Introduction

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THE CONTENDED GEOGRAPHICAL BOUNDARIES OF ANCIENT CHEMISTRY

Historians of chemistry have long discussed where and when chemistry became a science. Both questions have crucial implications for its identity, though they have been addressed in very different ways. Was the cradle of chemistry in Egypt or in the Near East? Did chemistry originate in the development of artisanal chemistry or in alchemists' speculations about the nature of matter? Did the Greek philosophers provide a theoretical framework from which all successive theories stemmed? Did the intense commercial exchange between the Mediterranean civilizations and India influence the spread of chemical ideas and practices? Did Chinese alchemical theories on the transmutation of gold reach the West?

Not surprisingly, the answers to these questions have often produced biased and inaccurate reconstructions. At the same time, these efforts, the first of which date back to early modern times, helped European chemists to find their own epistemological identity. Unlike the exact sciences, until the end of the eighteenth century chemistry embodied the practical arts, occult and religious beliefs, as well as professional guilds. Because of this confused picture of different and, at times, antithetical interests, its academic status and public image suffered from a poor reputation long after the introduction of the first university chairs in the subject. Writing the history of the science, then, became a powerful means of endorsing a specific image of chemistry, at times privileging its experimental background, at others its metaphysical, religious, and philosophical principles, and at yet others its economic value. It should be stressed that the chemical arts have always played a diffuse and vital role in ancient and modern economic systems. Many products of the Mediterranean trade and exchange, now on display in the principal archaeological museums, bear the signs of chemical manipulations. This pervasive influence, however, did not lead to the construction of an image of chemistry that equaled the prestige and reputation of other scientific disciplines. Indeed, the practical and economic value of the chemical arts conflicted with the ancient idea that science was primarily a contemplative and speculative form of knowledge.

Numerous and highly diverse histories of chemistry were published in the early modern period that attempted to elevate the subject beyond a mere corpus of useful knowledge. Already in the second half of the seventeenth century, chemical historiography established the philological foundations of later works; this was due, in particular, to the controversial theories of the chemist Ole Borch (1668, 1674) and the erudite physician Hermann Conring (1669; Abbri 2000). In an impressive display of scholarship, Borch vindicated the antediluvian origins of chemistry and situated its most significant development in ancient Egypt and in the putative work of Hermes Trismegistus, a god who created the art as an emanation of his metaphysical power. In his reconstruction, Borch regarded ancient chemistry as a holy art that combined experimental skills with a religious foundation. Thanks to the rediscovery of this combination, he argued, early modern alchemists were able to enhance the art and restore the prestige it was afforded in ancient times. Although Hermann Conring concurred with Borch's idea that Egypt was the region where ancient chemistry and alchemy made the most significant progress, he believed that the art actually originated in the teachings of Moses (Conring 1669). Borch's and Conring's views were contemporaneously contested by Johann Heinrich Ursin, who asserted the importance of the Zoroastrian tradition and introduced the Near East into the geography of chemistry (Ursin 1661). Regardless of these differences, these scholars sought evidence to show that the chemical arts embodied a superior form of knowledge.

Behind the controversy about the historical and geographical origins of chemistry there was much at stake. Those who supported its mythical and ancient origins defended the relevance of the theoretical and philosophical background provided by alchemical writers. Already during the sixteenth century, however, several authors, such as Vannoccio Biringuccio and Georg Agricola, contested the antiquity of the chemical arts and invited their contemporaries to abandon vain speculation about the superior knowledge of the ancient sages and to support instead the recent progress of the practical arts, such as mining, metallurgy, and glassmaking.

During the eighteenth century, Borch's position began to lose consensus and Jean Baptiste Senac in his famous *Nouveau cours de chymie suivant les* *principes de Newton et de Stahl* (Paris, 1737) adopted a position that would prevail throughout the century (Beretta 1991). He maintained that "at the beginning chemistry was the art of working metals for the satisfactions of human needs," and that any theoretical assumptions concerning the nature of matters came only after the chemical arts were sufficiently developed. Such a position principally aimed at undermining the influential role still played by alchemy, which was also defended through the noble history of transmutation in Diderot's and d'Alembert's *Encyclopédie* (Beretta 2014).

During the nineteenth century, when chemistry became an established academic discipline and alchemy was left behind, historians of chemistry began to adopt a more balanced position concerning the origins of the science. A few of them, notably Justus Liebig, Ferdinand Hoefer, Hermann Kopp, and Marcellin Berthelot, tried to show the relations between the ancient chemical arts, now regarded as the first steps towards a sound philosophy of matter, and alchemical beliefs (Beretta 2011). The studies published during the nineteenth century, in particular those by Kopp and Berthelot, were often supported by alchemical manuscripts and, for more than a century, these works contributed to designating the perimeters of the history of ancient chemistry. In fact, after Berthelot's and Ruelle's edition of the Greek alchemical corpus of texts (1888), interest in the question of the origin of chemistry was lost, and even scholars like Edmund Lippmann, who heavily criticized the philological reliability of this edition, accepted the idea that the dawn of chemistry occurred in the shadow of Hellenistic and Byzantine alchemy, and that Alexandria in Egypt, the Middle East, and Constantinople were the principal geographical areas where, between the second century BCE and the fourth CE, alchemy and chemistry emerged. Thus, rejecting Borch's claim that chemistry began in antediluvian times, nineteenth-century historians focused their attention on a more recent epoch and on an extremely circumscribed tradition of literary texts. This shift depended both on the importance attributed to literary evidence and on the prevailing idea that Western science originated in Greek culture.

