemical work on the "Path of Initiation" has been expressed to the world, according to occultists as Corinne Helene (1882-1975), is through some of the great compositions of classical music. To wit, the nine symphonies of Beethoven (1770-1827) were divided into two groups. The first, the third, the fifth, and the seventh are vigorous, powerful and of command, representing the *intellect*. The second, the fourth, the sixth and the eighth are elegant, ternurent, gracious and beautiful, representing the *heart (intuition)*. They culminate in the symphony with human voices, the ninth symphony, in which the equilibrium between *mind* and *heart* or the "Chymical Wedding" ritual, where the *Christ Within* – the Adept – is born ("consumatun est"). Johan Herde speaks of Beethoven as "... *God acts on earth through evolved men...*" and Beethoven speaks of himself as "... *I do not have friends, that is why I must live alone, but I know from the deepest of my heart, that God is closer to me than to others. I come close to Him without fear, because I have always known Him...*".

Occultists also point out that many of the works of William Shakespeare (1564-1616), the music-dramas of Wagner, Goethe's *Faust*, Dante's *Divine Comedy* or Camoens's epic *Lusiads*, and a few other books of comparable rank, are designed for *esoteric* as well as *exoteric* reading. In Shakespeare's works, specific signatures, cryptically conveyed, also are presented. In *Love's Labour's Lost* a whole scene is devoted to revealing, in an ingenious way to those possessing the keys, the Rosicrucian connection. The scene closes with a remark addressed to Goodman Dull, a representative of the unperceiving multitude, that during the entire scene he has not spoken a word. "No," comes his response, "*nor understood none neither*". [3]

The Manifestos

If one abstracts from the symbolic associations of the *rose* and the *cross*, which have been visioned by many since ancient epochs, it is known that three treatises or manifestos which gave rise to this movement were published in the German language between 1614 and 1616:

- 1614: *Fama Fraternitatis*
- 1615: *Confessio Fraternitatis*
- 1616: *Chymical Wedding of Christian Rosenkreutz*

Between 1614 and 1620, about 400 manuscripts and books were published which discussed the Rose-Croix documents.

The peak of the so-called "Rosicrucianism furor" was reached when two mysterious posters appeared in the walls of Paris in 1622 within few days from each other. The first one started with the saying "*We, the Deputies of the Higher College of the Rose-Croix, do make our stay, visibly and invisibly, in this city (...)*" and the second one ended with the words "*The thoughts attached to the real desire of the seeker will lead us to him and him to us*".

The following lines can be found in *The Muses' Threnodie* by H. Adamson (Perth, 1638): "*For what we do presage is riot in grosse, for we are brethren of the Rosie Crosse; We have the Mason Word and second sight, Things for to come we can foretell aright.*"

The Rosicrucians took the union of the rose and the cross for their symbol because this union embodies the meaning of their effort and emphasizes the fact that that effort must be made by all men, as the aim of humanity on earth is to attain *divine wisdom*. Only two ways lead to this divine wisdom: knowledge and love. By the rose blooming in the middle of the cross, the whole meaning of the universe is explained: in order to realize its possibilities and become perfect, mankind must develop the capacity for love to the point of loving all creatures and all forms perceptible to the senses; it must enlarge the capacity for knowledge and understanding to the point of comprehending the laws that govern the worlds, and of being able to proceed, through intuition and the loving intelligence of the heart, from every effect to every cause [4].

Modern groups

During the late nineteenth and early twentieth centuries, various groups styled themselves Rosicrucian. Almost all claimed to be authentic heirs to a historical Rosicrucian tradition. These include the Ancient Mystical Order Rosae Crucis (AMORC), the Confraternity of the Rose Cross (CR+C), Fraternitas Rosae Crucis, the Rosicrucian Order Crotona Fellowship, Societas Rosicruciana, the Hermetic Order of the Golden Dawn, Societas Rosicruciana in Anglia, and others as well.

Esoteric Christianity groups vs. Para-Masonic groups

These diverse groups can be divided into two categories: the para-Masonic groups and the Esoteric Christianity groups. There has never been any connection between these two streams.

Para-Masonic groups may be defined as being late heirs of the alchemy and hermetic knowledge created by the original 15th or 17th century "College of Invisibles" and

generally speak of a historical heritage. The inner structure of these groups is based upon Masonic lines, such as grades, initiations and titles.

The Esoteric Christianity groups regard themselves as representing a "rebirth" in the *New World* of the inner worlds as described by the original Rosicrucian Order and generally speak of a *spiritual* heritage. Their mission is to prepare the whole world for a new phase in Religion during the next six centuries toward the Age of Aquarius.

List of 'Para-Masonic' groups

- Ancient Mystical Order Rosae Crucis
 - Christian Bernard (1951 -): current (2004) Emperor of AMORC; presented the *Positio Fraternitatis Rosae Crucis* [5] in 2001 (AMORC Rosicrucian Year 3354).
 - Julie Scott (1958 -): current (2004) Grand Master of the English Grand Lodge for the AMORC.
 - Gary L. Stewart: Emperor of AMORC from 1987 to 1990; founded the CR+C in 1996.
 - Ralph Maxwell Lewis (1904 - 1987): the son of Harvey Spencer Lewis; was the Emperor of AMORC from 1939 to 1987.
 - Harvey Spencer Lewis (1883 - 1939): founder and the first Emperor of AMORC from 1915 until 1939; also founded the Rosicrucian Egyptian Museum (1929).
- Rosicrucian Order Crotona Fellowship
 - George Alexander Sullivan (1890-1942), founder of the Rosicrucian Order Crotona Fellowship
- Fraternitas Rosae Crucis
 - Reuben Swinburne Clymer (1878 - 1966): succeeded Edward H. Brown as Supreme Grand Master of Fraternitas Rosae Crucis in 1922.
 - Paschal Beverly Randolph (1825 - 1875): founder of the Fraternitas Rosae Crucis (1858).
- Hermetic Order of the Golden Dawn
 - Samuel Liddell MacGregor Mathers (1854-1918): a famous magician and one of the most influential figures in modern Occultism, co-founder of the Hermetic Order of the Golden Dawn in 1888.
- Societas Rosicruciana in Anglia
 - William Wynn Westcott (1848 - 1925): became Magus of the Societas Rosicruciana in Anglia in 1890; author of the *Rosicrucian Thoughts on the Ever-Burning Lamps of the Ancients* (1903) [6] and other extensive writings in the fields of medicine and the occult literature.

List of 'Esoteric Christianity' groups

- The Rosicrucian Fellowship

- Max Heindel (1865-1919): founder of The Rosicrucian Fellowship in 1909/11; author of *The Rosicrucian Cosmo-Conception* (1909) and many other *esoteric Christian* and *spiritual astrology* writings.
- Anthroposophical Society
 - Rudolf Steiner (1861-1925): founder of the Anthroposophical Society, lecturer of the *Esoteric Christianity and the Mission of Christian Rosenkreutz* [7] and author of many *Rosicrucian Christianity* lectures.
- The Heindel-Steiner Connection (2005) & *Rosicrucianism and Religion* (1995) by Charles Weber
- The Mystic Gallery "Rosicrucians" & The Mystic World Gallery by Reinhard Ponty (Art Gallery; 2002-2005)
- Lectorium Rosicrucianum
 - Jan van Rijckenborgh (1896-1968) and Catharose de Petri (1902-1990): after leaving the Rosicrucian Fellowship, in 1935, founded the Lectorium Rosicrucianum as a *gnostic Spiritual School*.

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- Max Heindel, *Christian Rosenkreuz and the Order of Rosicrucians*, 1909, [13].
- William Wynn Westcott, *Rosicrucian Thoughts on the Ever-Burning Lamps of the Ancients*, 1903, [14].
- Hargrave Jennings, *The Rosicrucians: Their Rites and Mysteries*, 1870, advanced an eccentric solar-phallic interpretation of the brotherhood.

Essays

- Alexandre David, *Fama Fraternitatis - Introduction*, [15].
- Corinne Heline, *The Seven Jewels and the Seven Stages of Initiation*, [16]

Fictional literature

- Edward Bulwer-Lytton, *Zanoni: A Rosicrucian Tale* (1842), [17].
- Prentiss Tucker, *In the Land of the Living Dead: an Occult Story* (1929), [18].
- Hermann Hesse, *Journey to the East* (1932, also "Journey to the Land of the Morning/of the Tomorrow" (*Die Morgenlandfahrt*))
- Hermann Hesse, *The Glass Bead Game* (1943), also known as "Magister Ludi" (Master of the Game).

Conspiracy literature

- Michel Baigent, Richard Leigh and Henry Lincoln, *Holy Blood, Holy Grail* (1982), advanced a pseudohistorical relation of Rosicrucianism with a secret society called Priory of Sion.
- Umberto Eco, *Foucault's Pendulum* (1988), *Serendipities: Language and Lunacy* (1998).
- Dan Brown, *The Da Vinci Code* (2003), follows the *Holy Blood, Holy Grail's* conspiracy theories line.

Song

- Leonard Cohen's "Dress Rehearsal Rag" (*Songs of Love and Hate*, 1971) features the lyrics:

Why don't you join the Rosicrucians, they can give you back your hope, you can find your love with diagrams on a plain brown envelope.

Hermetic Alchemy

Hermetic Alchemy or **The Operation of the Sun** is a spiritual technique used to purify and refine oneself. Disagreements exist over whether physical alchemy or spiritual, Hermetic alchemy came first. Scholars of science tend to believe that spiritual alchemy is the offspring of physical alchemy, while occult scholars tend to believe that physical alchemy is the perversion of its spiritual counterpart. Others, such as Manly P. Hall, believe that both are plausible and that spiritual alchemy is the key to successfully doing physical alchemy. (Hall *The Secret Teachings of All Ages* p. 509)

Hermetic Alchemy came forth from Egypt, as a Hermetic art, and during the Middle Ages dominated the other branches (Astrology and Theurgy). (Hall *The Hermetic Marriage* p. 225) This art and Astrology are known as the two oldest sciences in the world. A legend even exists which purports that an angel had given to Adam knowledge of these two arts and told him that mankind could reenter Eden once both were mastered. (Hall *The Secret Teachings of All Ages* p. 494) *It gained much support from those who required logic, reason, and philosophy once religion in Europe lost its philosophical edge and became entrenched in blind faith.* (Hall *The Hermetic Marriage* p. 226)

Alchemy has given birth to chemistry through the work of such men as Roger Bacon. (Hall *The Hermetic Marriage* p. 225) However, according to Hermetic alchemists, the physical side to the art is only half of it, the spiritual is the other. This is revealed in the symbolism of the Egyptian goddess Isis whose veil hides the other half from the unworthy. (Hall *The Secret Teachings of All Ages* p. 126)

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 - 3.7 Coagulation

The Physical Chicken and the Spiritual Egg

Much like the old riddle of "which came first, the chicken or the egg?", scholars debate over whether the physical alchemy or spiritual alchemy came first. Invariably, those with an opinion on the matter contend that the version which came first spurned the version that came after. Both sides have evidence in their favor.

Metaphorical Alchemical Substances

Gold

Silver

Lead

Salt

Mercury

Sulphur

Philosopher's Stone

Panacea

Spiritual Alchemical Process

Calcination

Dissolution

Separation

Conjunction

Fermentation

Distillation

Coagulation

Philosopher's stone

The **philosopher's stone**, in Latin *lapis philosophorum*, is a mythical substance that supposedly could turn inexpensive metals into gold and/or create an elixir that would make humans younger, thus delaying death. It was a longtime "holy grail" of Western alchemy. In the mystic view of alchemy, making the philosopher's stone would bring enlightenment upon the maker and conclude the Great Work. It is also known by several other names, such as *materia prima*.

Philosopher's Stone is also a modern slang name for certain hallucinogenic mushroom; see *Psilocybe*.

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 - 4.1 Novels

The stone in alchemy

Transmutation of metals

The concept apparently originated from the theories of the 8th century Islamic alchemist Geber. He analyzed each Aristotelian element in terms of four basic qualities of *hotness*, *coldness*, *dryness*, and *moistness*. Thus, fire was both hot and dry, earth cold and dry, water cold and moist, and air hot and moist. He further theorized that every metal was a combination of these four principles, two of them interior and two exterior.

From this premise, it was reasoned that the transmutation of one metal into another could be effected by the rearrangement of its basic qualities. This change would presumably be mediated by a substance, which came to be called *al-iksir* in Arabic (from which comes the Western term "elixir"). It was often imagined as a dry powder, made from a mythical stone — the "philosopher's stone". The stone was believed to have been composed of a substance called carmot.

Geber's theory and the concept of the philosopher's stone may have been inspired by the knowledge that metals like gold and silver could be hidden in alloys and ores, from which they could be recovered by the appropriate chemical treatment. Geber himself is believed to be the inventor of aqua regia, a mixture of muriatic and nitric acids, which is one of the few substances that can dissolve gold (and is still often used for gold recovery and purification).

The stone as a spiritual metaphor

Alchemy has always made extensive use of analogy, symbolism, and so forth to relate chemical and physical concepts to esoteric and mystic ones. In some epochs and contexts, these metaphysical aspects came to predominate, and the chemical processes were then viewed as mere symbols of spiritual processes. In this hermetic side of alchemy, the "philosopher's stone", supposed to be the most tangible and dense crystallization or condensation of a subtle substance, became a metaphor for an inner potential of the spirit and reason to evolve from a lower state of imperfection and vice (symbolized by the base metals) to a higher state of enlightenment and perfection (symbolized by gold). In this view, spiritual elevation, the transmutation of metals, and the purification and rejuvenation of the body were seen to be manifestations of the same concept.

The mystical revival in the late 20th century renovated the public interest on alchemy, and particularly on this metaphysical and philosophical conception of the philosopher's stone — which is now subscribed by many people, especially within several New Age movements.

Claims and frauds

The concept of a substance that could turn inexpensive metals into valuable gold naturally attracted the attention of many entrepreneurs of all sorts — learned and amateurish, skeptical and gullible, honest and dishonest. An example that illustrates the spirit of the times is that of Rudolf II (1552-1612). This king of Bohemia, having found himself in financial difficulties, decided to invest heavily in the search for the philosopher's stone. He thus attracted to Prague a large number of alchemists, who were

given ample material and financial support, and promised rewards if they could solve the problem. This "virtual gold rush" may have involved even the Danish astronomer Tycho Brahe, then at Rudolf's court, who had an alchemical lab built on the grounds of his observatory.

Rudolf never saw his dream realized, and he eventually became insane and had to be deposed by his relatives. It is not known whether his insanity was due to natural causes, or to misuse of alchemical "remedies" — which often included toxic materials like sulphur, lead, mercury, arsenic, and antimony.

Edward Kelley

Among those who took Rudolf's offer were the English scholar John Dee, and his assistant Edward Kelley, one of the many alchemists who have claimed possession of the philosopher's stone.

Specifically, Kelley claimed that he had acquired in England small amounts of two powders, one white and one red, which had allegedly been found in Wales, in the raided tomb of a Bishop. From these two powders, Kelley would prepare a red "tincture", one drop of which could turn a larger quantity of heated mercury into gold. There are reports that he performed this feat several times, once even in the presence of Rudolf's court officials, and the gold was later tested and found to be genuine. He is also reported as sending to queen Elizabeth I of England a copper bed warmer which had been partly transmuted into gold.

