1

Commodities and Natural Objects

Eighteenth-century chemists studied an astonishingly rich arsenal of materials, ranging from entire plants, roots, leaves, flowers, bones, hair, nails, and other organized vegetable and animal parts to balsams, resins, gums, oils, fats, and blood extracted from plants and animals, to composite materials such as ceramics, porcelain, and glass, all the way to processed chemical substances such as metals, mineral acids, alkalis, and salts. When we include all kinds of raw materials and processed substances eighteenth-century chemists studied in their laboratories, described in their experimental histories, and classified at their writing desks, their number amounts to thousands. And even if we omitted the many composite and organized materials which eighteenth-century chemists reproduced, extracted, analyzed, and further explored in their laboratories, focusing only on those processed substances which look more like the typical "chemical substances," the number of those selected substances would still be astonishing. The famous table of chemical nomenclature and the adjoined chemical lexicon, published in 1787 by Antoine-Laurent Lavoisier and his collaborators, listed—apart from an impressive number of metals, acidifiable bases, alkalis, earths, metal oxides, compounds of metal oxides, alloys, and compounds of acidifiable bases—hundreds of salts made from twenty-six different acids.

1.1 Origin from the three natural kingdoms

Where did these materials come from? Almost all eighteenth-century chemists classified materials according to their origin from the three natural kingdoms. Especially in the teaching of chemistry and chemistry textbooks, they ordered materials in this naturalistic fashion, thus representing them as objects of nature. For example, Herman Boerhaave's (1668–1738) *Elementa Chemiae* (1732),[1] one of the most influential early eighteenth-century chemical textbooks, presents chapters on the history of minerals, vegetables, and animals in its "theoretical part." It retains this division in its "practical part," which first describes 88 "chemical operations upon vegetables," followed by descriptions of 39 "chemical operations upon animals" and 100 "chemical operations upon minerals." In France, Nicolas Lemery's (1645–1715) famous *Cours de Chymie* (1675), the last French edition of which appeared in 1757, was divided into three main parts with the headings "Of Minerals," "Of Vegetables," and "Of Animals."[2] Lemery's *Cours* belonged to a tradition of seventeenth-century French textbooks that organized their practical parts along the naturalistic tripartite distinction.[3] Guillaume François Rouelle (1703–1770), whose teaching at the Parisian *Jardin du Roi* between 1742 and 1768 made chemistry a prominent Enlightenment subject, also structured his experimental lectures according to the three natural kingdoms.[4] Two other famous French chemical textbooks of the mid-eighteenth century, Pierre Joseph

1 Boerhaave [1732]. For life and work of Boerhaave, see Gillispie [1970–1980] vol. II p. 224ff.
2 See the contemporary English translation of the *Cours:* Lemery [1677]. For life and work of Lemery, see Gillispie [1970–1980] vol. VIII p. 172ff.

Macquer's (1718–1784) *Elemens de Chymie-Pratique* (1751) and Antoine Baumé's (1728–1804) *Manuel de Chymie* (1763) continued this tradition.[5] In the same vein, Gabriel François Venel (1723–1775) wrote in his article *Chymie*, presented in Diderot's *Encyclopédie*, that the three kingdoms of nature provide "three large divisions according to which we have distributed chemical subjects; the minerals, vegetables and animals fill out these divisions."[6] Many additional examples could be mentioned, including the period immediately after the Chemical Revolution in the last third of the eighteenth century.

In the chemistry lectures and textbooks of the eighteenth century, the materials grouped together under headings such as plants or vegetable substances, animals or animal substances, and minerals were extremely diverse. The class of vegetable substances, for example, comprised entire plants, roots, leaves, fruits, seeds, and other organs of plants; materials extracted from plants such as resins, gums, essential and fatty oils, balsams, and salts; vinegar, wine, beer, and spirit of wine obtained from fermented plants; as well as composite pharmaceuticals and other artificial chemical preparations made from natural plant materials (figure 1.1). Chemists used a set of different criteria to order these materials further, such as natural origin from a species of plant or provenance, the mode of chemical extraction, and perceptible properties, both physical and chemical. A striking feature of this mode of classification is the combination of apparently conflicting criteria of classification. The classification of materials as "plant materials," for example, identified them as natural objects. But on the rank of genus and species, the same material was often identified by the way it was prepared chemically; that is, as a product of chemical art. The class of distilled waters, for example, was ordered into the higher taxon of plant materials and at the same time identified by its mode of chemical preparation, namely distillation. Elixirs and other composite preparations made from many different ingredients, ardent spirits like spirit of wine and pure alcohol, and the various kinds of ethers are additional examples of classes of materials that were ordered into the class of plant substances despite the fact that chemists considered them to be not natural, but chemically altered materials.