This approach was first questioned in 1935 by James R. Partington, one of the most important historians of chemistry of the twentieth century, in his monumental *Origins and Development of Applied Chemistry*. Partington occupied the chair of chemistry at London's Queen Mary College from 1919 to 1951 and wrote several important historical works, culminating in his four-volume masterpiece *A History of Chemistry*. In *Origins and Development of Applied Chemistry*, he gave a detailed account of the chemical sources and materials "in Egypt, Babylonia, Assyria, the Aegean, Asia Minor, Persia, Syria and Palestine, from the earliest time to the end of the Bronze Age" (Partington 1935: v). He presented in a descriptive but informative way an immense array of material, not least his own analysis of the archaeological findings of the British Museum made available to him. The disproportion between the number of archaeological objects and the scarcity of literary sources conditioned the narrative of this work, which inevitably focused more on the material background of ancient chemistry, leaving aside all the issues of the origins of the chemical and alchemical theories that had attracted the attention of earlier historians. When Partington tried to take into consideration the history of the philosophies of matter in his *History of Chemistry*, before his death he was only able to complete the part related to Greek and Byzantine authors (Partington 1970). The complexity and variety of sources was a major obstacle to the compilation of a homogeneous narrative encompassing the whole of antiquity.

Most histories of chemistry published before Partington's emphasized the central importance of the Mediterranean civilizations and of the Near East, alternatively giving primacy to the Egyptians, the Mesopotamians, and, more often, the Greeks. However, already during the first half of the nineteenth century, the physician and lexicographer Ferdinand Hoefer showed that in China and in India the chemical arts as well as alchemical theories of matter were developed in ancient times and accumulated discoveries that warranted more thorough attention (Hoefer 1866: vol. 1, 9–30). While Hoefer ultimately expanded the map of ancient chemistry to the Far East, he did not advance any serious hypothesis concerning the relations and exchanges between China, India, and the Mediterranean civilizations. It took until the twentieth century before key studies devoted to the history of ancient chemistry in India (Ray 1903–9; Ray and Ray 1956) and China (Needham 1983) shed light on the historical and cultural importance of both traditions and posited the existence of cultural exchanges with the West. However, all efforts to identify relevant mutual influence between Mediterranean civilizations and the Far East have so far failed to produce any compelling evidence. While we cannot exclude that further study will provide us with a different scenario, currently a conservative view of the absence of substantive influences seems closest to what both the material and literary sources are telling us.

The organization of the present reconstruction is limited to the analysis of ancient chemical arts in the Mediterranean and Near East civilizations. In addition to the limitations of space, this choice was driven by two principal reasons. First, we know that chemical artisans, recipes, and ideas were exchanged between Mesopotamia, Egypt, Phoenicia, Greece, Rome, and Byzantium over a very long period. This interconnected history of chemistry has so far escaped scholarly attention, offering the opportunity for the present volume to provide the first synthesis of this epoch of intense exchanges and to explore the strength of these connections in depth. Second, the sources, techniques, materials, and instruments that were transmitted from antiquity to medieval and Renaissance alchemy and chemistry mostly stemmed from the Mediterranean region and the Near East. The growing exchange between the West and the Far East following the opening up of the Silk Road appears not to have significantly contributed to the exchange of practical and philosophical chemical knowledge. Eloquent evidence of this is the rediscovery in mid-eighteenth-century France of the "secret" formula for Chinese porcelain, which had been produced there for over a thousand years.

BETWEEN ART AND NATURE: THE PRIMORDIAL POWER OF FIRE

The knowledge and techniques that have progressively accumulated in the scientific discipline that we now call chemistry are so varied that it is almost impossible to trace back with precision the exact origin of the science. Chemistry became a stable academic discipline by the end of the eighteenth century and it was only during the subsequent century that it acquired a relatively homogeneous and standardized professional curriculum. In sharp contrast to this late academic development, the chemical arts likely preceded all other forms of technical and scientific knowledge. Although the exact origin of the human appropriation of fire technology remains a controversial issue, recent archaeological studies date it to 1.9 million BCE (Gowlett and Wrangham 2013). The first use of fire was for making food, thus altering the chemical properties of foodstuffs. Subsequently, fire was used in agriculture and, with the development of smelting techniques, in metallurgy. While it is not the aim of this introduction to deal with prehistoric epochs, it should be emphasized that already in antiquity the discovery and routine control of fire was regarded as a major achievement in the evolution of human civilization. The appropriation of the transformative power of fire was, in fact, regarded as the first and most important conquest of human civilization, the key to transforming the status of mankind and to opening up a path towards its radical biological and cultural transformations.

In a vivid exposition of the evolution of mankind, Lucretius (first century BCE) used the prehistory and history of man to illustrate this process of biological transformation. Primitive man was naturally equipped with a robust physique that "was built up on larger and more solid bones within, fastened with strong sinews traversing the flesh; not easily to be harmed by heat or cold or strange food or any taint of the body" (Lucr. *DRN* V 925–30). Thanks to these biological characteristics, adapted to resist a hostile environment, primitive men "prolonged their lives after the roving manner of wild beasts" (932), and lived without the assistance of any arts, simply following their instincts, "trusting in their wondrous strength of hand and foot" (966). When they were tired, "like bristly boars, these woodland men would lay their limbs naked on the ground … wrapping themselves up around with leaves and foliage" (970–2). The condition of these wretched beings – at the mercy of the most disparate adversities and perils – was only made bearable by their ignorant state, unconscious of events and incapable of imagining how they might compete with the overwhelming forces of nature.

Everything changed once man discovered fire, because "… their chilly limbs could not now so well bear cold under the roof of heaven" (Lucr. *DRN* V 1015). This discovery came about by sheer serendipity – a lightning bolt or the friction of tree branches that resulted in a burst of flames, demonstrating to our curious ancestors how heat could be propagated. "Either of these happenings may have given fire to mortals. And then the sun taught them how to cook food and soften it by the heat of the flame" (1101–2). The mastery of fire brought about a gradual change in the morphology of man, who lost his primitive constitution and could no longer survive like the other animals in the wild, where he now risked extinction. It was, therefore, not nature that dictated man's evolution in a particular direction; it was the discovery of fire and the possibility of recreating it artificially that, according to Lucretius, influenced man's biological evolution even before his cultural development. The softening of his constitution by the warmth of fire compelled man to first construct a hut for shelter, then to protect his body from the inclement weather with the skins of animals, and, finally, to recognize himself as a social animal.