Kelley also carried with him a cryptic manuscript, which he claimed had been found with the powders, and which presumably held the secret of their manufacture. On the basis of these claims, Kelley obtained much support from Rudolf — so much so that, when Dee broke with him and returned to England, Kelley chose to remain in Prague. However, Kelley eventually ran out of his magic powders, was jailed by Rudolf in a tower of his castle, and died of injuries sustained in an extravagant escape attempt.

The nature of Kelley's powders is open to conjecture. Gold can be dissolved by aqua regia to give a red-colored chloride, from which the metal can be easily recovered by heat or simple chemical means. Although that salt has a tendency to decompose on its own, it seems at least possible that Kelley simply plated a layer of gold on some other metal (possibly dissolved in the mercury to form an amalgam) and then used sleight-of-hand or bribery to pass the goldsmith's test.

The stone and modern science

Though the notion of a simple philosopher's stone of the alchemic sense fell out of scientific conception by at least the 19th century, its metaphors and imagery persisted: man's attempt to discover the essential secret of the universe, redemptively transforming not just lead into gold, but death into life.

In 1901, Ernest Rutherford and Frederick Soddy discovered that radioactivity was a sign of fundamental changes within elements, and it was Soddy who quickly made the connection between this and the ancient search for the philosopher's stone (Soddy had studied alchemy extensively as a hobby). At the moment of realization that their radioactive thorium was converting itself into radium, bit by bit, Soddy later recalled that he shouted out: "Rutherford, this is transmutation!" Rutherford snapped back, "For Christ's sake, Soddy, don't call it *transmutation*. They'll have our heads off as alchemists." However the term stuck, in part because it drew the new discoveries in nuclear physics into a longer cultural and mystical web.

When it was discovered that radioactivity was also tapping into a latent source of energy bound inside atoms, this furthered the thought that radioactive decay might be the ultimate philosopher's stone. Later, the discovery of nuclear fission would become consciously connected into the same narrative, especially with optimistic hopes of energy "too cheap to meter" and great utopian cities of the future run on nuclear energy.

The stone in art and entertainment

The philosopher's stone has been subject, inspiration, or plot feature of innumerable artistic works — novels, comics stories, movies, animations, and even musical compositions. It is also a popular item in many video games. The following is a very incomplete list.

Novels

- *Philosopher's Stone*, by Hans Christian Andersen.
- *The Trumpeter of Krakow* (1928), by Eric P. Kelly.
- *The Philosopher's Stone (Colin Wilson book)* (1971), by C. H. Wilson.
- *The Ogre Downstairs* (1974), by Diana Wynne Jones.
- *The Alchemist* (1988), by Paulo Coelho.
- *Foucault's Pendulum* (1988), by Umberto Eco , where a character claims that the Stone is actually the mythical Holy Grail.
- *Harry Potter and the Philosopher's Stone* (1997), by J. K. Rowling.
- The *Baroque Cycle* trilogy (2003–2004), by Neal Stephenson, where it is used to explain an unusually dense gold sample.
- *Indiana Jones and the Philosopher's Stone* (1995), by Max McCoy.

Musical works

- The album *Grand Materia* by the Swedish band Morgana Lefay (2005) is about Nicholas Flamel and the Philosopher's Stone.
- *Philosopher Stone* is a Van Morrison song in the Wonder Boy album.
- "The Grudge" by the band TOOL is about the mystical transmutation of the soul.

Alchemical symbol

Alchemical symbols, originally devised as part of the protoscience of alchemy, were used to denote some elements and some compounds until the 18th century. Note that while notation like this was mostly standardized, style and symbol varied between alchemists, so this page lists the most common.

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- [5 12 Core Alchemical processes](#)

Four basic Elements

- Fire 
- Water 
- Earth 
- Air 

Seven Planetary Metals

Planetary metals were "dominated" or "ruled" by one of the seven planets known by the ancients. Although they occasionally have a symbol of their own (denoted by also:), they were usually symbolized by the planet's symbol. Uranus, Neptune, and Pluto were not yet discovered while Alchemy was commonly practiced, though many modern alchemists consider them representative of Uranium, Neptunium and Plutonium, respectively.

- Gold dominated by Sol  (also: )
- Silver dominated by Luna 
- Copper dominated by Venus  (also: )
- Iron dominated by Mars 
- Tin dominated by Jupiter 
- Mercury (Quicksilver) dominated by Mercury 
- Lead dominated by Saturn 

Mundane Elements

- Antimony
- Arsenic
- Bismuth ☿
- Boron
- Magnesium ⊕
- Phosphorus
- Platinum
- Potassium
- Stone ♁
- Sulfur ☿ ♀
- Zinc

Alchemical Compounds

- Sal armoniac *
- Aqua Fortis A.F.
- Aqua Regia A.R.
- Spirit of Wine S.V.
- Amalgama ååå
- Cinnabar (Mercury sulfide) ☿ 3

12 Core Alchemical processes

The 12 Alchemical processes are considered to be the basis of modern Chemical processes. Each of these processes is "dominated" or "ruled" by one of the 12 Zodiac signs.

- Decomposition through Calcination (Aries ♈)
- Decomposition through Digestion (Leo ♌)
- Decomposition through Fermentation/Putrefaction (Capricorn ♐ ♑)
- Modification through Congelation (Taurus ♉)
- Modification through Fixation (Gemini ♊)
- Modification through Ceration (Sagittarius ♐)
- Separation through Distillation (Virgo ♍)
- Separation through Sublimation (Libra ♎)
- Separation through Filtration (Scorpio ♏)
- Union through Solution (Cancer ♋)
- Union Multiplication (Aquarius ♒)
- Union Projection (Pisces ♓)

Astrology and alchemy

Alchemy in the Western World and other locations where it was widely practiced was (and in many cases still is) closely allied and intertwined with traditional Babylonian-Greek style astrology; in numerous ways they were built to complement each other in the search for hidden knowledge. Traditionally, each of the seven planets in the solar system as known to the ancients was associated with, held dominion over, and *ruled* a certain metal.

The list of rulership is as follows:

- The Sun rules Gold (☉)
- The Moon, Silver (☾)
- Mercury, Quicksilver/Mercury (☿)
- Venus, Copper (♀)
- Mars, Iron (♂)
- Jupiter, Tin (♃)
- Saturn, Lead (♄)

Some *modern* alchemists/astrologers obviously associate:

- Uranus with Uranium
- Neptune, Neptunium
- Pluto, Plutonium

As these planets were not discovered until relatively recently, there is no classical or traditional basis for these associations as there is for the ancient planets and metals.

As Isaac Newton was indisputably a well known alchemist of his time period, and astrology and alchemy were (and in some cases still are) so closely linked, it is very plausible that Newton had a very good working knowledge of astrology, or at the very least a basic understanding of astrological methodology as it was related to alchemy. Logically then, one would certainly have to know a good bit about astrology in order to use alchemy effectively, and Newton along with other prominent alchemists definitely knew this. For more information see Isaac Newton's occult studies.

Geber

15th-century European portrait of "Geber", Codici Ashburnhamiani 1166, Biblioteca Medicea Laurenziana, Florence

Jabir Ibn Hayyan (full name **Abu Musa Jabir Ibn Hayyan Al-Azdi**, أبو موسى جابر بن حيان الأزدي; ca.721, Tus, Khorasan – 815, Kufa, Iraq), known in Europe by the

Latinized name **Geber**, was one of the most notable Islamic alchemists. His books strongly influenced European alchemists and justified their search for the philosopher's stone. He is credited with the invention of many types of now-basic chemical laboratory equipment, and with the discovery and description of many now-commonplace chemical substances and processes — such as the hydrochloric and nitric acids, distillation, and crystallization — that have become the foundation of today's chemistry and chemical engineering.

Jabir Ibn Hayyan and Geber were also pen names of an anonymous 14th century European alchemist, author of the treatise Summa Perfectione and several other books: see Pseudo-Geber.

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Biography

Jabir Ibn Hayyan was born around 721 in the town of Tus in Khorasan, present-day Iran, then part of the Islamic Caliphate. His father, a druggist of the Arabian Azd tribe, was executed for conspiring to overthrow the Umayyad caliphate.

As a young man Jabir was sent to Kufa (present Iraq), to study the Qu'ran and mathematics. In Kufa he became a student of the celebrated Islamic teacher and sixth Imam Ja'far al-Sadiq. He lived for most of his life at Kufa, where he died in 815.

Contributions to chemistry

Jabir is often called "Father of Chemistry", because he was the first scholar to scientifically systematize that science, to whose theory and practice he made many noteworthy contributions.

In spite of his leanings toward mysticism (he was considered a Sufi) and superstition, he more clearly recognized and proclaimed the importance of experimentation. "The first essential in chemistry," he declared, "is that you should perform practical work and conduct experiments, for he who performs not practical work nor makes experiments will never attain the least degree of mastery."

Jabir wrote more than one hundred treatises on various subjects, of which twenty two are about alchemy. Firmly grounded on experimental observation, his books systematized the knowledge about the fundamental chemical processes of the alchemists — such as crystallization, distillation, calcination, sublimation and evaporation — thus making a great step in the evolution of chemistry from an occult art to a scientific discipline. In particular, Jabir emphasized that definite quantities of various substances are involved in a chemical reaction, thus anticipating by almost a thousand years the principles of quantitative chemistry and the law of definite proportions.

Jabir is also credited with the invention and development of several chemical instruments that are still used today, such as the alembic, which made distillation easy, safe, and efficient. By distilling various salts together with sulfuric acid, Jabir discovered hydrochloric acid (from salt) and nitric acid (from saltpeter). By combining the two, he invented aqua regia, one of the few substances that can dissolve gold. Besides its obvious applications to gold extraction and purification, this discovery would fuel the dreams and despair of alchemists for the next thousand years. He is also credited with the discovery of citric acid (the sour component of lemons and other unripe fruits), acetic acid (from vinegar), and tartaric acid (from wine-making residues).

Jabir applied his chemical knowledge to the improvement of many manufacturing processes, such as making steel and other metals, preventing rust, engraving gold, dyeing and waterproofing cloth, tanning leather, and the chemical analysis of pigments and other substances. He developed the use of manganese dioxide in glassmaking, to counteract the green tinge produced by iron — a process that is still used today. He noted that boiling wine released a flammable vapor, thus paving the way to Al-Razi's discovery of ethanol.

The seeds of the modern classification of elements into metals and non-metals could be seen in his chemical nomenclature. He proposed three categories: "spirits" which vaporize on heating, like camphor, arsenic and ammonium chloride; "metals", like gold, silver, lead, copper, iron; and "stones" that can be converted into powders.

In the Middle Ages, Jabir's treatises on chemistry were translated into Latin and became standard texts for European alchemists. These include the *Kitab al-Kimya* (titled *Book of the Composition of Alchemy* in Europe), translated by Robert of Chester (1144); and the *Kitab al-Sab'een* by Gerard of Cremona (before 1187). Berthelot translated some of his books under the fanciful titles *Book of the Kingdom*, *Book of the Balances*, and *Book of Eastern Mercury*. Several technical terms introduced by Jabir, such as *alkali*, have found their way into various European languages and have become part of scientific vocabulary.

Jabir also made important contributions to medicine, astronomy, and other sciences. Only a few of his books have been edited and published, and fewer still are available in translation.

Contributions to alchemy

Jabir became an alchemist at the court of Caliph Harun al-Rashid, for whom he wrote the *Kitab al-Zuhra* ("The Book of Venus", on "the noble art of alchemy").

Jabir's alchemical investigations revolved around the ultimate goal of *takwin* — the artificial creation of life. Alchemy had a long relationship with Shi'ite mysticism; according to the first Imam, Ali ibn Abi Talib, "alchemy is the sister of prophecy". Jabir's interest in alchemy was probably inspired by his teacher Ja'far al-Sadiq, and he was himself called "the Sufi", indicating that he followed the ascetic form of mysticism within Islam.

In his writings, Jabir pays tribute to Egyptian and Greek alchemists Hermes Trismegistus, Agathodaimon, Pythagoras, and Socrates. He emphasizes the long history of alchemy ...*whose origin is Arius ... the first man who applied the first experiment on the [philosopher's] stone, ...* and he declares that man possesses the ability to imitate the workings of Nature...." (Nasr, Seyyed Hossein, *Science and Civilization of Islam*).

Jabir states in his *Book of Stones* (4:12) that "The purpose is to baffle and lead into error everyone except those whom God loves and provides for!". His works were deliberately written in highly esoteric code, so that only those who had been initiated into his alchemical school could understand them. It is therefore difficult at best for the modern reader to discern which aspects of Jabir's work are to be read as symbols (and what those symbols mean), and what is to be taken literally. Because his works rarely made overt sense, the term gibberish is believed to have originally referred to his writings (Hauck, p. 19).

Jabir's alchemical investigations were theoretically grounded in an elaborate numerology related to Pythagorean and Neoplatonic systems. The nature and properties of elements was defined through numeric values assigned the Arabic consonants present in their name, ultimately culminating in the number 17.

To Aristotelian physics, Jabir added the four properties of hotness, coldness, dryness, and moistness (Burkhardt, p. 29). Each Aristotelian element was characterized by these qualities: Fire was both hot and dry, earth cold and dry, water cold and moist, and air hot and moist. This came from the elementary qualities which are theoretical in nature plus substance. In metals two of these qualities were interior and two were exterior. For example, lead was cold and dry and gold was hot and moist. Thus, Jabir theorized, by rearranging the qualities of one metal, based on their sulfur/mercury content, a different metal would result. (Burckhardt, p. 29) This theory appears to have originated the search for *al-iksir*, the elusive elixir that would make this transformation possible — which in European alchemy became known as the philosopher's stone.

Writings by Jabir

The writings of Jabir Ibn Hayyan can be divided into four categories:

1. **The 112 Books** dedicated to the Barmakids, viziers of Caliph Harun al-Rashid who were descended from Zoroastrian priests from Bactria. This group includes the Arabic version of the *Emerald Tablet*, an ancient work that is the foundation of the Hermetic or "spiritual" alchemy. In the Middle Ages it was translated into Latin (*Tabula Smaragdina*) and widely diffused among European alchemists.

2. **The Seventy Books**, most of which were translated into Latin during the Middle Ages. This group includes the *Kitab al-Zuhra* ("Book of Venus") and the *Kitab Al-Ahjar* ("Book of Stones").

3. **The Ten Books on Rectification**, containing descriptions of "alchemists" such as Pythagoras, Socrates, Plato and Aristotle.

4. **The Books on Balance**; this group includes his most famous 'Theory of the balance in Nature'. It might be difficult to determine which of these were written by him and which by his students, but they all can be considered works of the 'Jabir' school of alchemy.