From a broad comparative view, the eighteenth-century chemical order according to the three natural kingdoms is indeed remarkable. In the sixteenth century and early seventeenth century, most alchemists and chemists divided substances into natural raw materials on the one hand and chemical preparations on the other.[7] From the per-

3 The French chemical textbook tradition began with the *Elemens de Chymie* by Jean Beguin (1550–1620), the Latin edition of which appeared in 1610 (Beguin [1624]; for life and work of Beguin, see Gillispie [1970–1980] vol. I p. 571f.). The naturalistic tripartite division was introduced in the chemical textbook (1633–1635) by William Davison (1593–c. 1669), the first professor of chemistry at the Parisian *Jardin du Roi*. (For life and work of Davison, see ibid. vol. III p. 596f.) When introducing the naturalistic tripartite division in the last, practical part of his textbook, Davison referred to the Arabic physician Rhazes (c. 860–925) (see Partington [1961–1970] vol. III p. 6: *Rasis in libro Diuinitatis*). The tripartite naturalistic classification was adopted in the practical parts of the chemical textbooks by de Clave, Le Febvre, Glaser and Lemery; see de Clave [1646]; Le Febvre [1664]; Glaser [1676]; and Lemery [1677].

4 See Rouelle [n.d.]. For life and work of G. F. Rouelle, see Gillispie [1970–1980] vol. XI p. 562ff.

5 See Macquer [1751]; Baumé [1763].

6 Diderot and d'Alembert [1966] vol. III p. 418. All translations are our own, except where stated.

spective of the second half of the nineteenth century and afterward, the ordering of all kinds of raw materials and processed substances according to their origin from the three natural kingdoms is equally curious. In the inorganic and organic chemistry of that later period chemists classified chemical substances according to composition, constitution, and molecular structure. For this mode of classification the origin of substances, natural or experimental, was irrelevant.

Why did eighteenth-century chemists classify materials according to their origin from the three natural kingdoms? At first glance it seems obvious to interpret chemists' acceptance of the naturalistic tripartite distinction as a mere convenience allowing them to order a plethora of materials. But even if we consider this kind of classification to be a convenience, it must be admitted that it was a convenience in the absence of compelling alternatives. Chemists' classification of materials according to the three natural kingdoms is significant since it informs us about the absence of, or rather chemists' collective reluctance toward, an alternative already developing in the early eighteenth century; namely, classification based on knowledge about the composition of chemical substances and a chemical theory of composition. Chemists did not consider knowledge of composition to be a reliable resource for ordering all of the kinds of materials they were dealing with, especially plant and animal materials.[8] Analytical knowledge and the theory of composition were not the organizing grid for the *entire* culture of eighteenth-century chemistry. But this still does not explain sufficiently why the majority of European chemists accepted the division of substances according to the three natural kingdoms. If chemists did not consider chemical analysis to be reliable in all areas of chemistry, other alternatives of classifying materials

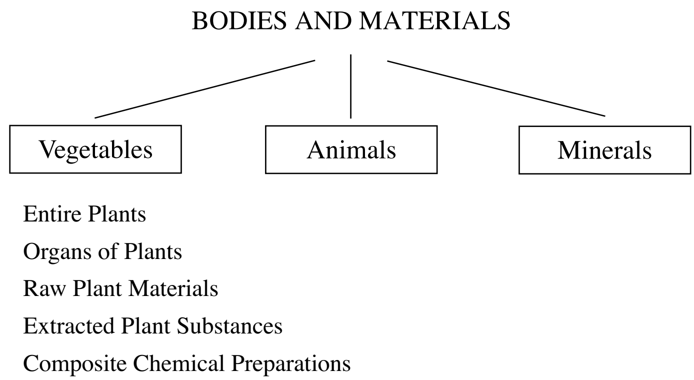

Figure 1.1: Classification according to the three natural kingdoms.

7 See below, chapter 2. As we will show in part III, this classification still had an impact in the early eighteenth century, especially in chemical-pharmaceutical contexts where chemists divided the natural *simplicia* from the artificial preparations and *composita* (see chapter 11.3).

