From Alchemy to Chemistry: The Origins of Today's Science

By Michelle Feder, Big History Project on 07.30.16
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An engraving of Robert Boyle, who is often considered the father of modern chemistry. BELOW: Alchemist's equipment in a 14th-century castle in Arcy-sur-Cure, France. Courtesy of Metropolitan Museum of Art. Photo: William Faithorne, Corbis/ Big History Project

The word "alchemy" brings to mind a cauldron full of images: witches hovering over a boiling brew, or perhaps sorcerers in smoky labs or cluttered libraries. Despite these connotations of the mythic and mystical, alchemical practice played an important role in the evolution of modern science.

Historically, alchemy refers to both the investigation of nature and an early philosophical and spiritual discipline that combined chemistry with metalwork. Alchemy also encompassed physics, medicine, astrology, mysticism, spiritualism, and art. The goals of alchemy were:

• to find the "elixir of life" (it was thought that this magical elixir would bring wealth, health, and immortality);

• to find or make a substance called the "philosopher's stone," which when heated and combined with "base" (non-precious) metals such as copper and iron, would turn it into gold, thought to be the highest and purest form of matter; and

to discover the relationship of humans to the cosmos and use that understanding to improve the human spirit.

Alchemy was scientific but it was also a spiritual tradition. Some of its practitioners had altruistic intentions. For instance, if alchemists could learn the secret of "purifying" base metals into gold, they might gain the ability to purify the human soul. At the same time, alchemy has often been seen as a get-rich-quick scheme and some alchemists were called charlatans and pretenders. But many alchemists were in fact serious-minded practitioners whose work helped lay the groundwork for modern chemistry and medicine.

The central science

Alchemy began as a quest to know the world around us — its composition as well as our own. That quest for knowledge required an understanding of chemical processes, and while alchemy itself would not survive the Enlightenment (the Age of Reason of the seventeenth and eighteenth centuries), the quest it began continues today in chemistry. To understand the ever-evolving field of chemistry, which is sometimes called "the central science" because it connects natural sciences like physics, geology, and biology, it's critical to grasp its beginnings.

Alchemists contributed to an incredible diversity of what would later be recognized as chemical industries: basic metallurgy, metalworking, the production of inks, dyes, paints, and cosmetics, leather-tanning, and the preparation of extracts and liquors. It was a fourth-century Indian alchemist who first described the process of zinc production by distillation, a seventeenth-century German alchemist who isolated phosphorus, and another German alchemist of the same period who developed a porcelain material that broke China's centuries-old monopoly on one of the world's most valuable commodities. These contributions proved valuable to the societies in which alchemists lived, and to the advancement of civilization.

But alchemists often made no distinction between purely chemical questions and the more mystical aspects of their craft. They lacked a common language for their concepts and processes. They borrowed the terms and symbols of biblical and pagan mythology, astrology, and other spiritual arenas, making even the simplest formula read like a magic spell or ritual. And although there were commonly used techniques, alchemists shared no standardized, established scientific practice.

Roots in the ancient world

The origins of alchemy are difficult to track down. In the East, in India and China, alchemy started sometime before the Common Era (CE) with meditation and medicine designed to purify the spirit and body and to thereby achieve immortality. In the West, alchemy probably evolved from Egyptian metallurgy as far back as the fourth millennium BCE. The ideas of Aristotle (384–322 BCE), who proposed that all matter was composed of the four "elements" — earth, air, fire, and water — began to influence alchemical practices when his student Alexander the Great (356–323 BCE) established Alexandria as a center of

learning. Alexander is said by some to have discovered the Greek god Hermes's famous Emerald Tablet, reputed to contain the secret of the philosopher's stone, and to have built the Library of Alexandria specifically to house alchemical texts. These texts were, however, almost entirely destroyed in the third century, and soon thereafter the Alexandrian Zosimus wrote what are now the oldest known books on alchemy, which emphasized its mysticism rather than its medical or practical applications.

Islamic Arabs took over Alexandria in the seventh century CE, and as the center of learning shifted to Damascus and the newly founded Baghdad, alchemical texts were translated from Greek to Arabic. An eminent figure at that time was Jabir ibn Hayyan (721–815), although some sources say he never existed, who became a royal alchemist in Baghdad. Jabir's writings were the first to mention such important compounds as corrosive sublimate (mercuric chloride), red oxide of mercury (mercuric oxide), and silver nitrate. Like Aristotle, Jabir believed metals grew in the Earth, adding to the Aristotelian theory the notion that metals were differentiated by how much mercury and sulfur they contained. Making gold thus required the purification of these ingredients. Scholars in the West first learned about alchemy in roughly the twelfth and thirteenth centuries as they copied and translated Arabic texts into Latin. Medieval science was still dominated by the ideas of Aristotle.