Fire was endowed with another quality that was greatly admired by Mediterranean and Near East civilizations. By appropriating the force of this element mankind could reproduce artificially the infinitely creative power of natural fire. Artisans working with fire reproduced the force that gods attributed to nature. When it came to fire and its multiple uses, the characteristic conflict between art and nature that so deeply pervaded the culture of ancient civilizations ceased. We have an echo of the admiration of the ancients for the power of fire in the following passage from Pliny the Elder's *Naturalis historia*:

> We cannot help marvelling that here is almost nothing that is not brought to a finished state by means of fire. Fire takes this or that sand, and melts it, according to the locality, into glass, silver, cinnabar, lead of one kind or another, pigments or drugs. It is fire that smelts ore into copper, fire that produces iron and also tempers it, fire that purifies gold, fire that burns the stone which causes the blocks in buildings to cohere. There are other substances that may be profitably burnt several times; and the same substance can produce something different after a first, a second or a third firing. Even charcoal itself begins to acquire the special property only after it has been fired and quenched: when we presume it to be dead it is growing in vitality. Fire is a vast unruly element, and one which causes us to doubt whether it is more a destructive or a creative force.
>
> (Plin. *NH* XXXVI 68)

This beautiful image of the extraordinarily creative power of fire combined the Heraclitean doctrine of fire, the relatively recent Stoic notion of *pyr technikòn* (artificial fire), and the extensive attention that Hellenistic natural philosophers paid to the prodigious progress of the chemical arts.

By assigning to fire a central role in the chemical arts, Pliny's remarkable assessment is deliberately ambiguous, because it is not clear if he is referring to natural fire or to the flame artificially controlled in the artisanal workshops of the chemical arts he enumerates. By keeping the boundaries between art and nature extremely vague, Pliny regarded the chemical arts as a bridge that could narrow the tension and, at the same time, could enhance the theoretical value of artisanal knowledge. Pliny's ingenious position was, in fact, the outcome of a long-standing tradition dating back to Mesopotamian and Egyptian crafts.

The effort to bridge the tension between art and nature is also shown by the attempt of various Hellenistic philosophers to reconstruct the origins of metallurgy. Pseudo-Aristotle wrote the following regarding a fire that had broken out in an Iberian forest:

> In Iberia they say that when the undergrowth has been burned by shepherds and the earth heated by wood, that the ground can be seen to flow with silver and that after a time earthquakes have occurred and the ground split, that much silver has been collected, which supplied the Massaliots with considerable revenue.
>
> (Aristotle, *On Marvellous Things Heard*, 87)

Seneca says that Posidonius (ca. 135–51 BCE), too, believed in the natural origin of metallurgy on the basis of a similar reconstruction. "Philosophers discovered iron and copper mines, when the earth, burnt by forest fires in molten form cast surface veins of ores" (Kidd 1988: 964).

Lucretius presents a more detailed explanation in the *De rerum natura*:

> … copper and gold and iron were discovered, so also heavy silver and massive lead, when fire upon the great mountains had burnt up huge forests with its heat: whether by some lightning stroke from heaven, or because men waging war in the forests had brought fires upon their foes to affright them … which flaming heat with appalling din had devoured the forests deep down to the roots and parched up the earth with fire, through the hot veins into some hollow place of the earth would ooze and collect a stream of silver and gold, of copper also and lead …
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> (*DRN* V 1241 ff)

The creation of this myth – the fusion of metals as the result of occasional natural events, subsequently appropriated by man to imitate nature through the introduction of chemical technology – enabled writers to show a parallel between nature and human activity. The rivers of metal that ancient man could see imprisoned within the smith's unhealthy workshop were nothing but the repetition and emulation of that which nature had indicated at the origins of civilization. In this regard, the vivid images of Vulcan's workshop should be remembered, which Empedocles situated inside an actual volcano. Also here the mythological origins of metallurgy were depicted as in nature. This analogy offered a cultural legitimization of these activities and, more importantly, allowed products of metallurgy to be seen as things of philosophic and scientific inspiration. Ancient artisans engaging in the manipulation of matter revealed a skill that enabled them to imitate nature, and their dexterity was appreciated by Mesopotamian and Egyptian priests as well as by Greek philosophers. In the field of chemistry, the coexistence of art and nature was stressed repeatedly. Theophrastus, speaking of a sand with special properties, noticed a means of imitating nature efficaciously in experiments and in technology, thereby outlining a theoretical principle that would later be continued in classical alchemy. In this regard, Theophrastus wrote:

> It is clear from three facts that art imitates nature and creates its own peculiar products, some of them for use, and some only for show, such as paints, and others for both purposes equally, such as quicksilver.
>
> (*On Stones*, 58)

Among the chemical arts, glassmaking is perhaps the most notable example of the harmonious balance between art and nature. Pliny the Elder reconstructed the history of this material as follows:

> There is a story that once a ship belonging to some [Phoenician] traders in natural soda [*nitri*], put in here [on the beach near the mouth of the river Belus] and that they scattered along the shore to prepare a meal. Since, however, no stones suitable for supporting their cauldrons were forthcoming, they rested them on lumps of soda from their cargo. When these became heated and were completely mingled with the sand on the beach a strange translucent liquid flowed forth in streams; and this it is said, was the origin of glass.
>
> (Plin. *NH* XXXVI 65)

The story told by Pliny, whose original source is unknown, has often been considered unlikely by archaeologists, even though the passage is cited in many histories of glass. Pliny's reconstruction, however, is of great interest not only because it emphasizes the seminatural origin of glass, but also because it evokes, albeit implicitly, its typical characteristic of being a product of trade. Pliny underlines the marvelous event witnessed by the merchants, who, by submitting the siliceous sand and the soda to the action of fire, saw, after an almost spontaneous chemical reaction, the formation of glass filaments.