8 Eighteenth-century chemists' cautionary remarks about the inadequacy of their analytical means in plant and animal chemistry can hardly be overlooked. They are repeated over and over again in practically all of the eighteenth-century publications dealing with the analysis of plant and animal substances. See also chapters 12 and 13.

existed as well. Classification according to types of preparation or according to chemical properties would have been possible alternatives and, indeed, were preferred by a few chemists.[9]

It is well known that the distinction between the three natural kingdoms was not an invention of chemists, but had been widely accepted by Enlightenment naturalists and philosophers. Therefore the fact that chemists shared this classification with other savants is also telling about the relationship between eighteenth-century chemistry and other learned cultures. It provides information about chemists' self-representation in broader eighteenth-century culture. Whereas classification according to types of chemical operations and chemical properties would have highlighted chemistry as a manipulative art, the naturalistic mode of classifying emphasized chemists' inquiry into nature. It rendered chemists as naturalists and natural philosophers, and connected chemistry with the grand theme of Enlightenment: nature. Unlike early seventeenth-century chemists, who justified chemistry, chemical pharmacy, and chemical medicine by emphasizing the power of chemical art and the superiority of chemical preparations over natural materials, and unlike late nineteenth-century chemists who envisioned chemistry as a productive enterprise spurring industrialization and creating a new world of synthetic artifacts, eighteenth-century chemists presented their art and science to the Enlightenment public in terms of nature and natural objects and processes.

1.2 Commodities

Like naturalists, eighteenth-century chemists presented their objects of inquiry as natural things and processes. Yet, when we "go out into nature" we do not find pure metals (with the exception of gold), acids, salts, alkalis, essential oils, distilled waters, and so on. What we do find in mountains and fields are roots, fruits, herbs, beetles and worms, ores, stones, spring water, and many other raw materials. But those substances that strike us as typically "chemical" are absent in nature. Rethinking the common order of representing chemical substances, the French chemist Pierre Joseph Macquer remarked in 1751 that salts, metals, half-metals, and other typical—that is, processed—chemical substances were "far from being presented to us by nature in the state of perfection and degree of purity we normally assume when we introduce them in chemical textbooks." He then proposed that an elementary chemical textbook should not start with metals, acids, salts, and other processed substances well-known to chemists, but rather with the natural raw materials from which these substances were separated.[10]

Many of the substances that eighteenth-century chemists studied were indeed not natural objects; that is, not substances "found in nature." This is quite obvious for

---

9 Among the chemists who classified materials on the highest taxonomic rank according to types of operations were Cartheuser [1753]; Vogel [1755]; Erxleben [1784]; and Guyton de Morveau [1777–1778].

10 See Macquer [1751] vol. I p. vi.

composite materials, such as glass, ceramics, porcelain, and composite remedies, which were manufactured in workshops and pharmaceutical laboratories. But how did chemists get access to the more typical chemical substances? We tend to suppose that mercury, vitriolic acid, nitric acid, copper sulfate, silver nitrate, lime, potash, and so on were chemical substances procured in the chemical or alchemical laboratory. And there is no question that these substances were ubiquitous in eighteenth-century chemical laboratories and often used to perform chemical experiments. As the French chemist Etienne François Geoffroy (1672–1731) emphasized, they were "the principal materials with which one usually works in chemistry."[11] In 1718, when Geoffroy made this utterance, metals, acids, salts, earths, and alkalis, which were the bulk of substances represented in his famous table of affinities (or *rapports*), already had a long history as chemical laboratory substances. Many eighteenth-century chemical novices first encountered these substances when they entered a chemical laboratory. But a great number of eighteenth-century chemists first met with these substances at quite different sites, namely in apothecary's shops, foundries and salt works, or when traveling to mines and taking courses in assaying.

What do we mean when we say that mercury, vitriolic acid, nitric acid, copper sulfate, potash, and so on were typical chemical substances used and procured in the eighteenth-century chemical laboratory? Do we mean that they were discovered by learned men in the course of their attempts to unravel the secrets of nature? And do we assume that the seventeenth- and eighteenth-century alchemical or chemical laboratory was mainly, or even exclusively, a site for the acquisition of natural knowledge? In the words of F. L. Holmes, were the processed chemical substances the results of "thriving investigative activity" by eighteenth-century chemists or the previous alchemists?[12] Or do we mean, alternatively, that they were reproduced in academic laboratories, but originally produced at different social sites? And is it not possible that the early modern laboratory was also a place for artisanal production and inquiry—as the Latin *laborare*, "to work," indicates? These are questions that concern a central aspect of the history of science: the coming into being of the objects themselves that are at stake in scientific investigation.