Alchemy after the Middle Ages

Among the most important of the European alchemists was Paracelsus (1493–1531), a Swiss traveling physician/surgeon and the first toxicologist. Paracelsus believed that the body's organs worked alchemically, that is, their function was to separate the impure from the pure, and proposed that a balance of three controlling substances (mercury, sulfur, and salt), which he called the "tria prima," was necessary for maintaining health. Paracelsus treated the plague and other diseases with an alchemical approach that included administering inorganic salts, minerals, and metals. He believed that what he called the "alkahest," the supposed universal solvent, was the philosopher's stone, but had no interest in the transmutation of metals, writing, "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."

In 1662, Robert Boyle (1627–1691) articulated Boyle's Law, which states that the volume of a gas decreases as the pressure on it increases, and vice versa. For this and other important contributions to scientific inquiry, Boyle is sometimes called the father of modern chemistry, but he was not a scientist in the current sense of the word. Rather, he is what is called a natural philosopher, someone who studied fundamental questions about nature and the physical Universe before the nineteenth century, when dramatic advances in technology began to revolutionize our understanding of and approach to these questions.

Boyle wrote two papers on the transmutation of the elements, claiming to have changed gold into mercury by means of “quicksilver,” the ingredients of which he did not reveal. This caught the attention of Isaac Newton, another enthusiastic alchemist, who, like Boyle, was motivated in his research “by the good it may do in the world.” The two struck up a correspondence.

Central to Boyle’s efforts was his “corpuscularian hypothesis.” According to Boyle, all matter consisted of varying arrangements of identical corpuscles. Transforming copper to gold seemed to be just a matter of rearranging the pattern of its corpuscles into that of gold.

Boyle used his 1661 text *The Sceptical Chymist* to explain his hypothesis and to dismiss Aristotle’s four-elements theory, which had persisted through the ages. Boyle recognized that certain substances decompose into other substances (water decomposes into hydrogen and oxygen when it is electrically charged) that cannot themselves be broken down any further. These fundamental substances he labeled elements, which could be identified by experimentation.

Boyle was a prolific experimenter who kept meticulous accounts about both his failures and successes. He was a pioneer of chemical analysis and the scientific method, endlessly repeating his experiments with slight variations to obtain better results and, unheard of among earlier alchemists, always publishing the methods and details of his work in clear terms that could be widely understood.

A new framework

By the late eighteenth century, the field of chemistry had fully separated from traditional alchemy while remaining focused on questions relating to the composition of matter. Experimentation based on the scientific method, the publication of research results, the search for new elements and compounds and their application in medicine and industry beneficial to all mankind, and other concerns first addressed by alchemists dating back many centuries were now the domain of modern science.

Among the most significant of the post-alchemical chemists were the French nobleman Antoine-Laurent Lavoisier (1743–1794) and the Russian chemist Dmitri Mendeleev (1834–1907). In 1789, Lavoisier wrote the first comprehensive chemistry textbook, and, like Boyle, he is often referred to as the father of modern chemistry. Lavoisier agreed with Boyle that Aristotle’s four-elements theory was mistaken, and in his textbook, he compiled a list of metallic and nonmetallic elements that would point toward the periodic table developed by Mendeleev in 1869. It was Mendeleev who demonstrated that the elements could be

arranged in a periodic — regular and recurring — relationship to each other based on their atomic weights, and who created a periodic table that could accurately predict the properties of elements that had yet to be discovered. Mendeleev's table is still used today.

Chemical questions: Our best hope for tomorrow

Just as alchemy was a touch point for myriad crafts, creations, and — for its time — cures, chemistry resides in the center of the sciences. As an inquisitive discipline, chemistry touches physics on one side and biology on the other. Chemical questions lead to environmental, industrial, and medical applications.

Often working together in research teams at universities and corporations, chemists around the world are developing new techniques and inventions. Like alchemists, sometimes the process of discovery might entail isolating specific components; other findings might come from developing new compounds.

Some recent research:

• University of California–San Francisco biochemists identified a memory-boosting chemical in mice, which might one day be used in humans to improve memory.

• Cheaper clean-energy technologies could be made possible thanks to a new discovery by a professor of chemistry at Penn State University.

• The Duke Cancer Institute found that an osteoporosis drug stopped the growth of breast cancer cells, even in resistant tumors.

These are just a few examples of how modern chemistry carries on the alchemical quest for the elixir of life.