Translated work of Jabir

- Holmyard, E.J. (ed.) *The Arabic Works of Jabir ibn Hayyan*(red) , two Vol. (Paris. P. Geuther)
- Syed Nomanul Haq, *Names, Natures and Things: The Alchemists Jabir ibn Hayyan and his Kitab al-Ahjar* (Book of Stones), [Boston Studies in the Philosophy of Science p. 158] (Dordrecht: Kluwer Academic Publishers, 1994).
- Donald R. Hill, 'The Literature of Arabic Alchemy' in *Religion: Learning and Science in the Abbasid Period*, ed. by M.J.L. Young, J.D. Latham and R.B. Serjeant (Cambridge University Press, 1990) pp. 328-341, esp. pp 333-5.
- William Newman, *New Light on the Identity of Geber*, *Sudhoffs Archiv*, 1985, Vol.69, pp. 76-90

Acid

Acids and bases:
Acid-base reaction theories pH Self-ionization of water Buffer solutions Systematic naming Electrochemistry
Acids:
<ul style="list-style-type: none">• Strong acids• Weak acids
Bases:
<ul style="list-style-type: none">• Strong bases

- Weak bases

An **acid** (from Arabic *Azait* meaning oil, often represented by the generic formula **HA**) is a water-soluble, sour-tasting chemical compound that when dissolved in water, gives a solution with a pH of less than 7.

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Definitions of acids and bases

The word "acid" comes from the Latin *acidus* meaning "sour", but in chemistry the term acid has a more specific meaning. There are three common ways to define an acid, namely, the **Arrhenius**, the **Brønsted-Lowry** and the **Lewis** definitions, in order of increasing generality.

- **Arrhenius**: According to this definition, an acid is a substance that increases the concentration of hydronium ion (H_3O^+) when dissolved in water, while bases are substances that increase the concentration of hydroxide ions (OH^-). This definition limits acids and bases to substances that can dissolve in water. Around 1800, many French chemists, including Antoine Lavoisier, incorrectly believed that all acids contained oxygen. English chemists, including Sir Humphry Davy at the same time believed all acids contained hydrogen. The Swedish chemist Svante Arrhenius used this belief to develop this definition of acid.
- **Brønsted-Lowry**: According to this definition, an acid is a proton donor and a base is a proton acceptor. The acid is said to be dissociated after the proton is donated. An acid and the corresponding base are referred to conjugate acid-base pairs. Brønsted and Lowry formulated this definition, which includes water-insoluble substances not in the Arrhenius definition.

- **Lewis:** According to this definition, an acid as an electron-pair acceptor and a base is an electron-pair donor. (These are frequently referred to as "Lewis acids" and "Lewis bases," and are electrophiles and nucleophiles in organic chemistry). Lewis acids include substances with no protons, such as iron(III) chloride. The Lewis definition can also be explained with molecular orbital theory. In general, an acid can receive an electron pair in its lowest unoccupied orbital (LUMO) from the highest occupied orbital (HOMO) of a base. That is, the HOMO from the base and the LUMO from the acid combine to a bonding molecular orbital. This definition was developed by Gilbert N. Lewis.

Although not the most general theory, the Brønsted-Lowry definition is the most widely used definition. The strength of an acid may be understood by this definition by the stability of hydronium and the solvated conjugate base upon dissociation. Increasing stability of the the conjugate base will increase the acidity of a compound. This concept of acidity is used frequently for organic acids such as carboxylic acid. The molecular orbital description, where the unfilled proton orbital overlaps with a lone pair, is connected to the Lewis definition.

Solutions of weak acids and salts of their conjugate bases form buffer solutions.

Acid/base systems are different from redox reactions in that there is no change in oxidation state.

Generally, acids have the following chemical and physical properties:

- **Taste:** Acids generally are sour when dissolved in water.
- **Touch:** Acids produce a stinging feeling, particularly strong acids.
- **Reactivity:** Acids react aggressively with or corrode most metals.
- **Electrical conductivity:** Acids are electrolytes.

Strong acids are dangerous, causing severe burns for even minor contact. Generally, acid burns are treated by rinsing the affected area abundantly with water and followed up with immediate medical attention.

Nomenclature

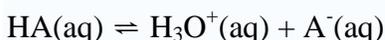
Acids are named according to the ending of their anion. That ionic ending is dropped and replaced with a new suffix according to the table below. For example, HCl has chloride as its anion, so the -ide suffix makes it take the form hydrochloric acid.

Anion Ending	Acid Prefix	Acid Suffix
per-anion-ate	per	ic acid
ate		ic acid
ite		ous acid

hypo-anion-ite	hypo	ous acid
ide	Hydro	ic acid

Chemical characteristics

In water the following equilibrium occurs between an acid (HA) and water, which acts as a base:



The acidity constant (or acid dissociation constant) is the equilibrium constant for the reaction of HA with water:

$$K_a = \frac{[\text{H}_3\text{O}^+] \cdot [\text{A}^-]}{[\text{HA}]}$$

Strong acids have large K_a values (i.e. the reaction equilibrium lies far to the right; the acid is almost completely dissociated to H_3O^+ and A^-). For example, the K_a value for hydrochloric acid (HCl) is 10^7 .

Weak acids have small K_a values (i.e. at equilibrium significant amounts of HA and A^- exist together in solution; modest levels of H_3O^+ are present; the acid is only partially dissociated). For example, the K_a value for acetic acid is 1.8×10^{-5} .

Strong acids include the hydrohalic acids - HCl, HBr, and HI. (However, hydrofluoric acid, HF, is relatively weak.) Oxoacids, which tend to contain central atoms in high oxidation states surrounded by oxygen, are also quite strong and include HNO_3 , H_2SO_4 , HClO_4 . Most organic acids are weak acids.

Note the following:

- The terms "hydrogen ion" and "proton" are used interchangeably; both refer to H^+ .
- In aqueous solution, the water is protonated to form hydronium ion, $\text{H}_3\text{O}^+(\text{aq})$. This is often abbreviated as $\text{H}^+(\text{aq})$ even though the symbol is not chemically correct.
- The strength of an acid is measured by its acid dissociation constant (K_a) or equivalently its $\text{p}K_a$ ($\text{p}K_a = -\log(K_a)$).
- The pH of a solution is a measurement of the concentration of hydronium. This will depend of the concentration and nature of acids and bases in solution.

Polyprotic acids

Polyprotic acids are able to donate more than one proton per acid molecule, in contrast to monoprotic acids that only donate one proton per molecule. Specific types of polyprotic acids have more specific names, such as **diprotic acid** (two potential protons to donate) and **triprotic acid** (three potential protons to donate)

A monoprotic acid can undergo one dissociation (sometimes called ionization) as follows and simply has one acid dissociation constant as shown above:

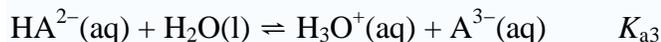


A diprotic acid (here symbolized by H_2A) can undergo one or two dissociations depending on the pH. Each dissociation has its own dissociation constant, K_{a1} and K_{a2} .



The first dissociation constant is typically greater than the second; i.e., $K_{a1} > K_{a2}$. For example, sulfuric acid (H_2SO_4) can donate one proton to form the bisulfate anion (HSO_4^-), for which K_{a1} is very large; then it can donate a second proton to form the sulfate anion (SO_4^{2-}), wherein the K_{a2} is intermediate strength. The large K_{a1} for the first dissociation makes sulfuric a strong acid. In a similar manner, the weak unstable carbonic acid (H_2CO_3) can lose one proton to form bicarbonate anion (HCO_3^-) and lose a second to form carbonate anion (CO_3^{2-}). Both K_a values are small, but $K_{a1} > K_{a2}$.

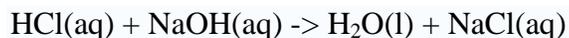
A triprotic acid (H_3A) can undergo one, two, or three dissociations and has three dissociation constants, where $K_{a1} > K_{a2} > K_{a3}$.



An inorganic example of a triprotic acid is orthophosphoric acid (H_3PO_4), usually just called phosphoric acid. All three protons can be successively lost to yield H_2PO_4^- , then HPO_4^{2-} , and finally PO_4^{3-} , the orthophosphate ion, usually just called phosphate. An organic example of a triprotic acid is citric acid, which can successively lose three protons to finally form the citrate ion. Even though the positions of the protons on the original molecule may be equivalent, the successive K_a values will differ since it is energetically less favorable to lose a proton if the conjugate base is more negatively charged.

Neutralization

Neutralization is the reaction between equal amounts of an acid and a base, producing a salt and water; for example, hydrochloric acid and sodium hydroxide form sodium chloride and water:



Neutralization is the basis of titration, where a pH indicator shows equivalence point when the equivalent number of moles of a base have been added to an acid.

Common acids

Strong inorganic acids

- Hydrobromic acid
- Hydrochloric acid
- Hydroiodic acid
- Nitric acid
- Sulfuric acid
- Perchloric acid

Medium to weak inorganic acids

- Boric acid
- Carbonic acid
- Chloric acid
- Hydrofluoric acid
- Phosphoric acid
- Pyrophosphoric acid

Weak organic acids

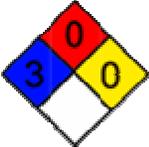
- Acetic acid
- Benzoic acid
- Butyric acid
- Citric acid
- Formic acid
- Lactic acid
- Malic acid
- Mandelic acid
- Methanethiol
- Propionic acid
- Pyruvic acid
- Valeric acid

Hydrochloric acid

The chemical substance **hydrochloric acid** is the aqueous (water-based) solution of hydrogen chloride ([HCl](#)) gas. It is a strong acid, the major component of gastric acid and of wide industrial use. As a highly corrosive liquid, hydrochloric acid should be handled only with appropriate safety precautions.

Hydrochloric acid, or **muriatic acid** by its historical but still occasionally used name, has been an important and frequently-used chemical from early history, and was discovered by the alchemist Jabir ibn Hayyan around the year 800. It was used throughout the Middle Ages by alchemists in the quest for the philosopher's stone, and later by several European scientists including Glauber, Priestley, and Davy, to help establish modern chemical knowledge.

During the Industrial Revolution, it became an important industrial chemical for many applications, including the large-scale production of organic compounds, such as vinyl chloride for PVC plastic and MDI/TDI for polyurethane, and smaller-scale applications, such as production of gelatin and other ingredients in food, and leather processing. At present, production is approximately 20 million metric tonnes annually (20 Mt/a) of HCl gas.

MSDS	External MSDS
NFPA 704	
Main Hazards	Highly corrosive
Flash point	? °C
R/S statement	R34, R37, S26, S36, S45
RTECS number	MW4025000
Supplementary data page	
Structure and properties	<i>n</i> , ϵ_r , etc.
Thermodynamic data	Phase behaviour Solid, liquid, gas
Spectral data	UV, IR, NMR, MS
Related compounds	
Other anions	HF, HBr, HI
Other cations	n/a
Related acids	Hydrobromic acid Hydrofluoric acid Hydroiodic acid Sulfuric acid
Except where noted otherwise, data are given for materials in their standard state (at 25 °C, 100 kPa) Infobox disclaimer and references	
	38% solution
Boiling point	110 °C (383 K), 20.2% solution; 48 °C (321 K), 38% solution.
Acid dissociation constant pK_a	-8.0
Viscosity	1.9 cP at 25 °C, 31.5% wt/wt
Dipole moment	? D
Hazards	

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History

Hydrochloric acid was first discovered around the year 800 by Persian alchemist Jabir ibn Hayyan (Geber), by mixing common salt with vitriol (sulfuric acid). Jabir discovered or invented many important chemicals, and wrote his findings in over 20 books, which carried his chemical knowledge of hydrochloric acid and other basic chemicals for hundreds of years. Jabir's invention of the gold-dissolving aqua regia, consisting of hydrochloric acid and nitric acid, contributed to the effort of alchemists trying to find the philosopher's stone.

In the Middle Ages, hydrochloric acid was known to European alchemists as *spirit of salt* or *acidum salis*. Gaseous HCl was called *marine acid air*. The old (pre-systematic) name *muratic acid* has the same origin (*muratic* means "pertaining to brine or salt"), and this name is still sometimes used. Notable production was recorded by Basilius Valentinus, the alchemist-canon of the Benedictine priory Sankt Peter in Erfurt, Germany in the 15th century.

In the 17th century, Johann Rudolf Glauber from Karlstadt am Main, Germany used salt (sodium chloride) and sulfuric acid for the preparation of sodium sulfate, releasing hydrogen chloride gas. Joseph Priestley from Leeds, England prepared pure hydrogen

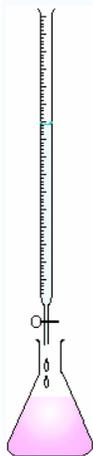
chloride in 1772, and in 1818 Humphry Davy from Penzance, England proved that the chemical composition included hydrogen and chlorine.

During the Industrial Revolution in Europe, demand for alkaline substances, such as soda ash increased, and the new industrial soda-process by Nicolas Leblanc (Issoundun, France) enabled cheap large-scale production. In the Leblanc process, salt is converted to soda ash, using sulfuric acid, limestone, and coal, releasing hydrogen chloride as a by-product. Until the Alkali Act of 1863, excess HCl was vented to the air. After the passage of the act, soda ash producers were obliged to absorb the waste gas in water, producing hydrochloric acid on an industrial scale.

When early in the 20th century the Leblanc process was effectively replaced by the Solvay process without hydrochloric acid by-product, hydrochloric acid was already fully settled as an important chemical in numerous applications. The commercial interest initiated other production methods which are still used today, as described below. Today, most hydrochloric acid is made by absorbing hydrogen chloride from industrial organic compounds production.

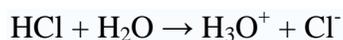
Hydrochloric acid is listed as a Table II precursor under the 1988 Convention Against Illicit Traffic in Narcotic Drugs and Psychotropic Substances because of its use in the production of heroin and cocaine [1].

Chemistry



Acid titration

Hydrogen chloride (HCl) is a monoprotic acid, which can dissociate (*i.e.*, ionize) only once to give up one H⁺ ion (a single proton). In aqueous hydrochloric acid, the H⁺ joins a water molecule to form a hydronium ion, H₃O⁺:



The other ion formed is Cl^- or chloride ion. Hydrochloric acid can therefore be used to prepare salts called *chlorides*, such as sodium chloride. Hydrochloric acid is considered a strong acid, since it is practically fully dissociated in water.



Molecular model of hydrogen chloride.

Monoprotic acids have one acid dissociation constant, K_a , which indicates the level of dissociation in water. For a strong acid like HCl, K_a is large. Theoretical attempts to assign a K_a to HCl have been made; see [2]. When chloride salts such as NaCl are added to aqueous HCl they have practically no effect on pH, indicating that Cl^- is an exceedingly weak conjugate base and that HCl is fully dissociated in aqueous solution. For intermediate to strong solutions of hydrochloric acid, the assumption that H^+ molarity (a unit of concentration) equals HCl molarity is excellent, agreeing to four significant digits.

Of the seven common strong acids in chemistry, all of them inorganic, hydrochloric acid is the monoprotic acid least likely to undergo an interfering oxidation-reduction reaction. It is one of the least-hazardous strong acids to handle; despite its acidity, it produces the less-reactive and non-toxic chloride ion. Intermediate-strength hydrochloric acid solutions are quite stable, maintaining their concentrations over time. These attributes, plus the fact that it is available as a pure reagent, means that hydrochloric acid makes an excellent acidifying reagent and acid titrant (for determining the amount of an unknown quantity of base in titration). Strong acid titrants are useful because they give more distinct endpoints in a titration, making the titration more precise. Hydrochloric acid is frequently used in chemical analysis and to digest samples for analysis. Concentrated hydrochloric acid will dissolve some metals to form oxidized metal chlorides and hydrogen gas. It will produce metal chlorides from basic compounds such as calcium carbonate or copper(II) oxide. It is also used as a simple acid catalyst for some chemical reactions.