Nonetheless, historians of chemistry have seldom raised questions like these. Based on the historical actors' presentation of chemical substances as natural objects stemming from the three kingdoms of nature, they have paid attention to experiments performed with substances, and to theories about salts, calces, gases, and other classes of substances. But they have not seriously examined the question of the provenance of the processed chemical substances that late seventeenth-century and eighteenth-century academic chemists studied in their laboratories and wrote about in their chemical histories. Neither did they wonder why chemists in the second half of the seventeenth century, when chemistry became accepted in academic institutions such as the Royal Society, the Paris Academy of Sciences, the Paris Royal Botanical Garden, and German medical faculties, intensified their studies of processed sub-

11 Geoffroy [1718] p. 203.
12 Holmes [1989] p. 1.

stances. Nor did they ask how processed substances came into their horizon of interests and practice.

The bulk of the processed substances studied by eighteenth-century chemists—in particular in the first half of the century—were neither found in nature nor were they the outcome of disinterested academic investigations. Rather, they were products long known in mining and metallurgy, in distilleries and apothecary's shops, or newer commodities, imported by merchants from foreign countries and prepared in native pharmaceutical and alchemical laboratories.[13] Gold, silver, copper, bronze, brass, tin, lead, and iron had been well-known metals since ancient times, widely applied in the manufacture of tools, vessels, coins, ornaments, mirrors, pigments, and remedies. Mercury, antimony, and arsenic were equally quotidian materials, which became prominent in sixteenth-century Paracelsian chemical pharmacy and medicine. Also of ancient origin were the alkalis potash and soda, used as remedies and in the making of soap and glass. The various kinds of earth analyzed by eighteenth-century chemists were materials applied in the manufacture of ceramics and porcelain. Likewise, the most important kinds of mineral acids used in eighteenth-century chemical laboratories—nitric acid, *oleum sulfuris* or vitriolic acid, and muriatic acid—were also applied as commodities. In the fifteenth century, nitric acid became widely applied in metallurgy for the separation of gold from silver; vitriolic acid, which was first used only as a reagent in late medieval alchemical laboratories, became applied pharmaceutically in the sixteenth century; and muriatic acid was introduced by Rudolph Glauber in the seventeenth century and thereafter used as a remedy or an ingredient for the preparation of remedies. Almost all mineral salts analyzed and re-synthesized by eighteenth-century chemists were also applied as medicines, as well as for dyeing (in the cases of copper and iron vitriol, alum, and sal-ammoniac), the making of pigments for painting (vitriols), the soldering of metals (borax and sal-ammoniac), and cooking (rock salt and sea salt).[14] Furthermore, almost all of the chemically extracted vegetable and animal materials examined by eighteenth-century chemists—vegetable extracts, animal fats, essential oils, distilled waters, ardent spirits, and so on—were commodities applied as remedies, cosmetics, and food. Even the apparently most natural objects with which eighteenth-century chemists experimented—entire plants and the roots, leaves, fruits, seeds, and other organs of plants—were for the most part herbal drugs obtained from medical and botanical gardens or purchased from merchants and druggists.

Trade and the arts and crafts constituted the space in which most of the objects of inquiry of eighteenth-century chemists came into being. Early eighteenth-century academic chemists purchased materials from merchants, apothecaries, miners, and other practitioners and reproduced them in their laboratories. They further purified these useful materials, studied their perceptible properties, and analyzed their composition. Performing analyses and re-syntheses, in the second half of the eighteenth

13 One of the best overviews on the history of chemical substances is still the one contained in Hermann Kopp's history of chemistry (see Kopp [1966a] vols. 3 and 4); see also Multhauf [1966]. For an overview of the history of the practical uses of materials, see also Fester [1923].

14 See the tables in chapter 8.

century in particular, chemists also introduced new kinds of substances and new experimental techniques that went beyond the existing artisanal types of materials, instruments, and operations, as was the case with the different "kinds of air," or gases. But even such apparently exotic substances like gases did not unambiguously belong to a world of scientific objects. Rather, many of these new chemical substances left the site of their discovery to become applied in medicine, the apothecary trade, and the mundane social world more broadly.[15] Technology constituted a space of possibilities for eighteenth-century chemists' experiments as well as their ontology of materials.[16] Materials went back and forth from academic institutions to sites of production and consumption. We will come back to this important issue in connection with our historical analyses in parts II and III.