Phoenicians, as is well known, have often been credited with many ancient technical inventions whose actual paternity is either Mesopotamian or Egyptian. However, their connection to the introduction of glass, unfounded as it now seems, was reasonable both because of the technical skills achieved by Phoenician glassmakers in the era when Pliny was writing his work (first century CE) and because of the fundamental role played by these merchants in exporting glass products throughout Mediterranean civilizations. In this regard, it is interesting to note that when glass was introduced in Egypt during the XVIII dynasty the Phoenicians increased their trade, thus becoming an essential medium of contact between the Near East, the Minoans, and the Egyptians (Partington 1935: 433). The trade of increasingly large quantities of glass products stimulated the interest in appropriating a technique that promised the possibility to imitate nearly any mineral and precious stone. While the Minoans and other Mediterranean civilizations showed a limited interest for glassmaking and were content to trade the products they brought from the Near East with the Phoenicians, the Egyptians aimed to create an independent industry. But Pliny's history of glass is important because it reveals a view of matter that was shared by the Mesopotamian, the Egyptian, and the Hellenistic technical cultures, namely that there were no differences between the glass produced by nature and the glass produced by craftsmen. This assumption, expressed in very different ways within the three civilizations, enhanced the creative power of the chemical arts and simultaneously increased the value of their artificial products.

The progress made in the chemical arts inspired pre-Socratic philosophers to adopt metaphors taken from techniques that could better explain their philosophy of nature (Mondolfo 1982: 35–50). The tinsmith's bellows were used by Anaximander to explain the fire emitted by the sun and the stars; the felting of textiles and the boiling of water were evoked by Anaximenes to illustrate the properties of matter; glass technology was used by Empedocles and later cosmologists to identify the nature of celestial bodies and spheres. Echoing the Egyptian religious tradition, Empedocles associated the four elements with the gods: "shining Zeus, life-bringing Hera, Aidoneus and Nestis who with her tears waters mortal springs" (Kirk et al. 1983: 296). Zeus represented Fire, Hera Air, Aidoneus Earth, and Nestis Water (Kingsley 1995). Empedocles explained the mechanism supporting this quadripartition of matter by resorting to a particular craft:

> As when painters are decorating offerings, men through cunning well skilled in their craft – when they actually seize pigments of many colours in their hands, mixing in harmony more of some and less of others, they

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> produce from them forms resembling all things, creating trees, and men and women, beasts and birds and water-bred fish, and love-lived gods, too, highest in honour.
>
> (Kirk et al. 1983: 293–4)

Interestingly, the analogy with how painters mixed the four elementary colors to evoke both material and metaphysical entities explained how the immense variety of things composing the universe could be created from only four elements. Moreover, colors did not merely represent the thing painted; they also evoked its essence, thus participating in its identity even when such an identity was metaphysical.

We should not be surprised that the origin of Greek philosophy was inspired by technological arts that, until recently, historians have regarded as extraneous to the history of science. The chemical arts, in fact, accompanied the everyday life of Mediterranean civilizations; every innovation introduced represented a landmark that not only deeply affected the material conditions in which people lived but also, in a few significant cases, inspired the imaginations of natural philosophers.

However, from the outset, the evolution of the chemical arts was marked by an ambivalent reception of their cultural value. On the one hand, the possibility of imitating and surpassing nature through the technical control of the manipulation of matter elevated the status of craftsmen to the role of superior men. Recent historiography shows that the prestige of the ancient alchemist cannot be properly understood without considering the prominent role played by the ancient chemical arts (Martelli 2019). On the other hand, the chemical arts, especially mineralogy and metallurgy, were often regarded as dangerous and dirty activities, better to be performed by slaves. Moreover, the skill showed by many craftsmen in counterfeiting natural products (gems, precious metals, and minerals) was also associated with fraudulent activities at a very early stage. This is a reason why alchemy, from its earliest appearance, was regarded both as a holy art and as a deception.

ANCIENT CHEMISTRY: AN INVISIBLE SCIENCE

Before examining the social structure and organization of the chemical arts in ancient culture, it is necessary to provide a brief etymology of the word "chemistry." In fact, in antiquity there was no such thing as chemistry, only technical arts manipulating matter; this detail has not hindered historians' extensive exploration of the subject. The origin of the word "chemistry" has been a matter of heated dispute among philologists and historians, who have not yet agreed upon a single etymology (Lippmann 1919: 282–327; Lagercrantz 1938; Hermann 1954). Does "chemistry" derive from the Egyptian term *kemet*, the black pigment used to paint the eyes, or is it the result of the evolution of the Greek verb *kymeia*, indicating fusion? Does it originate from the Akkadian verb *kamû*, which means to bake or to roast? Furthermore, to denote obsidian, a naturally occurring black volcanic glass, the Egyptians used the word *Aner chem* (black stone). Is this material connected to the origins of the chemical arts?

To complicate the picture further, it is interesting to note that one of the earliest associations between chemistry and gold-making is a report, compiled around the tenth century CE, in the Byzantine lexicon *Suda*. Under the heading *kymeia* we read:

> The preparation of silver and gold. Diocletian sought out and burned books about this. [It is said] that due to the Egyptians' revolting behaviour Diocletian treated them harshly and murderously. After seeking out the books written by the ancient [Egyptians] concerning the alchemy of gold and silver, he burned them so that the Egyptians would no longer have wealth from such a technique, nor would their surfeit of money in the future embolden them against the Romans.
>
> (*Suda* 2014, heading: chi, 280)

Despite the interesting insights it produced, these etymological researches have not found any conclusive evidence on the existence in ancient civilizations of a structured and professionalized scientific discipline encompassing the chemical arts. Moreover, the list of etymologies produced in these scholarly studies showed that the occurrence of terms that seemed to be at the origin of our idea of chemistry were all exceedingly rare.