Physical properties

The physical properties of hydrochloric acid, such as boiling and melting points, density, and pH depend on the concentration or molarity of HCl in the acid solution. They can range from those of water at 0% HCl to values for fuming hydrochloric acid at over 40% HCl.

Conc.	Conc.	Density	Molarity	pH	Viscosity	Specific	Vapor	Boiling	Melting
-------	-------	---------	----------	----	-----------	----------	-------	---------	---------

(w/w) c : kg HCl/kg	(w/v) c : kg HCl/m ³	ρ : kg/l	M		η : mPa·s	heat s : kJ/(kg·K)	pressure P_{HCl} : Pa	point b.p.	point m.p.
10%	104.80	1.048	2.87 M	-0.5	1.16	3.47	0.527	103 °C	-18 °C
20%	219.60	1.098	6.02 M	-0.8	1.37	2.99	27.3	108 °C	-59 °C
30%	344.70	1.149	9.45 M	-1.0	1.70	2.60	1,410	90 °C	-52 °C
32%	370.88	1.159	10.17 M	-1.0	1.80	2.55	3,130	84 °C	-43 °C
34%	397.46	1.169	10.90 M	-1.0	1.90	2.50	6,733	71 °C	-36 °C
36%	424.44	1.179	11.64 M	-1.1	1.99	2.46	14,100	61 °C	-30 °C
38%	451.82	1.189	12.39 M	-1.1	2.10	2.43	28,000	48 °C	-26 °C

The reference temperature and pressure for the above table are 20°C and 1 atmosphere (101 kPa).

Hydrochloric acid as the binary (two-component) mixture of HCl and H₂O has a constant-boiling azeotrope at 20.2% HCl and 108.6 °C (227 °F). There are four constant-crystallization eutectic points for hydrochloric acid, between the crystal form of HCl·H₂O (68% HCl), HCl·2H₂O (51% HCl), HCl·3H₂O (41% HCl), HCl·6H₂O (25% HCl), and of course ice (0% HCl). There is also a metastable eutectic at 24.8% between ice and the HCl·3H₂O crystallization.

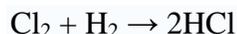
Production



Hydrochloric acid oven

Direct synthesis

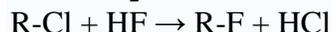
The large scale production of hydrochloric acid is almost always integrated with other industrial scale chemical production. In the chlor-alkali industry, salt solution is electrolyzed producing chlorine, sodium hydroxide, and hydrogen. The pure chlorine gas can be re-combined with the hydrogen gas, forming chemically pure HCl gas. As the reaction is exothermic, the installation is called an HCl oven.



The resulting pure hydrogen chloride gas is absorbed in demineralized water, resulting in chemically pure hydrochloric acid.

Organic synthesis

The largest production of hydrochloric acid is integrated with the formation of chlorinated and fluorinated organic compounds, e.g., Teflon, Freon and other CFCs, chloro-acetic acid, and PVC. Often this production of hydrochloric acid is integrated with captive use of it on-site. In the chemical reactions, hydrogen atoms are replaced by chlorine atoms, whereupon the released hydrogen atom re-combines with the spare atom from the chlorine molecule, forming hydrogen chloride. Fluorination is a subsequent chlorine-replacement reaction, producing again hydrogen chloride.



The resulting hydrogen chloride gas is either re-used directly, or absorbed in water, resulting in hydrochloric acid of technical or industrial grade.

Industrial market

Hydrochloric acid is produced in solutions up to 38% HCl (concentrated grade). Higher concentrations up to just over 40% are chemically possible, but the evaporation rate is then so high that storage and handling need extra precautions, such as pressure and low temperature. Bulk industrial-grade is therefore 30% to 34%, optimized for effective transport and limited product loss by HCl vapours. Solutions for household purposes, mostly cleaning, are typically 10% to 12%, with strong recommendations to dilute before use.

Major producers worldwide include Dow Chemical at 2 million metric tonnes annually (2 Mt/year), calculated as HCl gas, and FMC, Georgia Gulf Corporation, Tosoh Corporation, Akzo Nobel, and Tessenderlo at 0.5 to 1.5 Mt/year each. Total world production, for comparison purposes expressed as HCl, is estimated at 20 Mt/year, with 3 Mt/year from direct synthesis, and the rest as secondary product from organic and similar

syntheses. By far, most of all hydrochloric acid is consumed captively by the producer. The open world market size is estimated at 5 Mt/year.

Applications

Hydrochloric acid is a strong inorganic acid that is used in many industrial processes. The application often determines the required product quality.

Regeneration of ion exchangers

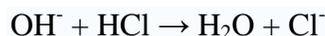
An important application of high-quality hydrochloric acid is the regeneration of ion exchange resins. Cation exchange is widely used to remove ions such as Na^+ and Ca^{2+} from aqueous solutions, producing demineralized water.



Ion exchangers and demineralized water are used in all chemical industries, drinking water production, and many food industries.

pH control and neutralization

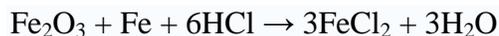
A very common application of hydrochloric acid is to regulate the basicity (pH) of solutions.



In industry demanding purity (food, pharmaceutical, drinking water), high-quality hydrochloric acid is used to control the pH of process water streams. In less-demanding industry, technical-quality hydrochloric acid suffices for neutralizing waste streams and swimming pool treatment.

Pickling of steel

Pickling is an essential step in metal surface treatment, to remove rust or iron oxide scale from iron or steel before subsequent processing, such as extrusion, rolling, galvanizing, and other techniques. Technical-quality HCl at typically 18% concentration is the most commonly-used pickling agent for the pickling of carbon steel grades.



The spent acid has long been re-used as ferrous chloride solutions, but high heavy-metal levels in the pickling liquor has decreased this practice.

In recent years, the steel pickling industry has however developed hydrochloric acid regeneration processes, such as the spray roaster or the fluidised bed HCl regeneration process, which allow the recovery of HCl from spent pickling liquor. These are two Pyrohydrolysis ACREG Processes. The most common regeneration process is the ACREG Dependeq ASTEC - Process, applying the following formula:

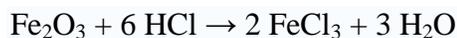


By this means, a closed acid loop is established. The ferric oxide by product of the regeneration process is a valuable by-product, used in a variety of secondary industries.

HCl is not a common pickling agent for stainless steel grades.

Production of inorganic compounds

Numerous products can be produced with hydrochloric acid in normal acid-base reactions, resulting in inorganic compounds. These include water treatment chemicals such as iron(III) chloride and polyaluminium chloride (PAC).



Both iron(III) chloride and PAC are used as flocculation and coagulation agents in wastewater treatment, drinking water production, and paper production.

Other inorganic compounds produced with hydrochloric acid include road application salt calcium chloride, nickel(II) chloride for electroplating, and zinc chloride for the galvanizing industry and battery production.

Production of organic compounds

The largest hydrochloric acid consumption is in the production of organic compounds such as vinyl chloride for PVC, and MDI and TDI for polyurethane. This is often captive use, consuming locally-produced hydrochloric acid that never actually reaches the open market. Other organic compounds produced with hydrochloric acid include bisphenol A for polycarbonate, activated carbon, and ascorbic acid, as well as numerous pharmaceutical products.

Other applications

Hydrochloric acid is a fundamental chemical, and as such it is used for a large number of small-scale applications, such as leather processing, household cleaning, and building construction. In addition, a way of stimulating oil production is by injecting hydrochloric acid into the rock formation of an oil well, dissolving a portion of the rock, and creating a large-pore structure. Oil-well acidizing is a common process in the North Sea oil production industry.

Many chemical reactions involving hydrochloric acid are applied in the production of food, food ingredients, and food additives. Typical products include aspartame, fructose, citric acid, lysine, hydrolyzed protein, and gelatin. Food-grade (extra-pure) hydrochloric acid can be applied when needed for the final product.

Hydrochloric acid and living organisms

Physiology and pathology

Hydrochloric acid constitutes the majority of gastric acid, the human digestive fluid. In a complex process and at a large energetic burden, it is secreted by parietal cells (also known as oxyntic cells). These cells contain an extensive secretory network (called canaliculi) from which the HCl is secreted into the lumen of the stomach. They are part of the epithelial fundic glands (also known as oxyntic glands) in the stomach.

Safety mechanisms that prevent the damage of the epithelium of digestive tract by hydrochloric acid are the following:

- negative regulators of its release
- a thick mucus layer covering the epithelium
- sodium bicarbonate secreted by gastric epithelial cells and pancreas
- the structure of epithelium (tight junctions)
- adequate blood supply
- prostaglandins (many different effects: they stimulate mucus and bicarbonate secretion, maintain epithelial barrier integrity, enable adequate blood supply, stimulate the healing of the damaged mucous membrane)

When, due to different reasons, these mechanisms fail, heartburn or peptic ulcers can develop. Drugs called proton pump inhibitors prevent the body from making excess acid in the stomach, while antacids neutralize existing acid.

In some instances, not enough of hydrochloric acid gets produced in the stomach. These pathologic states are denoted by the terms hypochlorhydria and achlorhydria. Potentially they can lead to gastroenteritis.

Chemical weapons

Phosgene (COCl_2) was a common chemical warfare agent used in World War I. The main effect of phosgene results from the dissolution of the gas in the mucous membranes deep in the lung, where it is converted by hydrolysis into carbonic acid and the corrosive hydrochloric acid. The latter disrupts the alveolar-capillary membranes so that the lung becomes filled with fluid (pulmonary edema).

Hydrochloric acid is also partly responsible for the harmful or blistering effects of mustard gas. In the presence of water, such as on the moist surface of the eyes or lungs, mustard gas breaks down forming hydrochloric acid.

Safety

Hydrochloric acid in high concentrations forms acidic mists. Both the mist and the solution have a corrosive effect on human tissue, potentially damaging respiratory organs, eyes, skin and intestines. Upon mixing hydrochloric acid with common oxidizing chemicals, such as bleach (NaClO) or permanganate (KMnO_4), the toxic gas chlorine is produced. To minimize the risks while working with hydrochloric acid, appropriate precautions should be taken. For example, never add water to the acid, as the water will boil; add acid to the water instead. See references for details.

Dangerous goods labels for hydrochloric acid:



The following Risk and Safety Statements for labeling apply:

Risk (R) and Safety (S) Statements	
R: 34	Causes burns.
R: 37	Irritating to the respiratory system.
S: 26	In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
S: 36	Wear suitable protective clothing.
S: 45	In case of accident or if you feel unwell, seek medical advice immediately (show label where possible).

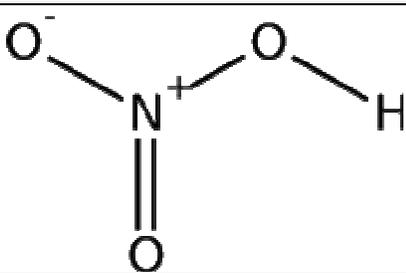
The hazards of solutions of hydrochloric acid depend on the concentration. The following table lists the EU classification of hydrochloric acid solutions:

Concentration by weight	Classification	R-Phrases
10%–25%	Irritant (Xi)	R36/37/38
>25%	Corrosive (C)	R34 R37

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Nitric acid

Nitric acid	
	
General	
Systematic name	Nitric acid
Other names	Hydrogen nitrate, aqua fortis
Molecular formula	HNO ₃
SMILES	[N+](=O)(O)[O-]
Molar mass	63.0129g g/mol
Appearance	Clear, colorless liquid

CAS number	7697-37-2
Properties	
Density and phase	1.51 g/cm ³
Solubility in water	miscible
Melting point	-42 °C (231 K)
Boiling point	83 °C (356 K)
Acidity (pK _a)	-2
Viscosity	? cP at ? °C
Structure	
Molecular shape	?
Dipole moment	? D
Hazards	
MSDS	External MSDS
EU classification	Oxidant (O) Corrosive (C)
NFPA 704	
R-phrases	R8, R35
S-phrases	S1/2, S23, S26, S36, S45
Flash point	not applicable
RTECS number	QU5775000
<u>Supplementary data page</u>	
Structure and properties	<i>n</i> , ϵ_r , etc.
Thermodynamic data	Phase behaviour Solid, liquid, gas
Spectral data	UV, IR, NMR, MS
Related compounds	
Related compounds	Nitrous acid

	Dinitrogen pentoxide
--	----------------------

Except where noted otherwise, data are given for materials in their standard state (at 25 °C, 100 kPa)
Infobox disclaimer and references

The chemical compound **nitric acid** (HNO₃), otherwise known as **aqua fortis**, is a colorless, corrosive liquid, a toxic acid which can cause severe burns. If the solution contains more than 86% nitric acid, it is referred to as **fuming nitric acid**, and can be separated into two kinds of fuming acids, white fuming nitric acid and red fuming nitric acid.

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History

Nitric acid was first synthesized circa 800 AD by alchemist Jabir ibn Hayyan, who also invented modern distillation and numerous other basic chemical processes still in use today.

Chemistry

Nitric acid is a strong acid with a pK_a of -2: in aqueous solution, it completely dissociates into the nitrate ion NO₃[−] and a hydrated proton, known as a hydronium ion, H₃O⁺. The salts of nitric acid (which contain the nitrate ion) are also known as nitrates. The overwhelming majority of them are very soluble in water.

At room temperature nitric acid gives off red or yellow fumes.

Nitric acid and its salts, the nitrates, should not be confused with nitrous acid and its salts, the nitrites.

Synthesis and Production

Nitric acid is made by mixing nitrogen dioxide (NO₂) with water. Creating a very pure nitric acid usually involves distillation with sulfuric acid, as nitric acid forms an

azeotrope with water with a composition of 68% nitric acid and 32% water. Commercial grade nitric acid solutions are usually between 52% and 68% nitric acid. Commercial production of nitric acid is via the Ostwald process after Wilhelm Ostwald.

Nitric acid can be made by reacting 200 g of potassium nitrate (KNO_3) in 106 ml of 96% sulfuric acid (H_2SO_4), and distilling this mixture at nitric acid's boiling point of $83\text{ }^\circ\text{C}$ until only a white crystalline mass, potassium hydrogen sulfate (KHSO_4), remains in the reaction vessel. The obtained red fuming nitric acid may be converted to the white nitric acid.

The dissolved NO_x are readily removed using reduced pressure at room temperature (10-30 min at 200 mmHg or 27 kPa). Obtained white fuming nitric acid has density 1.51 g/cm^3 . This procedure can also be performed under reduced pressure and temperature in one step in order to produce less nitrogen dioxide gas.

The acid can also be synthesized by oxidizing ammonia, but the product is diluted by the water also formed as part of the reaction. However, this synthesization method is important in producing ammonium nitrate from ammonia derived from the Haber process, because the final product can be produced from nitrogen, hydrogen, and oxygen as the sole feedstocks.