Two possible objections against our general argument concerning the origin of the materials studied by eighteenth-century chemists shall be addressed briefly at this point. The first objection concerns alchemy. It may be accepted that a certain number of eighteenth-century chemical substances—such as gold, silver, copper and mercury, metal alloys, calcareous earth, soda and potash, common salt, vegetable balsams, resins, wax, honey, milk, and so on—were ancient artisanal products. But, in a nutshell, it may also be argued that many of the eighteenth-century chemical substances had first been introduced in medieval and early modern alchemy. We have no problems with this view as long as "alchemy" is not defined unambiguously as an occult tradition, whose practical part aspired primarily to the preparation of the philosopher's stone and the transmutation of innoble metals into gold.[17] Most of the acids, salts, and other chemical preparations invented by sixteenth- and seventeenth-century alchemists—such as Paracelsus (1493–1541),[18] Oswald Croll (1560–1609),[19] Otto Tachenius (1610–1680),[20] Johann Rudolph Glauber (1604–1670), Johann Kunckel (c. 1630–1703),[21] and Johann Joachim Becher (1635–1682)—were sold and applied as chemical remedies. In the course of the second half of the seventeenth century these chemical remedies were included in official pharmacopoeias and other apothecary books. Indeed, all of the new acids and salts displayed in the first chemical table of affinity introduced by E. F. Geoffroy in 1718 were also used as chemical remedies.[22] As to alchemists like those mentioned above, it makes little sense to sort out their practical, commercial goals and interests from their philosoph-

15 For the application of gases in eighteenth-century medicine, see Levere [1994].

16 In this book, we use the term technology—which was coined only in the late eighteenth century—not as an actors' term, but as an analytical category to denote the ensemble of sites, techniques, instruments, materials, and products in the eighteenth-century arts and crafts (including medicine and pharmacy), as well as the forms of knowledge tied to that ensemble.

17 William Newman pointed out recently that "before the end of the seventeenth century, the word [alchemy] was widely used by early modern writers as a synonym for 'chymistry,' a discipline that included iatrochemistry and a host of technologies such as the refining of salts and metals, the production of acids, alcoholic libations, and pigments, and finally, the transmutation of base metals into noble ones." Newman [2004] p. xiii.

18 For life and work of Paracelsus, see Gillispie [1970–1980] vol. X p. 304ff.

19 For life and work of Croll, see ibid. vol. III p. 471f.

20 For life and work of Tachenius, see ibid. vol. XIII p. 234f.

21 For life and work of Kunckel, see ibid. vol. VII p. 524ff.

22 See chapter 8.

ical and religious objectives. They were craftsmen and entrepreneurs and at the same time learned men and authors of books. The mixed commercial and epistemic objectives of these educated artisans become obvious when we study their careers and their writings.[23] Many of their publications were collections of recipes addressing the reader as a potential maker-experimenter in the second person singular, giving him or her detailed instructions about instruments, techniques, substances, and the practical, mostly pharmaceutical, uses of chemical preparations.[24]

Second, one may object that the question of the origin of chemical substances, and of chemists' access to them, is merely a question of supply. This is a serious objection, in particular from a comparative point of view. Imagine a nineteenth-century merchant or gardener who delivered plants to a botanist, or a breeder who sold sheep to a geneticist. It may have been the case that the merchant, gardener, and breeder had interesting things to say to the botanist and geneticist about the origin, travel, storage, and ways of growing and breeding of the plant or animal specimen. But depending on the kind of scientific investigation, the information provided by these practitioners may have been totally uninteresting to the scientists. It may have been treated as a technical issue, which was left to the practitioner and could be black-boxed by the scientist.[25] There may have been cases—for example when obstacles arose—where the scientist went back to the practitioner to make inquiries that contributed to the solution of problems. But such cases were rare, and merchants, gardeners, and breeders were social groups distinct from academic botanists and geneticists.

Yet we assert that the relationship between eighteenth-century academic chemists and practitioners directly involved in the trade and commercial production was different from the example just discussed. There was close and stable interaction between eighteenth-century academic chemists and certain groups of educated practitioners, especially apothecaries, assayers, mining officials, and, especially in France, commissioners of state manufactories. This relationship was not merely the technical, commercial relationship of purchasers and providers. Although these social groups were not identical, they shared many interests and goals as well as materials, instruments, techniques, laboratories, and other items of material culture. Moreover, eighteenth-century chemistry itself was not restricted to academies, medical faculties, places of public and private teaching, botanical gardens, museums, and other institutions of learned inquiry. Academically educated chemists performed chemical operations and gathered experiential knowledge at non-academic sites as well, such as pharmaceutical laboratories, laboratories for assaying, arsenals, and manufactories for dyestuffs, ceramics, and sugar; and a significant of practitioners, especially apothecaries, were acknowledged as chemists. Eighteenth-century chemists were far from

23 For the alchemical laboratory practice and the mixed careers of seventeenth-century alchemists, see Newman [2000]; Newman and Principe [2002]; Nummedal [2002]; Smith [1994], and [2004]; and Moran [2005].