Indeed, the scarcity of ancient chemical and alchemical sources on the one hand, combined with the corruption of those transmitted from the third century CE onwards on the other, makes it difficult to reach conclusive arguments on the origins of ancient chemistry and its disciplinary identity. This difficulty is further underlined by the lack of consensus among historians on the theoretical purposes and the practical contents of chemical research. Partington (1970) attempted to identify ancient chemistry with the theoretical explanations set forth by the Greek philosophers of nature to explain the changes of matter, but in his earlier book he pointed out that the greatest technological breakthroughs made in ancient civilization were achieved within the chemical arts rather than in philosophical circles (Partington 1935). Other historians have insisted on the central role of Hellenistic and late antiquity alchemists, who were regarded as the first to devote works on subjects almost exclusively focused on the manipulation of matter and the use of chemical apparatus (Lindsay 1970). However, the identity of alchemy is also far from being straightforward. The tendency to reduce it to the sole operation of transmuting base metals into gold has led to a focus on the few passages of ancient literature that clearly identify such an intention, leaving aside many interesting texts containing other kinds of transmutation, the process of imitation, and several interesting detailed descriptions of chemical techniques (Halleux 1979). But projecting alchemy's dominant focus in the Middle Ages onto ancient chemical technology has resulted in interpretations that bear only a few literary traces in ancient texts. After all, gold was not seen as the most valuable material until late antiquity; rather, precious gems and lapis lazuli were often regarded as the most valuable minerals, and these stones were easily and often imitated in glass. The fact that glassmaking could already count on a rich ancient tradition of imitating precious stones by the Hellenistic period alone certainly merits the attention of historians of ancient alchemy, as it points to an important field that facilitates a better understanding of the historical background of the *Chrysopoeia* (gold-making).

The introduction of religious rituals before performing chemical operations in the Mesopotamian and Egyptian culture has led some historians to conclude that the chemical arts responded to a metaphysical need to connect matter and spirit (Jung 1944; Eliade 1956).

A recent and more perceptive approach, which is also represented in this volume, has called attention to the pervasive diffusion of recipe books in Mesopotamian, Egyptian, and Hellenistic cultures, thus showing an interesting line of transmission of knowledge that connects these three civilizations. However, the reader should always be aware that the scarcity of ancient sources on the one hand, and the corruption of those transmitted from the third century CE onwards on the other, makes it still difficult to reach conclusive arguments on the origins of ancient alchemy and chemistry and on their epistemological identities.

PRACTICAL ACHIEVEMENTS

The historiographical controversy surrounding the presumed antiquity of the science of chemistry cannot be resolved without taking into consideration two distinct elements that help to illustrate the meaning of this debate. Firstly, it should be noted that ancient craftsmen were masters of technical achievements and discoveries that were significantly surpassed only during the Renaissance. Secondly, the extremely efficient socioeconomic organization of the chemical arts that occurred in ancient cultures deeply influenced their appropriation during the Middle Ages and early modern times. This is not the place to elaborate the chemical discoveries made in ancient times, because their chronology and geography are still fluctuating. There are, however, a few achievements that help us to understand the focus of this volume.

Thanks to the large natural deposits of a dried lake situated in proximity to the Nile delta, the use of *natron* (soda) is attested in ancient Egypt from the fifth millennium BCE. With the addition of two equally common substances, salt and gypsum, Egyptian craftsmen perfected the art of embalming, food preservation, and cleansing (Multhauf 1982: 17–18). The introduction of metallurgy, dating back to the fifth and fourth millennia BCE, originated in the Near East, where gold, electrum, and copper were used at a very early stage. During the third millennium BCE, in the same area, the use of lead, silver, and bronze became equally widespread. Tin was discovered around 1700 BCE. Hittites began to smelt iron around 1500 BCE but, being a relatively rare metal, its diffusion was slow before it was replaced other metals. The geographical area of all these discoveries – the Near East – was crucial to the development of metallurgy in both Mesopotamian and Egyptian civilizations. Alum, a mineral used on a large scale by the Egyptians since the second millennium BCE, was used to fix natural dyestuffs onto cloth.

Glassmaking and glassworking technologies were introduced by Mesopotamian craftsmen in the third millennium BCE. They were perfected by Egyptians and culminated in the first century BCE somewhere in Palestine with the invention of glassblowing, a technical breakthrough that remained unsurpassed until the end of the eighteenth century (Beretta 2009). The early control of glass technology in Mesopotamian technical culture led to the imitation of precious stones such as lapis lazuli. Different recipes to imitate lapis lazuli using glass ingredients were later developed in Egypt with the successful discovery of so-called Egyptian blue in the area around Mount Vesuvius and the large-scale production of the pigment that the Romans called *caeruleum*.

Another area in which the chemical manipulation of matter proved to be extremely productive was that of medicine and pharmacology. Egyptians mastered the art of making medicines to such a degree that their superiority, as shown in the case of Cleopatra, was still acknowledged in Hellenistic times. The heirs of Near East civilizations, too, such as King Mithridates, were regarded as keepers of pharmacological secrets that, once revealed, remained extremely popular until early modern times.

While the Greeks outlined the most systematic effort to provide a theoretical account of the changes occurring in matter, they did not contribute to any major discovery in practical chemistry. This might at least partly be explained by the relative scarcity of mineral resources available in their territories. By contrast, thanks to the rapid geographical expansions of the Republic and the Empire, and the subsequent need to organize large-scale exploitation of the natural resources, the Romans contributed to important achievements and discoveries. Mining techniques made unprecedented progress, metallurgical processes were significantly improved, and the combination of these two factors led to the discovery of mercury, brass, caustic soda, and a wide range of previously unknown salts. As mentioned, the revolution brought about by glassblowing occurred in Palestine in the second half of the first century BCE, at that time a Roman territory. This innovation offers perhaps the best example of the high degree of organization introduced by the Romans in controlling and enhancing a chemical art once it was regarded useful.

The introduction of glassblowing enabled not only the production and manipulation of larger quantities of glass, but also an extraordinary variety of new colors among the objects produced. According to Pliny (Plin. *NH* XXXVI 198), "there is no other material nowadays that is more pliable." Thanks to this double advantage, the new technology enabled craftsmen to attain a hitherto unknown level of achievement and to create imitations of nearly any solid material. Such results were possible thanks to the combination of two factors:

1. The construction of furnaces that reached high temperatures (above 1000°C) and that made raw glass liquid;
2. The use of the blowpipe, which enabled easy handling of the glass melted in the crucibles.