White fuming nitric acid, also called 100% nitric acid or WFNA, is very close to the anhydrous nitric acid product. One specification for white fuming nitric acid is that it has a maximum of 2 % water and a maximum of 0.5 % dissolved NO_2 . Red fuming nitric acid, or RFNA, contains substantial quantities of dissolved nitrogen dioxide (NO_2) leaving the solution with a reddish-brown color. One formulation of RFNA specifies a minimum of 17% NO_2 , another specifies 13% NO_2 . In either event, an *inhibited* fuming nitric acid (either IWFNA, or IRFNA) can be made by the addition of 0.6 to 0.7% hydrogen fluoride, HF. This fluoride is added for corrosion resistance in metal tanks (the fluoride creates a metal fluoride layer that protects the metal).

Uses

Commonly used as a laboratory reagent, nitric acid is used in the manufacture of explosives such as nitroglycerin, trinitrotoluene (TNT) and Cyclotrimethylenetrinitramine (RDX), as well as fertilizers such as ammonium nitrate.

It has additional uses in metallurgy and refining as it reacts with most metals, and in organic syntheses. When combined with hydrochloric acid, it forms aqua regia, one of the few reagents capable of dissolving gold and platinum.

Nitric acid is also a component of acid rain.

Nitric acid is a very powerful oxidizing agent, and the reactions of nitric acid with compounds such as cyanides, carbides, and metallic powders can be explosive. Reactions

of nitric acid with many organic compounds, such as turpentine, are violent and hypergolic (i.e., self-igniting).

Concentrated nitric acid dyes human skin yellow on contact, due to interactions with the skin protein keratin. Yet these yellow stains turn orange when alkalisied.

The use for IFWNA is as an oxidizer in liquid fuel rockets.

Ostwald process

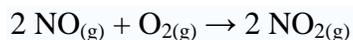
The **Ostwald process** is chemical process for producing nitric acid, which was developed by Wilhelm Ostwald (patented 1902). It is a mainstay of the modern chemical industry. Historically and practically it is closely associated with the Haber process, which provides the requisite raw material, ammonia.

Description

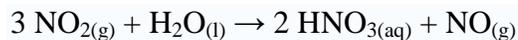
Ammonia is converted to nitric acid in two stages. It is oxidized (in a sense "burned") by heating with oxygen in the presence of a catalyst of platinum with 10% rhodium, to form nitric oxide and water. This step is strongly exothermic, making it a useful heat source once initiated ($\Delta H = -950$ kJ):



Stage two (combining two reaction steps) is carried out in the presence of water in an absorption apparatus. Initially nitric oxide is oxidized again to yield nitrogen dioxide:



This gas is then readily absorbed by the water, yielding the desired product (nitric acid, albeit in a dilute form), while reducing a portion of it back to nitric oxide:



The NO is recycled, and the acid is concentrated to the required strength by distillation.

Alternatively, if the last step is carried out in air:



Typical conditions for the first stage, which contribute to an overall yield of about 96%, are:

- pressure between 4 and 10 atmospheres (approx. 400-1010 kPa or 60-145 psig) and

- temperatures between 975 and 1125 K (approx. 700-850°C. or 1295-1565°F.).

History

An earlier patent (Kuhlmann, 1838) described the basic chemistry, but ammonia (from animal sources) was scarce at the time, so it was probably of only academic interest, either then or when Ostwald patented his version in 1902. A later date is frequently given for the development of the process (1908), and it may be that by then Fritz Haber's method of making ammonia was known, which would have changed the outlook entirely. Ostwald's primary contributions seem to have been practical ones concerning the catalyst and operating conditions, a matter perhaps more of chemical engineering than of basic science.

Prior to this the source of most industrial nitrogen was nitrates, primarily imported Chilean saltpeter, from which nitric acid was produced by treatment with sulfuric acid. The Ostwald process gained prominence as an adjunct to the fixing of nitrogen (Haber Process). The combined processes undoubtedly prolonged World War I, when Germany's overseas sources were cut off and explosives production was threatened. Subsequently their use of widely available raw materials (and the resulting low cost) led to their general adoption, resulting in vastly increased nitrogen consumption, mostly as fertilizers.

Initially the process was carried out in low pressure stoneware vessels, but the introduction of stainless steel made higher pressures practical, leading to higher yields.

Potassium nitrate

Potassium nitrate



General

Other names	Saltpetre Nitrate of potash
Molecular formula	KNO_3
Molar mass	101.1 g/mol
Appearance	white solid

CAS number	[7757-79-1]
Properties	
Density and phase	2.1 g/cm ³ , solid
Solubility in water	35.7 g/100 ml (25 °C)
Melting point	334 °C
Boiling point	400 °C <i>decomp.</i>
Structure	
Coordination geometry	?
Crystal structure	Aragonite
Hazards	
MSDS	External MSDS
EU classification	
NFPA 704	
R-phrases	
S-phrases	
<u>Supplementary data page</u>	
Structure and properties	<i>n</i> , ϵ_r , etc.
Thermodynamic data	Phase behaviour Solid, liquid, gas
Spectral data	UV, IR, NMR, MS
Related compounds	
Other anions	Potassium nitrite
Other cations	Lithium nitrate Sodium nitrate Rubidium nitrate Caesium nitrate
<p>Except where noted otherwise, data are given for materials in their standard state (at 25 °C, 100 kPa)</p>	

The chemical compound **potassium nitrate** is a naturally occurring mineral source of nitrogen. It is a nitrate with chemical formula KNO_3 .

Its common names include **saltpetre** (from Medieval Latin **sal petrae**: "stone salt" or possibly "salt of Petra"), American English **saltpeter**, **Chilean saltpetre**, **Nitrate of potash** and **nitre**. The name *saltpeter* is also applied to sodium nitrate.

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Description

It is the oxidizing (oxygen-supplying) component of black powder. Prior to the large-scale industrial fixation of nitrogen through the Haber process, a major source of Potassium nitrate was the deposits crystallising from cave walls or the drainings of decomposing organic material. Dung-heaps were a particularly common source: ammonia from the decomposition of urea and other nitrogenous materials would undergo bacterial oxidation to produce nitrate. It was and is also used as a component in some fertilizers.

Manufacture

Historically, nitre-beds were prepared by mixing manure with either mortar or wood ashes, common earth and organic material such as straw to give porosity to a compost pile typically 1.5 metres high by 2 metres wide by 5 metres long. The heap was usually under a cover from the rain, kept moist with urine, turned often to accelerate the decomposition and leached with water after approximately one year. The liquid containing various nitrates was then converted with wood ashes to potassium nitrates, crystallized and refined for use in gunpowder.

In England, the privilege of manufacturing explosives had been in the hands of the family of John Evelyn, the celebrated diarist, as a crown monopoly since before 1588.

Today, most potassium nitrate comes from the vast deposits of sodium nitrate (NaNO_3 , nitratine) in the Chilean deserts. The sodium nitrate is purified and then reacted in

solution with potassium chloride (KCl, sylvite), from which the less-soluble potassium nitrate is precipitated out.

Applications

One of the most useful applications of potassium nitrate is in the production of nitric acid, by adding concentrated sulfuric acid to an aqueous solution of potassium nitrate, yielding nitric acid and potassium sulfate which are separated through fractional distillation.

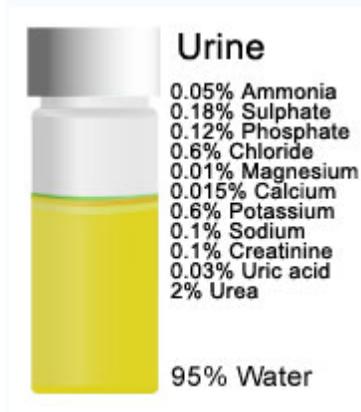
Potassium nitrate is also used as a fertilizer, as a model rocket propellant, and in several fireworks such as smoke bombs, in which a mixture with sugar produces a smoke cloud of 600 times their own volume. In the process of food preservation, potassium nitrate is a common ingredient of salted meat, but heart patients need take care with it. Potassium Nitrate is also a main component in stump remover. It has also been used in the manufacture of ice cream and is the active ingredient in toothpaste for sensitive gums.

A popular misconception is that potassium nitrate is an antaphrodisiac and was added to food in all-male institutions. In fact potassium nitrate has no such effect in humans. [1]

Recently, the use of potassium nitrate in toothpastes for sensitive teeth has increased dramatically, despite the fact that it has not been shown to actually help dental hypersensitivity. [2]

Human urine

Urine is liquid waste excreted by the kidneys and is produced by the process of filtration. This waste is eventually expelled from the body in a process known as urination. Most commonly the excretion of urine serves for flushing waste molecules collected from the blood by the kidneys, and for the homeostasis of the body liquids; however, many species also use it for olfactory communication.



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Composition

Urine is the byproduct or fluid secreted by the kidneys, transported by the ureters to the urinary bladder where it is stored until it is voided through the urethra. It is a transparent solution that is clear to amber in colour, and usually is light yellow. Urine is made up of a watery solution of metabolic wastes (such as urea), dissolved salts and organic materials. Fluid and materials being filtered by the kidneys, destined to become urine, comes from the blood or interstitial fluid. The composition of urine is adjusted in the process of reabsorption when essential molecules needed by the body, such as glucose, are reabsorbed back into the blood stream via carrier molecules. The remaining fluid contains high concentrations of urea and other excess or potentially toxic substances that will be released from the body via urination. Urine flows through these structures: the kidney, ureter, bladder, and finally the urethra. Urine is produced by a process of filtration, reabsorption, and tubular secretion.

Urine contains large amounts of urea, an excellent source of nitrogen for plants. As such it is a useful accelerator for compost. Urea is 10,000 times less toxic than ammonia and is a byproduct of deamination (2 NH₃ molecules) and cellular respiration's (1 CO₂ molecule) products combining together. Other components include various inorganic salts such as sodium chloride (the discharge of sodium through urine is known as "natriuresis".)

Colour

The typical clear, yellow, or yellow-orange colour of urine is caused by degradation products of bilirubin including urobilin. Unusual coloration may be the result of certain food products such as betacyanin as found in red beets. Abnormal coloration from bleeding within the urinary system is termed hematuria (blood in the urine), a symptom

that needs medical attention. Dark orange to brown urine can be a symptom of jaundice or Gilbert's syndrome. "Melanuria" refers to black or dark-colored urine and may be caused by a melanoma.

Amount

The amount of urine produce depends on numerous factors including state of hydration, activities, environmental factors, size, species, and health. In adult humans the average production is about 1 - 2L per day. Producing too much or too little urine needs medical attention: Polyuria is a condition of excessive production of urine (> 2.5L/day), in contrast to oliguria where < 400 mL are produced per day, or anuria with a production of < 100 mL per day.

Function

Urination is the primary method for excreting chemicals and drugs from the body. These chemicals can be detected and analysed by urinalysis.

In cases of kidney or urinary tract infection (UTI), the urine will contain bacteria, but otherwise urine is virtually sterile and nearly odorless when it leaves the body. However, after that, bacteria that contaminate the urine will convert chemicals in the urine into smelling chemicals that are responsible for the distinctive odor of stale urine; in particular, ammonia is produced from urea.

Some diseases alter the quantity and consistency of the urine, (e.g., sugar in the urine is a sign of diabetes). Urine therapy is the use of urine topically or consumed, especially as recommended by the traditional Indian medicine, Ayurveda, under the name Amaroili.:

Urine can give an indication of how well-hydrated a person is. A hydrated person will commonly urinate a clear, water-like urine, whereas a dehydrated person may pass a darker yellow or brown urine, as is often observed the morning after a night's drinking of large quantities of alcohol.

Urine in Medicine

Examination

Physicians of all ages have resorted to the inspection and examination of the urine of their patients. Hippocrates described urine examination. Hermogenes wrote about the colour and other attributes of urine as indicators of certain diseases. Diabetes mellitus got its name because the urine is plentiful and sweet. A urinalysis is a medical examination of the urine and part of routine examinations. A culture of the urine is performed when a urinary tract infection is suspected. A microscopic examination of the urine may be helpful to identify organic or anorganic substrates and help in the diagnosis.

Application

The use of urine as a medical treatment or daily health regimen is uncommon. Aztec physicians used urine to clean external wounds to prevent infection, and administered it as a drink to relieve stomach and intestine problems. Purported beneficiaries of the 'urine cure' include Mohandas Gandhi, Jim Morrison, and Steve McQueen. Its medicinal properties have been observed and is also used in China as a part of holistic medicine.

Resource

Urine may contain proteins or other substances that are useful for medical therapy. Urine from postmenopausal women is rich in gonadotropins that can yield follicle stimulating hormone for fertility therapy. The first such commercial product was Pergonal. Urine from pregnant women contains enough human chorionic gonadotropins for commercial extraction and purification to produce hCG medication. Pregnant mare urine is the source of estrogens, namely Premarin.

In recent times, the Port-a-John corporation of Utica, Michigan, USA has developed a filter to collect medically significant proteins from users of their chemical toilets.

Other Uses

The ancient Romans used urine as a bleaching agent for cleaning clothes and there are even isolated reports as a teeth whitener (supposedly originating in what is now Spain).

In Siberia, to communicate with the spirits, the Koryak people drank the urine of another who has consumed fly agaric (an entheogenic mushroom that is occasionally fatally poisonous), or of one who has in turn drunk urine of like source. Sometimes, the urine of reindeer that had eaten fly agaric would even be drunk. The potency of the mushroom does not decrease significantly until around the seventh drinker, because the muscimol from fly agaric is essentially unaltered after being secreted from the kidneys. Not only does this conserve the mushrooms, but it also eliminates unpleasant side-effects caused by muscarine, which does not pass on through urine. Likewise, reindeer licked the ground where there is urine containing fly agaric from the religious ritual. Despite these rumors, it is highly doubtful that any animal would eat the Amanita mushroom because its red and white markings let animals know that it is a poisonous mushroom.

Urine has applications in gardening and agriculture as a fertiliser. Gardeners often recommend a dilution of 10-15 parts water to one of urine for application to pot plants and flower beds during the growing season; pure urine can chemically burn the roots of some species. Urine typically contains more than 50% of the nitrogen and phosphorus and potassium content of whole sewage, and is widely considered as good as or better than commercially-available chemical fertilisers or stabilised sludge from sewage plants. Urine is also used in composting to increase the nitrogen content of the mulch, accelerating the composting process and increasing its final nutrient values.

Urine is also being actively considered as a fertilizer for use in food-crop agriculture in developed countries. Studies into its feasibility and safety usually indicate that it is an acceptable alternative to chemical fertilisers and stabilised sludge. However, the technology to implement its use on a large scale has not been developed, and is considered too expensive. There are also concerns over its safety regarding the potential for transmitting infectious disease and refluxing xenobiotic compounds (associated with toilet-cleaning products and prescribed drugs expelled in urine) in the human food chain. Proponents of adopting urine for this use usually claim the risks to be negligible or acceptable, and point out that sewage causes more environmental problems when it is treated and disposed of compared with when it is used as a resource. Critics generally agree that more research is needed into how the resource is to be collected, processed and handled.

Few people use urine as a crop fertilizer. These include organic farming cooperatives and eco-villages where special urine-diverting toilets with collecting tanks are installed. Many of these also employ concepts such as greywater irrigation and the composting of fecal matter. Many are the subject of ongoing feasibility studies sanctioned by governments and private organisations. These people generally reject safety concerns over its use on food crops provided that it is used with common sense. For example, application to fruit trees is considered safer than to bushes and especially root crops. It is also considered sensible to cease application at a safe interval before harvesting. However, the use of urine for this purpose is even rarer than its use on ornamental gardens.