24 This implies that sixteenth- and seventeenth-century alchemy was far from being a secretive practice throughout.

25 For the distinction between technical and epistemic objects at stake here, see Rheinberger [1997].

being unambiguous savants and "experimental philosophers." Many of them were hybrid savant-technologists who were actively involved in the arts and crafts as apothecaries, mining and metallurgical officials, state commissioners in manufactories, and project makers sponsored by the state.[26] We will argue further in the next chapter that eighteenth-century chemists often pursued questions and objectives related to the arts and crafts, especially in the technological strands of their experiments and their experimental histories.

1.3 Learned inquiry into materials

The bulk of the substances studied by eighteenth-century chemists originated in the artisanal world, and many of the new chemical substances that were discovered in academic chemists' laboratories soon became transformed into remedies and other commodities. In the eighteenth century substances traveled from pharmaceutical laboratories and workshops to academic chemical laboratories, and vice versa, to become reproduced, analyzed, technically improved, and applied as useful materials. But were the materials studied, produced, and applied by apprenticed artisans and craftsmen and investigated by academic chemists actually identical kinds of objects of inquiry? This is a key question tackled in detail in parts II and III of our book.

In this introductory part we discuss more general outlines of eighteenth-century chemical practices that contribute to answering this question. Materials were indeed transformed when they became objects of inquiry for academic chemists. Chemists invested them with new meaning, and sometimes even transformed their boundaries by splitting them into different kinds of substances. New individuations and identifications of substances—such as the division of air into different kinds of air—went hand in hand with material transformations. We have argued above that technology constituted a space of possibilities for eighteenth-century chemists' ontology of materials. Now we wish to add that chemists' ontology of materials was also conditioned by their distinctive chemical concepts, theories, analytical methods, and types of experiments. In the eighteenth century, the space of production and representation of chemical substances was constituted both by technology and by an ensemble of practices and concepts developed in scientific inquiry.

We distinguish three main styles and practices of studying materials in eighteenth-century academic chemistry that we will discuss later: experimental history, technological improvement, and experimental philosophy. Eighteenth-century chemists studied substances not only as applied materials, but also as perceptible objects of nature and as objects carrying imperceptible features. Their epistemic transformation of materials produced and applied in the arts and crafts into natural objects becomes manifest in their classification according to the three natural kingdoms. A second epistemic transformation, built on the first one, took place when chemists studied imperceptible features of chemical substances. Eighteenth-century chemists ascribed

26 For further arguments concerning the hybrid persona of the eighteenth-century chemist, see Klein [2005b].

new philosophical or theoretical meaning to substances when they studied their composition, reactions, and chemical affinities. The vast majority of materials studied by eighteenth-century chemists were commodities and at the same time objects of learned inquiry or scientific objects.

It is of central importance to the historical and philosophical questions tackled in this book that eighteenth-century chemists' most important objects of inquiry—chemical substances—were entities with many faces. They were not unambiguously constituted as philosophical objects, as were the atom, the vacuum, the magnetic and electrical fluids, and other imperceptible objects studied in experimental philosophy. They did not fit exclusively into the category of perceptible natural objects, such as plants, animals, and minerals. And they were not exhaustively defined as useful materials applied in the arts and crafts and the wider society. Studying chemical substances as applicable materials, perceptible natural objects, and things that carry imperceptible features, eighteenth-century chemists' inquiries moved from the perceptible to the imperceptible dimension of substances, and vice versa. In so doing they constituted multidimensional objects of inquiry that resist our common distinction between perceptible and imperceptible things, and scientific and technological objects.[27] The substances in eighteenth-century chemistry were all of this at once. We will come back to this point after our discussion of chemists' three strands of inquiry into chemical substances, which will further illuminate the different ways in which chemists constituted their objects of inquiry.

27 For these distinctions see, in particular, Sellars [1963]; Bachelard [1996] (first publication 1957); and Rheinberger [1997]. Sellar's distinction between manifest and scientific images largely coincides with the distinction between perceptible and imperceptible objects (see also van Brakel [2000] pp. 41–46).