The introduction of glassblowing radically transformed the traditional glassmaking craft over the course of a few decades, and it developed into such a prosperous industry that it is estimated that at the beginning of the second century CE, when the Roman Empire reached its greatest expansion and a population of 54 million people, "glassworkers had to turn out close to 100 million items annually just to keep pace with current demand – production on an industrial level indeed" (Fleming 1999: 60). Glassmaking's qualitative revolution was no less impressive than its quantitative one. Less than a century after the introduction of the new glassblowing technique, glass and glass paste were used in architectural decorations, wall mosaics, and windows to illuminate interior spaces; glass was also used in lamps, mirrors, tableware, aquariums, for unguent jars and the preservation of foods, for panels used in greenhouses, cinerary urns, sarcophagi, and ornaments, for the imitation of gems and the most precious stones, and the glass frit was even employed to produce certain colors for fresco painting, such as blue.

The remarkable discoveries achieved by ancient civilizations in practical chemistry were fostered by the socioeconomic organizations of craftsmen, which appreciated and enhanced their skill. Since Mesopotamian and Egyptian civilizations regarded precious minerals as material emanations of godly power, the professions involved in their manipulation were strictly controlled by the priesthood and their practice involved religious rituals. Although the locations of most ancient chemical laboratories remain unknown, a few archaeological findings, such as those at Dendera, have revealed the presence of chemical workshops in temples (Derchain 1990). We find a remarkable confirmation of the social prestige attributed by the Egyptians to specific crafts, such as the production of artificial lapis lazuli, in a famous passage from Theophrastus' *On Stones* (55), in which he remarked that the inventor of artificial blue (*kyanos*) was a king. This discovery had a crucial religious meaning because

Egyptians believed that the hair of gods was made of lapis lazuli and the formula recreating such a precious material had, therefore, to be controlled by the highest religious authority. Moreover, under royal supervision, the secret of the invention could be secured. The importance of keeping secret the ingredients of the discoveries made in Egyptian chemical workshops further enhanced the prestige of craftsmen and implied an encoded and regulated transmission of knowledge that envisaged the communication strategies later adopted by the Greek alchemists, many of whom were of Egyptian origins, and the organization of Roman *collegia* of arts, where the secrets were transmitted within guilds.

Roman sources provide us with a more complete picture of the rich social organization of the guilds involved in what we may call practical chemistry. Among them, we may recall the guilds of the glassmakers (*vitrearii*), the pearl- and gem-makers (the *gemmarii* and the *margaritarii*), the mosaicists (the *laquerarii* and the *diatretarii*), the pharmacists (*pharmacotribae*), the makers of medical spices (*aromatarii*), the makers of pigments (*pigmentarii*), the perfume-makers (*seplasarii*), and the smiths (*ferrarii*). The increasing scale of the trade towards the end of the Republic and the beginning of the Empire contributed to the specialization of crafts and to a sophisticated division of labor and transmission of knowledge that partially survived during the Middle Ages and the Renaissance.

Ancient chemical arts made important contributions to the equipment and instruments used in chemical workshops. While relatively little is known about the apparatus used in Mesopotamian and Egyptian workshops, the extraordinary results obtained by craftsmen in these contexts show a high degree of experimental knowledge. The most important practical achievements were related to the control and increase of the temperatures of furnaces, the use of durable crucibles, and the specializations of tools. The most important breakthrough, which stabilized the chemical laboratory for over a thousand years, was the introduction in the second half of the first century BCE of blown-glass instruments and receivers. The historical role of glass in these early chemical laboratories can hardly be overstated. Its chemical inertness and resistance to high temperature made it an ideal material for numerous operations and reactions. During the first centuries CE, we find few but significant references to glass apparatus in literary, scientific, and alchemical texts. But as early as the first century CE, the appreciation of glass's chemical inertness was very common. In his *De materia medica* (V 95), Dioscorides acknowledged the properties of glass receivers as resistant to the volatile action of mercury, showing that he was acquainted with the alchemists' technical expertise in the handling of chemical substances.

In the surviving alchemical texts published by Berthelot and Ruelle at the end of the nineteenth century, one finds several references to glass receivers and other vessels (Berthelot and Ruelle 1888), the shape and function of which are often difficult to identify. This difficulty is due to both the lack of archaeological correspondence between a given name and the item to which it refers and to the frequent references to the use of vessels and receivers in alchemical and pharmaceutical texts, of which we know only the ordinary uses established by archaeologists. Examples of the latter are vessels, also made of glass, such as the following typologies: *amphora*, *ampulla*, *aryballos*, *askos*, *calyx*, *catinum*, *crater*, *guttus*, *matula*, *oinochoé*, *patella*, *patera*, *phiala*, *poculum*, *pyxis*, *rython*, *scaphium*, and *schyphus*. These types of vessels were used both in daily life and in more specialized and scientific contexts. In a few instances, however, the description and nomenclature are more precise and specialized, providing us with useful indications about the progress achieved in constructing glass chemical apparatus. One example of this is the *botarion*, a glass instrument shaped like a breast (*mastarion*), which was used as a receiver for an alembic described by Synesius in the fourth century CE in his description of a process of distillation. In order to overcome the volatility of arsenic, Olympiodorus (fourth century CE) suggested the use of a special glass apparatus coated with earthenware, called *asympoton* by Africanus (third century CE), the aim of which was to cover the receiver in which the sublimation of arsenic was performed. The *angeion* often mentioned by the Alexandrian alchemists was probably a test tube. Glass vessels called *poteria* and *igdis* were used during the coloring of gems, in their turn products of glassmaking. And large glass jars called *bikoi* were intended as components of distillation apparatus. In a work that Berthelot and Ruelle (1888) attribute to Zosimos (third century CE), the difference between the male and female components of a glass alembic is briefly mentioned.