In developing countries, the application of pure urine to crops is also rare. However, whole, untreated sewage, termed night soil, is often applied to crops and is considered essential. It is worth noting that this practice is not new and has been applied, along with crop rotation schemes, for thousands of years.

In Japan, urine used to be sold to farmers who would process it into fertilizers.

Shipwrecked or people otherwise adrift at sea for long periods often resort to drinking their urine when no rainwater is available, seawater being unsuitable. People stranded in deserts often also drank urine to prevent life-threatening dehydration from setting in. However, this desperate measure achieves little to delay death from thirst, particularly if it causes vomiting.

During World War I, the Germans experimented with numerous poisonous gasses for use during war. After the first German chlorine gas attacks, Allied troops were supplied with masks of cotton pads that had been soaked in urine. It was found that the ammonia in the pad neutralized the chlorine. These pads were held over the face until the soldiers could escape from the poisonous fumes.

Urine has also been historically used as an antiseptic. In times of war, when other antiseptics were unavailable, urine, the darker the better, was utilized on open wounds to kill bacteria.

History

The yellow color of urine was previously thought to come from gold. Alchemists spent much time trying to extract gold from urine, and this led to some interesting discoveries such as white phosphorus, which was discovered by the German alchemist Hennig Brand in 1669 when he was distilling fermented urine. In 1773 the French chemist Hilaire Rouelle, discovered the organic compound urea by boiling urine dry.

Recently, in December of 2005, three students in Fairfax County, Virginia, were suspended for five days for urinating in plastic bottles and leaving them in their school's storage closet. The students, Mike Chimento, Ryan Spaulding, and Matt Dietz, will be further charged by the Fairfax County Police Department with endangering public health and safety.

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- "RAKSHANK" author Dr.Rakshak Mal Lodha + 91 291 2620975

Ammonia

Systematic name	Ammonia Azane (<i>see text</i>)
Trivial names	Spirit of hartshorn Nitrosil Vaporole
Molecular formula	NH ₃
Molar mass	17.03 g/mol
Appearance	Colourless gas with strong pungent odor
CAS number	[7664-41-7]
Properties	
Density and phase	.6813 g/L, gas
Solubility in water	54 g/100 ml
Melting point	-78.27 °C (195.42 K)
Boiling point	-33.49 °C (240.74 K)
Basicity (p <i>K</i> _b)	4.75

Ammonia is a compound of nitrogen and hydrogen with the formula NH_3 . At standard temperature and pressure ammonia is a gas. It is toxic and corrosive to some materials, and has a characteristic pungent odor.

An ammonia molecule has the shape of a loose tetrahedron known as a trigonal pyramid, as would be expected from VSEPR theory. This shape gives the molecule an overall dipole moment and makes it polar so that ammonia very readily dissolves in water. The nitrogen atom in the molecule has a lone electron pair, and ammonia acts as a base. In acidic or even neutral aqueous solutions, it can bond to a hydronium ion (H_3O^+), releasing a water molecule (H_2O) to form the positively charged ammonium ion (NH_4^+), which has the shape of a regular tetrahedron. The degree to which ammonia forms the ammonium ion depends on the pH of the solution.

The main uses of ammonia are in the production of fertilizers, explosives and polymers. It is also an ingredient in certain household glass cleaners. Ammonia is found in small quantities in the atmosphere, being produced from the putrefaction of nitrogenous animal and vegetable matter. Ammonia and ammonium salts are also found in small quantities in rainwater, while ammonium chloride (sal-ammoniac) and ammonium sulfate are found in volcanic districts; crystals of ammonium bicarbonate have been found in Patagonian guano. Ammonium salts also are found distributed through all fertile soil and in seawater. Substances containing ammonia or that are similar to it are called ammoniacal.

Acidity ($\text{p}K_a$)	<i>approx.</i> 34
Thermodynamic data	
Std enthalpy of formation $\Delta_f H^\circ_{\text{gas}}$	-45.92 kJ/mol
Standard molar entropy S°_{gas}	192.77 $\text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
Hazards	
EU classification	<i>Conc. dependent.</i> <i>See text</i>
R-phrases	<i>Conc. dependent</i> <i>See text</i>
S-phrases	S1/2, S16, S36/37/39, S45, S61
NFPA 704	
Supplementary data page	
Structure and properties	n , ϵ_r , etc.
Thermodynamic data	Phase behaviour Solid, liquid, gas
Spectral data	UV, IR, NMR, MS
Regulatory data	Flash point, RTECS number, etc.
Related compounds	
Related Amines	<i>See Amine</i>
Related Hydrides	Phosphine Arsine
Related compounds	Hydrazine Hydrazoic acid Hydroxylamine Chloramine
Except where noted otherwise, data are given for materials in their standard state (at 25 °C, 100 kPa) Infobox disclaimer and references	

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History

Salts of ammonia have been known from very early times; thus the term *Hammoniacus sal* appears in the writings of Pliny, although it is not known whether the term is identical with the more modern *sal-ammoniac*.

In the form of sal-ammoniac, ammonia was known to the alchemists as early as the 13th century, being mentioned by Albertus Magnus. It was also used by dyers in the Middle Ages in the form of fermented urine to alter the colour of vegetable dyes. In the 15th century, Basilius Valentinus showed that ammonia could be obtained by the action of alkalis on sal-ammoniac. At a later period, when sal-ammoniac was obtained by distilling the hoofs and horns of oxen and neutralizing the resulting carbonate with hydrochloric acid, the name **Spirit of hartshorn** was applied to ammonia.

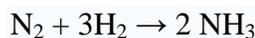
Gaseous ammonia was first isolated by Joseph Priestley in 1774 and was termed by him *alkaline air*. In 1777 Karl Wilhelm Scheele showed that it contained nitrogen, and Claude Louis Berthollet, in about 1785, ascertained its composition.

The Haber process to produce ammonia from the nitrogen contained in the air was developed by Fritz Haber and Carl Bosch in 1909 and patented in 1910. It was first used

on an industrial scale by the Germans during World War I. The ammonia was used to produce explosives to sustain their war effort.

Synthesis and production

Because of its many uses, ammonia is one of the most highly-produced inorganic chemicals. Today NH_3 is manufactured by the Haber process. In this process, N_2 and H_2 combine in the presence of an iron catalyst at a pressure of 200 bar (20 MPa, 3000 lbf/in²) and a temperature of 500 °C. A molybdenum promoter may also be used.

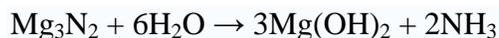


Compared to older methods, the feedstocks of the Haber process are relatively inexpensive—nitrogen makes up 78% of the atmosphere, while hydrogen is produced in situ from CH_4 . Thus, the industrial process entails heating air and natural gas, a by-product is CO_2 .

Before the start of WWI most ammonia was obtained by the dry distillation of nitrogenous vegetable and animal products; by the reduction of nitrous acid and nitrites with hydrogen; and also by the decomposition of ammonium salts by alkaline hydroxides or by quicklime, the salt most generally used being the chloride (sal-ammoniac) thus



It can also been obtained by the hydrolysis of many metal nitrides, for example,



Biosynthesis

Ammonia is produced from atmospheric N_2 by enzymes called nitrogenases. The overall process is called nitrogen fixation. Although it is unlikely that biomimetic methods will be developed that are competitive with the Haber process, intense effort has been directed toward understanding the mechanism of biological nitrogen fixation. The scientific interest in this problem is motivated by the unusual structure of the active site of the enzyme, which consists of an Fe_7MoS_9 ensemble.

Ammonia is also a metabolic product of amino acid deamination. In humans, it is quickly converted to urea, which is much less toxic. This urea is a major component of the dry weight of urine.

Properties

Ammonia is a colourless gas with a characteristic pungent smell; it is lighter than air, its density being 0.589 times that of air. It is easily liquefied and the liquid boils at -33.7 °C,

and solidifies at $-75\text{ }^{\circ}\text{C}$ to a mass of white crystals. Liquid ammonia possesses strong ionizing powers ($\epsilon = 22$), and solutions of salts in liquid ammonia have been much studied. Liquid ammonia has a very high standard enthalpy change of vaporization (23.35 kJ/mol, *c.f.* water 40.65 kJ/mol, methane 8.19 kJ/mol, phosphine 14.6 kJ/mol) and can therefore be used in laboratories in non-insulated vessels at room temperature, even though it is well above its boiling point.

It is miscible with water. All the ammonia contained in an aqueous solution of the gas may be expelled by boiling. The aqueous solution of ammonia is basic. The maximum concentration of ammonia in water (a saturated solution) has a density of 0.880 g cm^{-3} and is often known as '.880 Ammonia'.

It does not sustain combustion, and it does not burn readily unless mixed with oxygen, when it burns with a pale yellowish-green flame.

At high temperature and in the presence of a suitable catalyst, ammonia is decomposed into its constituent elements. Chlorine catches fire when passed into ammonia, forming nitrogen and hydrochloric acid; unless the ammonia is present in excess, the highly explosive nitrogen trichloride (NCl_3) is also formed.

The ammonia molecule readily undergoes nitrogen inversion at normal pressures, that is to say that the nitrogen atom passes through the plane of the three hydrogen atoms as if it were an umbrella turning inside out in a strong wind. The energy barrier to this inversion is 24.7 kJ/mol in ammonia, and the resonance frequency is 23.79 GHz, corresponding to microwave radiation of a wavelength of 1.260 cm. The absorption at this frequency was the first microwave spectrum to be observed (C. E. Cleeton & N. H. Williams, 1934).

Formation of salts

One of the most characteristic properties of ammonia is its power of combining directly with acids to form salts; thus with hydrochloric acid it forms ammonium chloride (sal-ammoniac); with nitric acid, ammonium nitrate, etc. However perfectly dry ammonia will not combine with perfectly dry hydrogen chloride, moisture being necessary to bring about the reaction.^[11]



The salts produced by the action of ammonia on acids are known as the ammonium salts and all contain the ammonium ion (NH_4^+).

Acidity

Although ammonia is well-known as a base, it can also act as an extremely weak acid. It is a protic substance, and is capable of dissociation into the **amide** (NH_2^-) ion, for example when solid lithium nitride is added to liquid ammonia, forming a lithium amide solution:



This is a Bronsted-Lowry acid-base reaction in which ammonia is acting as an acid.

Formation of other compounds

Ammonia can act as a nucleophile in substitution reactions. Amines can be formed by the reaction of ammonia with alkyl halides, although the resulting $-\text{NH}_2$ group is also nucleophilic and secondary and tertiary amines are often formed as by-products. Using an excess of ammonia helps minimise multiple substitution, and neutralises the hydrogen halide formed. Methylamine is prepared commercially by the reaction of ammonia with chloromethane, and the reaction of ammonia with 2-bromopropanoic acid has been used to prepare racemic alanine in 70% yield. Ethanolamine is prepared by a ring-opening reaction with ethylene oxide: the reaction is sometimes allowed to go further to produce diethanolamine and triethanolamine.

Amides can be prepared by the reaction of ammonia with a number of carboxylic acid derivatives. Acyl chlorides are the most reactive, but the ammonia must be present in at least a two-fold excess to neutralise the hydrogen chloride formed. Esters and anhydrides also react with ammonia to form amides.

Ammonium salts of carboxylic acids can be dehydrated to amides so long as there are no thermally sensitive groups present: temperatures of 150–200 °C are required.

The hydrogen in ammonia is capable of replacement by metals, thus magnesium burns in the gas with the formation of magnesium nitride Mg_3N_2 , and when the gas is passed over heated sodium or potassium, sodamide, NaNH_2 , and potassamide, KNH_2 , are formed.

Where necessary in substitutive nomenclature, IUPAC recommendations prefer the name **azane** to ammonia: hence chloramine would be named *chloroazane* in substitutive nomenclature, not *chloroammonia*.

Ammonia as a ligand

Ammonia can act as a ligand in transition metal complexes. It is a pure σ -donor, in the middle of the spectrochemical series, and shows intermediate hard-soft behaviour. For historical reasons, ammonia is named **ammine** in the nomenclature of coordination compounds. Some notable ammine complexes include:

- **Hexamminecopper(II)**, $[\text{Cu}(\text{NH}_3)_6]^{2+}$, a characteristic dark blue complex formed by adding ammonia to solution of copper(II) salts.
- **Diamminesilver(I)**, $[\text{Ag}(\text{NH}_3)_2]^+$, the active species in Tollens' reagent. Formation of this complex can also help to distinguish between precipitates of the different silver halides: AgCl is soluble in dilute (2 M) ammonia solution, AgBr is only soluble in concentrated ammonia solution while AgI is insoluble in aqueous solution of ammonia.

Ammine complexes of chromium(III) were known in the late 19th century, and formed the basis of Alfred Werner's theory of coordination compounds. Werner noted that only two isomers (*fac*- and *mer*-) of the complex $[\text{CrCl}_3(\text{NH}_3)_3]$ could be formed, and concluded that the ligands must be arranged around the metal ion at the vertices of an octahedron. This has since been confirmed by X-ray crystallography.

An ammine ligand bound to a metal ion is markedly more acidic than a free ammonia molecule, although deprotonation in aqueous solution is still rare. One example is the Calomel reaction, where the resulting amidomercury(II) compound is highly insoluble.



Uses

The most important single use of ammonia is in the production of nitric acid. A mixture of one part ammonia to nine parts air is passed over a platinum gauze catalyst at 850 °C, whereupon the ammonia is oxidized to nitric oxide.



The catalyst is essential, as the normal oxidation (or combustion) of ammonia gives dinitrogen and water: the production of nitric oxide is an example of kinetic control. As the gas mixture cools to 200–250 °C, the nitric oxide is in turn oxidized by the excess of oxygen present in the mixture, to give nitrogen dioxide. This is reacted with water to give nitric acid for use in the production of fertilizers and explosives.

In addition to serving as a fertilizer ingredient, ammonia can also be used directly as a fertilizer by forming a solution with irrigation water, without additional chemical processing. This later use allows the continuous growing of nitrogen dependent crops such as maize (corn) without crop rotation but this type of use leads to poor soil health.

Ammonia has thermodynamic properties that make it very well suited as a refrigerant, since it liquefies readily under pressure, and was used in virtually all refrigeration units prior to the advent of haloalkanes such as Freon. However, ammonia is a toxic irritant and its corrosiveness to any copper alloys increases the risk that an undesirable leak may develop and cause a noxious hazard. Its use in small refrigeration units has been largely replaced by haloalkanes, which are not toxic irritants and are practically not flammable. (Note: Butane and isobutane, which have very suitable thermodynamic properties for refrigerants, are extremely flammable.) Ammonia continues to be used as a refrigerant in large industrial processes such as bulk icemaking and industrial food processing. Ammonia is also useful as a component in absorption-type refrigerators, which do not use compression and expansion cycles but can exploit heat differences. Since the implication of haloalkane being major contributors to ozone depletion, ammonia is again seeing increasing use as a refrigerant.

Ammonia is a primary ingredient in old-style household cleaners.

It is also sometimes added to drinking water along with chlorine to form chloramine, a disinfectant. Unlike chlorine on its own, chloramine does not combine with organic (carbon containing) materials to form carcinogenic halomethanes such as chloroform.