Mary the Jewess (first or second century CE), an author probably from Alexandria or the Syrian–Palestinian coast, wrote a treatise entitled *Perì kaminon kai organon* (*On Furnaces and Instruments*), which dealt with experimental practice and was destined to have an important influence on the history of alchemy during the following centuries. In fact, this is the first known treatise on chemical instruments. In this and other works, Mary mentions more than eighty pieces of apparatus, thus showing the high degree of specialization achieved by Alexandrian alchemy. Among the instruments attributed to her, Zosimos mentions the *trìbikos* (still used for distillation), which was connected by three tubes, along with three glass *bikoi*. The invention of the *balneum Mariae* (the bain-marie, water bath, or double boiler) is also attributed to Mary, although it was already known in Theophrastus' time. Mary also introduced many new instruments made of metal, clay, and, above all, glass. Among the latter category, the most important was the *kerotakis*: a cylindrical instrument for softening metallic foils and for the production of compounds with chemical colorants, and thus capable of making artificial gold and silver.

The apparatus in the Hellenistic alchemical laboratory showed a remarkable degree of specialization, which remained unsurpassed until the beginning of the early modern era. Similarly, the experimental skill shown by ancient craftsmen remained unequaled, and the chemical secrets behind the realization of many beautiful artworks preserved in museums were, until very recently, a mystery.

THE LITERARY TRANSMISSION OF CHEMICAL KNOWLEDGE

The literary sources concerning the chemical arts are scant, and they cover only a few moments in a history that, as pointed out in the preceding paragraphs, was extremely rich in discoveries and technical inventions. This contrast between the results obtained in practical chemistry and the rare surviving written testimonies devoted to the methods and interpretations behind the experimental procedure that led to them is probably explained by the central role played by secrecy in the transmission of knowledge. Secrecy was ensured either by relying on the oral transmission of recipes to a limited number of adepts or by compiling recipe books in a coded language. The practice of keeping chemical recipes secret had at least three justifications:

1. As already pointed out in the previous section, the artificial production of precious stones was endowed with metaphysical meaning and was therefore under rigid control by religious authorities.
2. The only way to protect and control a new discovery was to keep it secret within the strict social environment of the guild. The preservation of such secrets allowed sites of production of chemicals and stones to maintain a prosperous monopoly over a long period of time.
3. With the diffusion of chemical texts in classical and late antiquity, secrecy and coded language became the means to enhance the transcendental meaning of chemical practice.

In the Hellenistic epoch, a community of philosophers of nature, which only later became known as alchemists, explored ways of communicating their knowledge that remained successful throughout the Middle Ages and early modern times. While alchemists acquired literary experience and wrote several works, their practice of keeping the art secret led them to create an allusive and often obscure language. Alchemical literature, however, was not the only literary genre circulating in ancient times. Long before the diffusion of alchemical texts another extremely successful genre imposed its authority.

The first written texts concerning chemical practice were produced in Mesopotamian cultures and concern the art of glassmaking. Mesopotamian texts about glass from about the twelfth century BCE resemble medical tablets in their literary form: they prescribe instructions in the form of recipes, and some even recommend religious rituals and prayers, invoking the need to perform certain experiments on propitious days. The reading of the extant recipes reveals a few notable aspects:

1. Glassmaking seems to have been perceived by Mesopotamian authors as a craft suspended between art and nature, which enabled the imitation of precious stones.
2. The literary style of using short and instructive recipes to transmit the secrets of the art appears to be the point of departure for a literary tradition that experienced great success among ancient alchemists.

Even if the technical literature of Mesopotamian glassmaking did not appear to rely on an alchemical philosophy of matter, many of the experimental procedures of coloring or the theoretical distinction between genuine and artificial stones set forth by these texts paved the way for a set of concepts that would be more systematically developed by the Egyptians.

Historians and archaeologists do not agree on the technical value of recipes that were written by scribes and not by craftsmen, and the reader is invited to explore the following chapters presented in this volume in order to obtain an overview of their cultural contexts. However, what is beyond dispute is that this literary genre became extremely successful; it survived the decline of Mesopotamian culture, was adopted in Hellenistic epochs, and became, during the Middle Ages and early modern period, the most popular way to transmit chemical knowledge. The style that was adopted in the first printed book on glassmaking, Antonio Neri's *L'arte vetraria* (1612), would have certainly be understood by Mesopotamian glassmakers. Here, too, as in Mesopotamian glass texts, second-person verbs succinctly prescribe the operations to be followed to produce different kinds of glass. Even today, cookery books echo the great success of this ancient literary genre.

Ancient recipes, both chemical and alchemical, were circulated widely, and a few of them were transmitted almost unaltered to early modern times. It is, however, extremely difficult to track the ways in which these recipes were transmitted from one civilization to another. We know very little about how cuneiform recipe books were translated into other ancient languages, nor the degree to which the migration of craftsmen exporting their technical know-how in different contexts contributed to the oral transmission of recipes. What we do know is that many technical recipes circulated through time and space without encountering major obstacles.

Ancient recipe books bear the signs of a corpus of layered knowledge that reflected a long-lasting tradition of practice. This is the case of two papyri dating from around the third century CE, better known as the *Papyrus Leidensis* and the *Papyrus Holmiensis*. They offer lists of recipes with technical instructions on how to fabricate (by coloration) silver and gold and other metallurgical operations;

how to produce and fix dyestuffs; how to imitate precious stones with the help of glass, rock crystal, and metal oxides; and how to identify fraud in the art of assaying. Many of these recipes surely predated these papyri by centuries, their record being transmitted across generations without major alterations. While the instructions were supposed to be technical, no reference was made to crucial information concerning weights and measures; moreover, sometimes the phrasing was deliberately obscure or encoded, and explicit invocations of secrecy reminded the reader that this kind of knowledge contained information that should be kept within the circles of initiated adepts. Recipe books of this kind established an interesting connection between technical know-how, theoretical aspirations, and useful knowledge of chemical processes. The intersections of these three elements formed the basis of alchemical literature that we have references to during the first century CE, in Pliny the Elder's *Naturalis historia*.