Liquid ammonia as a solvent

Liquid ammonia is the best-known and most widely studied non-aqueous ionizing solvent. Its most conspicuous property is its ability to dissolve alkali metals to form highly coloured, electrically conducting solutions containing solvated electrons. Apart from these remarkable solutions, much of the chemistry in liquid ammonia can be classified by analogy with related reactions in aqueous solutions. Comparison of the physical properties of NH_3 with those of water shows that NH_3 has the lower melting point, boiling point, density, viscosity, dielectric constant and electrical conductivity; this is due at least in part to the weaker H bonding in NH_3 and the fact that such bonding cannot form cross-linked networks since each NH_3 molecule has only 1 lone-pair of electrons compared with 2 for each H_2O molecule. The ionic self-dissociation constant of liquid NH_3 at $-50\text{ }^\circ\text{C}$ is approx. $10^{-33}\text{ mol}^2\cdot\text{l}^{-2}$.

Solubility of salts

	Solubility (g per 100 g)
Ammonium acetate	253.2
Ammonium nitrate	389.6
Lithium nitrate	243.7
Sodium nitrate	97.6
Potassium nitrate	10.4
Sodium fluoride	0.35
Sodium chloride	3.0
Sodium bromide	138.0
Sodium iodide	161.9
Sodium thiocyanate	205.5

Liquid ammonia is an ionizing solvent, although less so than water, and dissolves a range of ionic compounds including many nitrates, nitrites, cyanides and thiocyanates. Most ammonium salts are soluble, and these salts act as acids in liquid ammonia solutions. The solubility of halide salts increases from fluoride to iodide. A saturated solution of ammonium nitrate contains 0.83 mol solute per mole of ammonia, and has a vapour pressure of less than 1 bar even at $25\text{ }^\circ\text{C}$.

Solutions of metals

Liquid ammonia will dissolve the alkali metals and other electropositive metals such as Ca, Sr, Ba, Eu and Yb. At low concentrations ($< 0.06\text{ mol/L}$), deep blue solutions are

formed: these contain metal cations and solvated electrons, free electrons which are surrounded by a cage of ammonia molecules. These solutions are very useful as strong reducing agents. At higher concentrations, the solutions are metallic in appearance and in electrical conductivity. At low temperatures, the two types of solution can coexist as immiscible phases.

Redox properties of liquid ammonia

	E° (V, ammonia)	E° (V, water)
$\text{Li}^+ + \text{e}^- \rightleftharpoons \text{Li}$	-2.24	-3.04
$\text{K}^+ + \text{e}^- \rightleftharpoons \text{K}$	-1.98	-2.93
$\text{Na}^+ + \text{e}^- \rightleftharpoons \text{Na}$	-1.85	-2.71
$\text{Zn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Zn}$	-0.53	-0.76
$\text{NH}_4^+ + \text{e}^- \rightleftharpoons \frac{1}{2}\text{H}_2 + \text{NH}_3$	0.00	-
$\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu}$	+0.43	+0.34
$\text{Ag}^+ + \text{e}^- \rightleftharpoons \text{Ag}$	+0.83	+0.80

The range of thermodynamic stability of liquid ammonia solutions is very narrow, as the potential for oxidation to dinitrogen, $E^\circ (\text{N}_2 + 6\text{NH}_4^+ + 6\text{e}^- \rightleftharpoons 8\text{NH}_3)$, is only +0.04 V. In practice, both oxidation to dinitrogen and reduction to dihydrogen are slow. This is particularly true of reducing solutions: the solutions of the alkali metals mentioned above are stable for several days, slowly decomposing to the metal amide and dihydrogen. Most studies involving liquid ammonia solutions are done in reducing conditions: although oxidation of liquid ammonia is usually slow, there is still a risk of explosion, particularly if transition metal ions are present as possible catalysts.

Detection and determination

Ammonia and ammonium salts can be readily detected, in very minute traces, by the addition of Nessler's solution, which gives a distinct yellow coloration in the presence of the least trace of ammonia or ammonium salts. Sulfur sticks are burnt to detect small leaks in industrial ammonia refrigeration systems. Larger quantities can be detected by warming the salts with a caustic alkali or with quicklime, when the characteristic smell of ammonia will be at once apparent. The amount of ammonia in ammonium salts can be estimated quantitatively by distillation of the salts with sodium or potassium hydroxide, the ammonia evolved being absorbed in a known volume of standard sulfuric acid and the excess of acid then determined volumetrically; or the ammonia may be absorbed in hydrochloric acid and the ammonium chloride so formed precipitated as ammonium hexachloroplatinate, $(\text{NH}_4)_2\text{PtCl}_6$.

Safety precautions

Toxicity

The toxicity of ammonia solutions does not usually cause problems for humans and other mammals, as a specific mechanism exists to prevent its build-up in the bloodstream. Ammonia is converted to carbamoyl phosphate by the enzyme carbamoyl phosphate synthase, and then enters the urea cycle to be either incorporated into amino acids or excreted in the urine. However fish and amphibians lack this mechanism, as they can usually eliminate ammonia from their bodies by direct excretion. Ammonia even at dilute concentrations is highly toxic to aquatic animals, and for this reason it is classified as *dangerous for the environment*.

Household use

Solutions of ammonia (5–10% by weight) are used as household cleaners, particularly for glass. These solutions are irritating to the eyes and mucous membranes (respiratory and digestive tracts), and to a lesser extent the skin. They should **never** be mixed with chlorine-containing products, for example household bleach, as a variety of toxic and carcinogenic compounds are formed (*e.g.*, chloramine, hydrazine).

Laboratory use of ammonia solutions

The hazards of ammonia solutions depend on the concentration: "dilute" ammonia solutions are usually 5–10% by weight (<5.62 mol/L); "concentrated" solutions are usually prepared at >25% by weight. A 25% (by weight) solution has a density of 0.907 g/cm³, and a solution which has a lower density will be more concentrated. The European Union classification of ammonia solutions is given in the table.

Concentration by weight	Molarity	Classification	R-Phrases
5–10%	2.87–5.62 mol/L	Irritant (Xi)	R36/37/38
10–25%	5.62–13.29 mol/L	Corrosive (C)	R34
>25%	>13.29 mol/L	Corrosive (C) Dangerous for the environment (N)	R34, R50

S-Phrases: S1/2, S16, S36/37/39, S45, S61.

The ammonia vapour from concentrated ammonia solutions is severely irritating to the eyes and the respiratory tract, and these solutions should only be handled in a fume hood. Saturated ("0.880") solutions can develop a significant pressure inside a closed bottle in warm weather, and the bottle should be opened with care: this is not usually a problem for 25% ("0.900") solutions.

Ammonia solutions should not be mixed with halogens, as toxic and/or explosive products are formed. Prolonged contact of ammonia solutions with silver, mercury or iodide salts can also lead to explosive products: such mixtures are often formed in qualitative analysis, and should be acidified and diluted before disposal once the test is completed.

Laboratory use of anhydrous ammonia (gas or liquid)

Anhydrous ammonia is classified as **toxic (T)** and **dangerous for the environment (N)**. The gas is flammable (autoignition temperature: 651 °C) and can form explosive mixtures with air (16–25%). The permissible exposure limit (PEL) in the United States is 50 ppm (35 mg/m³), while the IDLH concentration is estimated at 300 ppm. Repeated exposure to ammonia lowers the sensitivity to the smell of the gas: normally the odour is detectable at concentrations of less than 0.5 ppm, but desensitized individuals may not detect it even at concentrations of 100 ppm.

Ammonia reacts violently with the halogens, and causes the explosive polymerization of ethylene oxide. It also forms explosive compounds with compounds of gold, silver, mercury, germanium or tellurium, and with stibine. Violent reactions have also been reported with acetaldehyde, hypochlorite solutions, potassium ferricyanide and peroxides.

Anhydrous ammonia corrodes copper- and zinc-containing alloys, and so brass fittings should not be used for handling the gas. Liquid ammonia can also attack rubber and certain plastics.

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Sulfate

In inorganic chemistry, a **sulfate** (IUPAC-recommended spelling; also **sulphate** in British English) is a polyatomic anion or a compound containing this group. It consists of one central sulfur atom surrounded by four identical oxygen atoms in a tetrahedral arrangement.

The ion carries a negative two formal charge and has the formula SO_4^{2-} . The conjugate acid of the sulfate ion is HSO_4^- whose own conjugate acid is H_2SO_4 , sulfuric acid.

Almost all ionic compounds with sulfate anions are soluble in water at standard temperature and pressure (the exceptions include CaSO_4 , SrSO_4 , and BaSO_4).

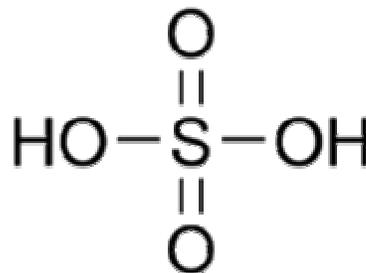
Sulfates, also known as sulfur oxides, are important in both the chemical industry and biological systems:

- The Lead-acid battery typically uses sulfuric acid.
- Organisms living near deep sea thermal vents depend on sulfates for energy in lieu of the sun.
- Copper sulfate is a common algaecide.
- Magnesium sulfate, commonly known as Epsom salts, is used in therapeutic baths.

Sulfates occur as microscopic particles (aerosols) resulting from fossil fuel and biomass combustion. They increase the acidity of the atmosphere and form acid rain. There is a negative radiative forcing from aerosols because, while in the atmosphere, they reflect incoming solar radiation. This is an increase in albedo.

Sulfuric acid

Sulfuric acid



General

Systematic name	Sulfuric acid
Other names	Oil of Vitriol
Molecular formula	H ₂ SO ₄
Molar mass	98.08 g/mol
Appearance	Clear, colorless, odorless oil
CAS number	[7664-93-9]

Properties

Density and phase	1.84 g/cm ³ , liquid
Solubility in water	fully miscible (exothermic!)
Melting point	10 °C (283 K)
Boiling point	337 °C (610 K)
pK _a	-3.0 1.99
Viscosity	26.7 cP at 20 °C

Hazards

MSDS	External MSDS
EU classification	Corrosive (C)
NFPA 704	
R-phrases	R35
S-phrases	S1/2, S26, S30, S45
Flash point	not flammable
RTECS number	WS5600000

Sulfuric acid (British English: **sulphuric acid**), H₂SO₄, is a strong mineral acid. It is soluble in water at all concentrations. The old name for sulfuric acid was **Zayt al-Zaj**, or **oil of vitriol**, coined by medieval Iranian chemist Jabir Ibn Hayyan, the chemical's probable discoverer^[1]. Sulfuric acid has many applications, and is produced in greater amounts than any other chemical besides water. World production in 2001 was 165 million tonnes, with an approximate value of \$8 billion. Principal uses include fertilizer manufacturing, ore processing, chemical synthesis, wastewater processing, and oil refining.

Supplementary data page	
Structure & properties	<i>n</i> , <i>ε_r</i> , etc.
Thermodynamic data	Phase behaviour Solid, liquid, gas
Spectral data	UV, IR, NMR, MS
Related compounds	
Related strong acids	Selenic acid Hydrochloric acid Nitric acid Phosphoric acid
Related compounds	Hydrogen sulfide Sulfurous acid Peroxymonosulfuric acid Sulfur trioxide Oleum
Except where noted otherwise, data are given for materials in their standard state (at 25°C, 100 kPa) Infobox disclaimer and references	

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Physical properties

Forms of sulfuric acid

Although 100% sulfuric acid can be made, this loses SO_3 at the boiling point to produce 98.3% acid. The 98% grade is also more stable for storage, making it the usual form for "concentrated" sulfuric acid. Other concentrations of sulfuric acid are used for different purposes. Some common concentrations are:

- 10%, dilute sulfuric acid for laboratory use
- 33.5%, battery acid (used in lead-acid batteries)
- 62.18%, chamber or fertilizer acid
- 77.67%, tower or Glover acid
- 98%, concentrated

Different purities are also available. Technical grade H_2SO_4 is impure and often colored, but it is suitable for making fertiliser. Pure grades such as US Pharmacopoeia (USP) grade are used for making pharmaceuticals and dyestuffs.

When high concentrations of $\text{SO}_3(g)$ are added to sulfuric acid, $\text{H}_2\text{S}_2\text{O}_7$ forms. This is called fuming sulfuric acid or oleum or, less commonly, Nordhausen acid. Concentrations of oleum are either expressed in terms of % SO_3 (called % oleum) or as "% H_2SO_4 (the amount made if H_2O were added); common concentrations are 40% oleum (109% H_2SO_4) and 65% oleum (114.6% H_2SO_4). Pure $\text{H}_2\text{S}_2\text{O}_7$ is in fact a solid, melting point 36 °C.

Polarity and conductivity

Anhydrous H_2SO_4 is a very polar liquid, with a dielectric constant of around 100. This is due to the fact that it can dissociate by protonating itself, a process known as *autoprotolysis*,^[2] which occurs to a high degree, more than 10 billion times the level seen in water:



This allows protons to be highly mobile in H_2SO_4 . It also makes sulfuric acid an excellent solvent for many reactions. In fact, the equilibrium is more complex than shown above. 100% H_2SO_4 contains the following species at equilibrium (figures shown as mmol per kg solvent): HSO_4^- (15.0), H_3SO_4^+ (11.3), H_3O^+ (8.0), HS_2O_7^- (4.4), $\text{H}_2\text{S}_2\text{O}_7$ (3.6), H_2O (0.1).

Chemical properties

Reaction with water

The hydration reaction of sulfuric acid is highly exothermic. If water is added to concentrated sulfuric acid, it can boil and spit dangerously. One should always add the

acid to the water rather than the water to the acid. This can be remembered through mnemonics such as "Do as you oughta: add acid to water", "A.A.: Add Acid", or "Drop acid, not water." Note that part of this problem is due to the relative densities of the two liquids. Water is less dense than sulfuric acid and will tend to float above the acid. The reaction is best thought of as forming hydronium ions, as such:



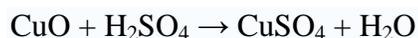
And then:



Because the hydration of sulfuric acid is thermodynamically favorable ($\Delta H = -880$ kJ/mol), sulfuric acid is an excellent dehydrating agent, and is used to prepare many dried fruits. The affinity of sulfuric acid for water is sufficiently strong that it will take hydrogen and oxygen atoms out of other compounds; for example, mixing starch ($\text{C}_6\text{H}_{12}\text{O}_6$)_n and concentrated sulfuric acid will give elemental carbon and water which is absorbed by the sulfuric acid (which becomes slightly diluted): $(\text{C}_6\text{H}_{12}\text{O}_6)_n \rightarrow 6\text{C} + 6\text{H}_2\text{O}$. The effect of this can be seen when concentrated sulphuric acid spilled on paper; the starch reacts to give a burned appearance, the carbon appears as soot would in a fire.