Thanks to the combination of a new passion for gems and the state-of-the-art Roman glassmaking, Pliny mentioned several methods in subsequent chapters of his work that were used during his time to counterfeit all kinds of precious stones. Related to this discussion, he mentioned the publication of technical treatises devoted to the imitation of natural products (Halleux and Cannella 1998: 45–6). In the *Naturalis historia* (XXXVII 75), while testifying to the recent discovery of "a method of transforming genuine stones of one kind into false stones" and lamenting "considerable difficulty in distinguishing genuine stones from false," Pliny mentioned the existence of treatises (*commentarii*), whose authors he preferred to omit, which gave "instructions [on] how to stain crystal in such a way as to imitate smaragdus and other transparent stones, how to make sardonyx of sarda, and other gems in a similar manner" (Plin. *NH* XXXXVII 75).

The circulation of literature of this kind is very important because it attested to the existence of presently unknown authors who wrote about topics that, for centuries, had either been kept secret or treated in general and encyclopedic works such as Pliny's. The amazing dexterity that Roman artisans demonstrated in imitating precious stones justified the diffusion of this literature. While the practice of imitating stones must have been as ancient as chemistry itself, the publication of treatises explicitly devoted to it must have been relatively recent to Pliny's day, as no similar references can be found in earlier sources.

The fact that Pliny deliberately chose to omit the names of the authors of these treatises on glassmaking reveals that the debate about the relationship between natural and artificial stones must have been particularly lively, and that the ambition to create gems using the chemical arts was regarded with contempt by traditional naturalists. Inspired by a conservative philosophical standpoint, Pliny, like Seneca, despised the pretentious attitude of craftsmen who contended with nature over the act of creation. The ancient philosophers' position seemed to be incompatible with the proliferation of opinions and practices that, in Pliny's and Seneca's eyes at least, revealed the cultural and moral decadence of their contemporaries. The high social status of both these authors justified their negative attitude towards the *commentarii* and their authors, but one wonders if their perceptive attention to the recent technical progress in glassmaking was not itself a sign of the power such products exerted on the intellectuals of the epoch. But there were other authors, namely the alchemists, who held a different opinion, and by taking the chemical arts as their point of departure they developed new theories on the properties of matter.

Another ancient literary genre that exerted a considerable influence was represented by lists of minerals, stones, and pharmaceutical remedies. Pliny, in his books dedicated to metals and stones, mentions the main sources for his work, which, besides Theophrastus, amount to forty authors, for most of whom nothing but their names remain. From what one can gather by browsing Pliny's bibliographic references, it is clear that many of the lapidaries he commented upon were written by Egyptian and Persian authors; moreover, the nearly 2,000 observations (*observationes*) and data (*historiae*) he gives in the mineralogical books (XXXVI and XXXVII) of his *Naturalis historia* reflect a richness and variety of approaches – of which Theophrastus' represents the most authoritative, but not necessarily the most popular and influential, work of the field.

According to Halleux and Schamp (1985), the ancient lapidaries derive from four distinct literary traditions. The first was still indebted to the Theophrastian model privileging a descriptive method of classification and, notwithstanding some concessions to superstitious beliefs, placed stones within a taxonomic perspective. The second tradition, inspired by the spread of texts supposedly coming from the Orient, openly adopted a magical and esoteric approach. The third, connected to this, associated mineralogy with astrology – an approach that would be adopted with great success by Paracelsus in the Renaissance. The last tradition, directly inspired by Judeo-Christian beliefs, discussed stones and the mineral world by means of allegories. Although references to glass are not absent in the magical–esoteric tradition, the approach inaugurated by Theophrastus would have greater scientific relevance and was destined to have the most enduring influence. Lapidaries, however, were not the only books that treated the properties of stones and gems, and the tendency to the production of specialized texts led to compilations of lists of minerals as parts of pharmaceutical textbooks. An example is Dioscorides' *De materia medica* (first century CE), the earliest surviving pharmacological treatise and the only complete text belonging to the catalog tradition. It lists remedies taken from the vegetable, animal, and mineral worlds, not presented in alphabetical order, but rather classified according to scrupulous descriptions without concessions to occult or magical beliefs. This approach must have been quite an important tradition, since Pliny almost always stops to describe the therapeutic properties of stones and gems – an aspect completely absent from Theophrastus' work. The therapeutic purpose of the treatise put the different methods of preparing substances at the forefront, although, not unsurprisingly, glass is not mentioned among the remedies. Dioscorides shows that he was familiar with the latest techniques for handling chemical substances. Moreover, the preparation of remedies derived from mineral substances presupposed a familiarity with such chemical operations as calcination and the use of furnaces.

The variety of literary genres and media by which chemical recipes circulated in ancient civilizations and their subsequent enduring influence provide us with a valuable indication of the cultural importance of the chemical arts. The chapters that follow aim to illustrate their historical contexts.

While following the same outline of the other five volumes of the *Cultural History of Chemistry*, the chapters that follow have been written by three different authors (Sydney H. Aufrère, Cale Johnson, and Matteo Martelli), and each ends with a general conclusion (written by myself). The reason for this choice of format is due to the peculiar nature of this volume, which covers over 3,000 years of history and the interactions of three distinct civilizations. The philological skills required to deal with Egyptian, Mesopotamian, and Greco-Roman chemistry necessitate highly specialized competencies that nowadays are impossible to expect from one scholar alone. By subdividing the chapters into three parts, we hope to provide the reader with an easily understood and more homogeneous reconstruction.

Ancient theories of matter were heavily dependent on religious and mythological assumptions, and experimental practice as we know it was rudimentary and still lacking the spaces where it could be practiced in a methodical manner. When it comes to economic structure and growth, the economy was only partially based on trade and industry, but the invention and use of chemical processes did increase the profits of many of the civilizations treated in this volume. This increase was not exclusively positive, as the predominant role of slavery in the exploitation of natural resources also hindered an in-depth reflection on the polluting effects of the chemical arts on their environment.

Thus, when it came to reconstructing the history of ancient chemical arts, the contributors to this volume reflected on problems that hitherto have not been sufficiently explored and that therefore could be addressed only in an indirect way. As ancient chemistry obviously cannot be compared to modern chemistry, the reader will be invited to explore its multidisciplinary ramifications through an attentive reconstruction of the historical and cultural contexts from which they stemmed.

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