Other reactions of sulfuric acid

As an acid, sulfuric acid reacts with most bases to give the corresponding sulfate. For example, copper(II) sulfate, the familiar blue salt of copper used for electroplating and as a fungicide, is prepared by the reaction of copper(II) oxide with sulfuric acid:



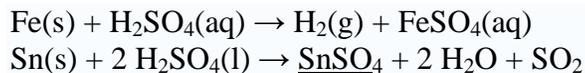
Sulfuric acid can be used to displace weaker acids from their salts, for example sodium acetate gives acetic acid:



Likewise the reaction of sulfuric acid with potassium nitrate can be used to produce nitric acid, along with a precipitate of potassium bisulfate. With nitric acid itself, sulfuric acid acts as both an acid and a dehydrating agent, forming the nitronium ion NO_2^+ , which is important in nitration reactions involving electrophilic aromatic substitution. This type of reaction where protonation occurs on an oxygen atom, is important in many reactions in organic chemistry, such as Fischer esterification and dehydration of alcohols.

Sulfuric acid reacts with most metals in a single displacement reaction to produce hydrogen gas and the metal sulfate. Dilute H_2SO_4 attacks iron, aluminium, zinc, manganese and nickel, but tin and copper require hot concentrated acid. Lead and tungsten are, however, resistant to sulfuric acid. The reaction with iron (shown) is typical

for most of these metals, but the reaction with tin is unusual in that it produces sulfur dioxide rather than hydrogen.



Environmental aspects

Sulfuric acid is a constituent of acid rain, being formed by atmospheric oxidation of water and sulfur dioxide. Sulfur dioxide is the main product when sulfur-containing fuels such as coal or oil are burned together.

Common myth states that sulfuric acid is a major component in the hot atmosphere of the planet Venus, and as a result exploration of Venus with spacecraft is difficult. However, it is overall a trace chemical and is nearly absent near the surface, found mostly in the upper clouds instead. The hazards in exploration of Venus are a pressure nearly ninety times that of Earth's and a surface temperature hot enough to melt lead.

History of sulfuric acid

The discovery of sulfuric acid is credited to the medieval Arabic chemist Jabir Ibn Hayyan but the 9th century Persian physician and alchemist Ibn Zakariya al-Razi (Rhases) is also sometimes credited. Rhases obtained the substance by dry distillation of minerals including iron (II) sulfate heptahydrate, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, called green vitriol, and copper(II) sulfate pentahydrate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, called blue vitriol. When heated, these compounds decompose to iron(II) oxide and copper(II) oxide, respectively, giving off water and sulfur trioxide, which combine to produce a dilute solution of sulfuric acid. This method was popularized in Europe through translations of Islamic treatises and books by European alchemists, such as the 13th-century German Albertus Magnus. For this reason, sulfuric acid was known to medieval European alchemists as *oil of vitriol* and *spirit of vitriol*, among other names.

In the 17th century, the German-Dutch chemist Johann Glauber prepared sulfuric acid by burning sulfur together with saltpeter (potassium nitrate, KNO_3), in the presence of steam. As the saltpeter decomposes, it oxidizes the sulfur to SO_3 , which combines with water to produce sulfuric acid. In 1736, Joshua Ward, a London pharmacist, used this method to begin the first large-scale production of sulfuric acid.

In 1746 in Birmingham, John Roebuck began producing sulfuric acid this way in lead-lined chambers, which were stronger, less expensive, and could be made larger than the glass containers which had been used previously. This *lead chamber process* allowed the effective industrialization of sulfuric acid production, and with several refinements remained the standard method of production for almost two centuries.

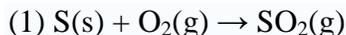
John Roebuck's sulfuric acid was only about 35–40% sulfuric acid. Later refinements in the lead-chamber process by the French chemist Joseph-Louis Gay-Lussac and the British chemist John Glover improved this to 78%. However, the manufacture of some dyes and other chemical processes require a more concentrated product, and throughout the 18th century, this could only be made by dry distilling minerals in a technique similar to the original alchemical processes. Pyrite (iron disulfide, FeS_2) was heated in air to yield iron (II) sulfate, FeSO_4 , which was oxidized by further heating in air to form iron(III) sulfate, $\text{Fe}_2(\text{SO}_4)_3$, which when heated to $480\text{ }^\circ\text{C}$ decomposed to iron(III) oxide and sulfur trioxide, which could be passed through water to yield sulfuric acid in any concentration. The expense of this process prevented the large-scale use of concentrated sulfuric acid.

In 1831, the British vinegar merchant Peregrine Phillips patented a far more economical process for producing sulfur trioxide and concentrated sulfuric acid, now known as the contact process. Essentially all of the world's supply of sulfuric acid is now produced by this method.

Manufacture

Sulfuric acid is produced from sulfur, oxygen and water via the contact process.

In the first step sulfur is burned to produce sulfur dioxide.



This is oxidised to sulfur trioxide using oxygen in the presence of a vanadium(V) oxide catalyst.



Finally the sulfur trioxide is treated with water (usually as 97-98% H_2SO_4 containing 2-3% water) to produce 98-99% sulfuric acid.



Note that directly dissolving SO_3 in water is impractical due to the highly exothermic nature of the reaction. Mists are formed instead of a liquid. Alternatively, the SO_3 is absorbed into H_2SO_4 to produce oleum ($\text{H}_2\text{S}_2\text{O}_7$), which is then diluted to form sulfuric acid.



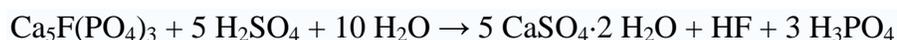
Oleum is reacted with water to form concentrated H_2SO_4 .



In 1993, US production of sulfuric acid amounted to 36.4 million tonnes. World production in 2001 was 165 million tonnes.

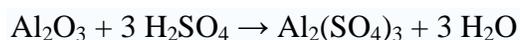
Uses

Sulfuric acid is a very important commodity chemical, and indeed a nation's sulfuric acid production is a good indicator of its industrial strength.^[3] The major use (60% of total worldwide) for sulfuric acid is in the "wet method" for the production of phosphoric acid, used for manufacture of phosphate fertilisers as well as sodium triphosphate for detergents. In this method phosphate rock is used, and more than 100 million tonnes is processed annually. This raw material is shown below as fluorapatite, though the exact composition may vary. This is treated with 93% sulfuric acid to produce calcium sulfate, hydrogen fluoride (HF) and phosphoric acid. The HF is removed as fluorosilicic acid. The overall process can be represented as



Sulfate fertilisers such as ammonium sulfate are manufactured using sulfuric acid, although in smaller quantities than phosphates.

Another important use for sulfuric acid is for the manufacture of aluminium sulfate, also known as papermaker's alum. This can react with small amounts of soap on paper pulp fibres to give gelatinous aluminium carboxylates, which help to coagulate the pulp fibres into a hard paper surface. It is also used for making aluminium hydroxide, which is used at water treatment plants to filter out impurities, as well as to improve the taste of the water. Aluminium sulfate is made by reacting bauxite with sulfuric acid:



Sulfuric acid is used for a variety of other purposes in the chemical industry. For example, it is the usual acid catalyst for the conversion of cyclohexanoneoxime to caprolactam, used for making nylon. It is used for making hydrochloric acid from salt via the Mannheim process. Much H_2SO_4 is used in petroleum refining, for example as a catalyst for the reaction of isobutane with isobutylene to give isooctane, a compound that raises the octane rating of gasoline (petrol). Sulfuric acid is also important in the manufacture of dyestuffs.

A mixture of sulfuric acid and water is used as the electrolyte in various types of lead-acid battery where it undergoes a reversible reaction where lead and lead dioxide are converted to lead(II) sulfate. Sulfuric acid is also the principal ingredient in some drain cleaners, used to clear blockages consisting of paper, rags, and other materials not easily dissolved by caustic solutions.

Safety

Laboratory hazards

The corrosive properties of sulfuric acid are accentuated by its highly exothermic reaction with water. Hence burns from sulfuric acid are potentially more serious than those of comparable strong acids (e.g. hydrochloric acid), as there is additional tissue damage due to dehydration and particularly due to the heat liberated by the reaction with water, i.e. secondary thermal damage. The danger is obviously greater with more concentrated preparations of sulfuric acid, but it should be remembered that even the normal laboratory "dilute" grade (approx. 1 M, 10%) will char paper by dehydration if left in contact for a sufficient length of time. The standard first aid treatment for acid spills on the skin is, as for other corrosive agents, irrigation with large quantities of water: in the case of sulfuric acid it is important that the acid should be removed before washing, as a further heat burn could result from the exothermic dilution of the acid. Washing should be continued for a sufficient length of time—at least ten to fifteen minutes—in order to cool the tissue surrounding the acid burn and to prevent secondary damage. Contaminated clothing must be removed immediately and the underlying skin washed thoroughly.

Preparation of the diluted acid can also be dangerous due to the heat released in the dilution process. It is essential that the concentrated acid is added to water and not the other way round, to take advantage of the relatively high heat capacity of water. Addition of water to concentrated sulfuric acid leads at best to the dispersal of a sulfuric acid aerosol, at worst to an explosion. Preparation of solutions greater than 6 M (35%) in concentration is the most dangerous, as the heat produced can be sufficient to boil the diluted acid: efficient mechanical stirring and external cooling (e.g. an ice bath) are essential.

Industrial hazards

Although sulfuric acid is non-flammable, contact with metals in the event of a spillage can lead to the liberation of hydrogen gas. The dispersal of acid aerosols and gaseous sulfur dioxide is an additional hazard of fires involving sulfuric acid. Water should **not** be used as the extinguishing agent because of the risk of further dispersal of aerosols: carbon dioxide is preferred where possible.

Sulfuric acid is not considered toxic besides its obvious corrosive hazard, and the main occupational risks are skin contact leading to burns (see above) and the inhalation of aerosols. Exposure to aerosols at high concentrations leads to immediate and severe irritation of the eyes, respiratory tract and mucous membranes: this ceases rapidly after exposure, although there is a risk of subsequent pulmonary edema if tissue damage has been more severe. At lower concentrations, the most commonly reported symptom of chronic exposure to sulfuric acid aerosols is erosion of the teeth, found in virtually all studies: indications of possible chronic damage to the respiratory tract are inconclusive as of 1997. In the United States, the permissible exposure limit (PEL) for sulfuric acid is fixed at 1 mg/m^3 : limits in other countries are similar.

Source

Institut National de Recherche et de Sécurité. (1997). "Acide sulfurique". *Fiche toxicologique n°30*, Paris: INRS, 5 pp.

References

1. ^ Chenier, Philip J. *Survey of Industrial Chemistry*, pp 45-57. John Wiley & Sons, New York, 1987. ISBN 0471010774.
2. ^ Greenwood, N.N. and A. Earnshaw. *Chemistry of the Elements*, pp 837-845. Pergamon Press, Oxford, UK, 1984. ISBN 0080220576.
3. ^ *Handbook of Chemistry and Physics*, 71st edition, CRC Press, Ann Arbor, Michigan, 1990.
4. ^ Khairallah, Amin A. *Outline of Arabic Contributions to Medicine*, chapter 10. Beirut, 1946.

Sodium nitrate

Sodium nitrate is a type of salt (NaNO_3) which has long been used as an ingredient in explosives and in solid rocket propellants, as well as in glass and pottery enamel, and as a food preservative (such as in hot dogs), and has been mined extensively for those purposes. It is also variously known as **caliche**, **Chile saltpeter**, **saltpeter**, and **soda niter**.

The world's largest natural deposits of caliche ore were in the Atacama desert of Chile, and many deposits were mined for over a century, until the 1940s. The former Chilean saltpeter mining communities of Humberstone and Santa Laura were declared Unesco World Heritage sites in 2005.

Chile still has the largest reserves of caliche, with active mines in such locations as Pedro de Valdivia, Maria Elena and Pampa Blanca. Sodium nitrate, potassium nitrate, sodium sulfate and iodine are all obtained by the processing of caliche.

Sodium nitrate is also manufactured synthetically by reacting nitric acid with soda ash.

The compound has antimicrobial properties when used as a food preservative. It is found naturally in leafy green vegetables. It has possible health benefits for increasing oxygen to blood, as well as known health side effects in particular at high doses.

It can be used in the production of nitric acid by combining with sulfuric acid and subsequent separation through fractional distillation of the nitric acid, leaving behind a residue of sodium bisulfate.

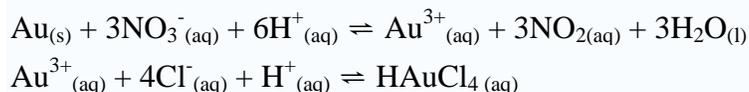
Properties	
General	
Name	Sodium nitrate
Chemical formula	NaNO_3
Appearance	White powder or colorless crystals
Physical	
Formula weight	85.0 amu
Melting point	580 K (307 °C)
Boiling point	decomposes at 653 K (380 °C)
Density	$2.3 \times 10^3 \text{ kg/m}^3$
Crystal structure	?
Solubility	92 g in 100mL water
Thermochemistry	
$\Delta_f H^0_{\text{liquid}}$	-452 kJ/mol
$\Delta_f H^0_{\text{solid}}$	-468 kJ/mol
S^0_{solid}	117 J/mol·K
Safety	
Ingestion	May cause gastroenteritis and abdominal pains.
Inhalation	respiratory irritation
Skin	May cause irritation.
Eyes	May cause irritation.
More info	MSDS
SI units were used where possible. Unless otherwise stated, standard conditions were used.	
Disclaimer and references	

Aqua regia

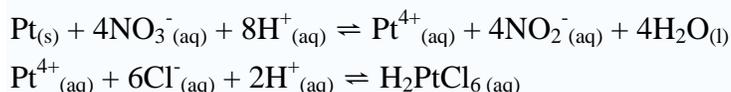
Aqua regia (Latin for "royal water") is a highly corrosive, fuming yellow liquid, formed by a fresh mixture of concentrated nitric acid (otherwise known as *aqua fortis*) and concentrated hydrochloric acid, usually in the ratio of one to three. It is one of the few reagents able to dissolve gold and platinum. It was so named because it can dissolve the so-called royal, or noble metals, although tantalum, iridium, and a few other extremely passive metals are able to withstand it. Aqua regia is used in etching and in certain analytic procedures. Aqua regia does not last very long; thus, it has to be mixed immediately before use.

How it works

Aqua regia works to dissolve gold, even though neither constituent acid will do so alone, because, in combination, each acid performs a different task. Nitric acid is a powerful oxidizer, which will actually dissolve a *tiny* (virtually undetectable) amount of gold, forming gold ions. The hydrochloric acid provides a ready supply of chloride ions, which react with the gold to produce gold chloride, also in solution, but far to the right in equilibrium. This allows further oxidation of gold to take place, and so, the gold is dissolved. Appropriate equations are:



A similar set of reactions occurs with platinum:



History

Hydrochloric acid was first discovered around the year 800 by the Islamic alchemist Jabir Ibn Hayyan (Gaber), by mixing common salt with vitriol (sulfuric acid). Jabir's invention of gold-dissolving **aqua regia**, consisting of hydrochloric acid and nitric acid, contributed to the effort of alchemists to find the philosopher's stone.

When Germany invaded Denmark in World War II, the Hungarian chemist George de Hevesy dissolved the gold Nobel Prizes of Max von Laue and James Franck into aqua regia to prevent the Nazis from stealing them. He placed the resulting solution on a shelf in his laboratory at the Niels Bohr Institute. After the war, he returned to find the solution undisturbed and precipitated the gold out of the acid. The Nobel Society then recast the Nobel Prizes using the original gold.