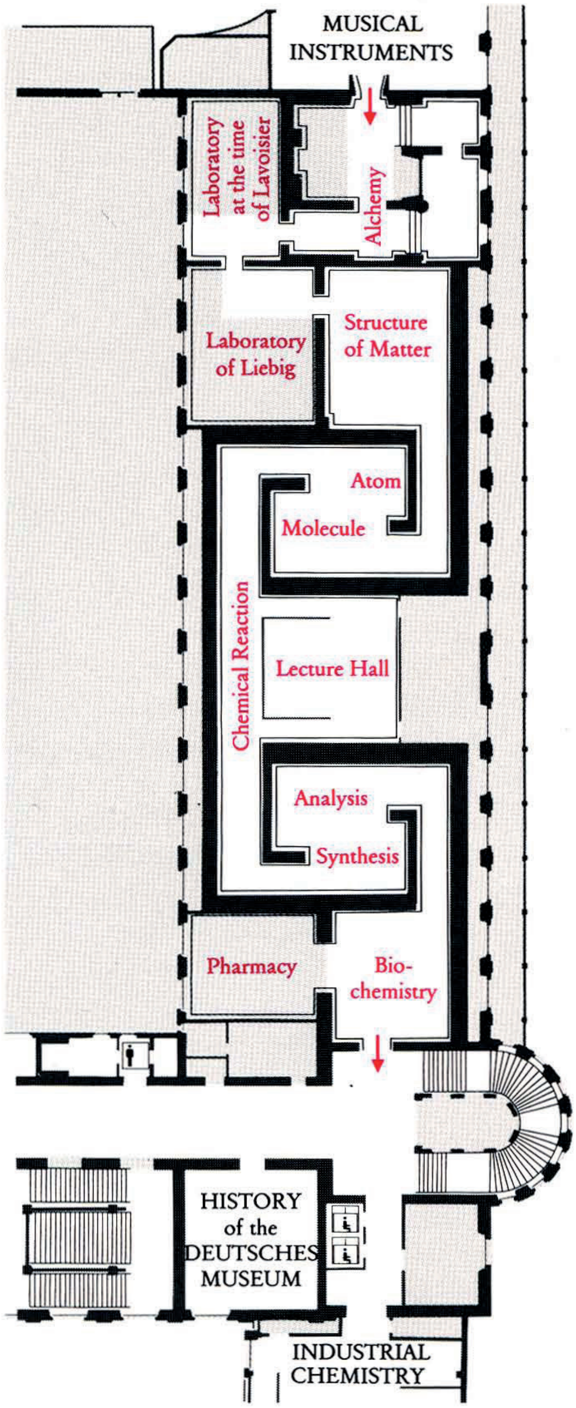
Chemistry



Chemistry is the subject of two different exhibitions in the Deutsches Museum: one of mainly experimental character, named *Chemistry;* the other, named *Industrial Chemistry,* contains exhibits which belong rather to the field of technology.
In Antiquity, chemical knowledge was mainly used for the production of medicines and of poisons. In addition, there were special techniques for gilding, used especially in temple workshops. This is also where the first attempts to imitate gold were made. Rudiments of the theory of chemical elements date back to the natural philosophy of Antiquity.

During the 1st century A.D., alchemy developed in Hellenistic Egypt, under the influence of ancient mythical ideas and Gnostic doctrine and in association with Aristotelian thought. The teachings of alchemy were taken over by the Arabs who continued to develop them.

During the Latin Middle Ages, alchemy spread throughout Europe. The medicine-oriented iatrochemistry of Paracelsus, too, was based upon alchemical ideas.

Apart from alchemy, there was also a largely theory-free technical branch of chemistry which was mainly applied in metallurgy. However, alchemy played an important part until the 17th and 18th centuries and was substituted only slowly by chemistry in the proper sense.

The first comprehensive theory of chemical reactions was provided in the 17th and 18th centuries by the phlogiston theory developed by Johann Joachim Becher and Georg Ernst Stahl. After the invention of the pneumatic trough by Stephen Hales, in 1727, pneumatic chemistry developed – primarily in England – and led to the discovery of numerous new gases. Above all, James Black, Henry Cavendish, Joseph Priestley and Karl Wilhelm Scheele took part in these discoveries. The chemical composition of water, too, was discovered and described. As a result of the research work done by Antoine Laurent de Lavoisier, the phlogiston theory was supplanted, towards the end of the 18th century, by the oxygen theory which ascribes the combustion of substances to the absorption of oxygen. Lavoisier also defined the element as a chemically indestructible matter and formulated the law of conservation of matter, which brought about the breakthrough in the quantitative approach to the study of chemical reactions. Together with his assistants, he created the chemical nomenclature, the essential part of which is still valid today.

Jeremias Benjamin Richter's law of constant equivalent weights (1791), Joseph Louis Proust's law of constant proportions (1797) and John Dalton's law of multiple proportions (1803) definitely established chemistry as a quantitative science. A theoretical explanation of these empirically determined laws was given in 1803 by Dalton who affirmed that matter was composed of atoms and that all atoms of a single element were the same, but different from the atoms of all other elements.

By the extensive determination of atomic weights, Jöns Jakob Berzelius tried to give an empirical base to this new theory. He also introduced many of the chemical symbols commonly used today.

The 19th century also brought about a considerable increase of knowledge in the field of organic chemistry, of which K.W. Scheele may be considered the founder; he was the first to isolate many organic compounds. In 1828, Friedrich Wöhler proved by the urea synthesis, and in 1845 Hermann Kolbe by the acetic acid synthesis, that – in principle – there is no difference between inorganic and organic matter. From 1831 to 1837, Justus von Liebig developed the accurate analysis of organic-chemical substances. Discovering the identical composition of cyanic acid and fulminic acid, Liebig, Wöhler and Berzelius created the term "isomerism" in 1831 and thus laid the foundation for structural chemistry. Of great help was the introduction of the valence symbol into chemical symbolism by Archibald Scott Couper (1857) and August Kekulé's

discovery of the tetravalence of the carbon atom. In addition to Friedrich Rochleder and A. S. Couper, Kekulé developed the idea of the self-bonding of carbon atoms in 1857. In 1860, he postulated the ring structure of benzene.
Since Amedeo Avogadro's hypothesis was not accepted generally, ideas of the real equivalent weights and of the formulae of chemical compounds were unclear at that time. Not until the 1860 Chemists' Congress of Karlsruhe was the confusion ended by Stanislao Cannizzaro. In 1859, Robert Wilhelm Bunsen and G. Kirchhoff introduced the spectral analysis. In 1868/69, Lothar Meyer and Mendeleyev established the periodic system of classification for chemical elements. In the course of further development, more and more independent branches, such as biochemistry, industrial chemistry, radiochemistry etc., came into existence.

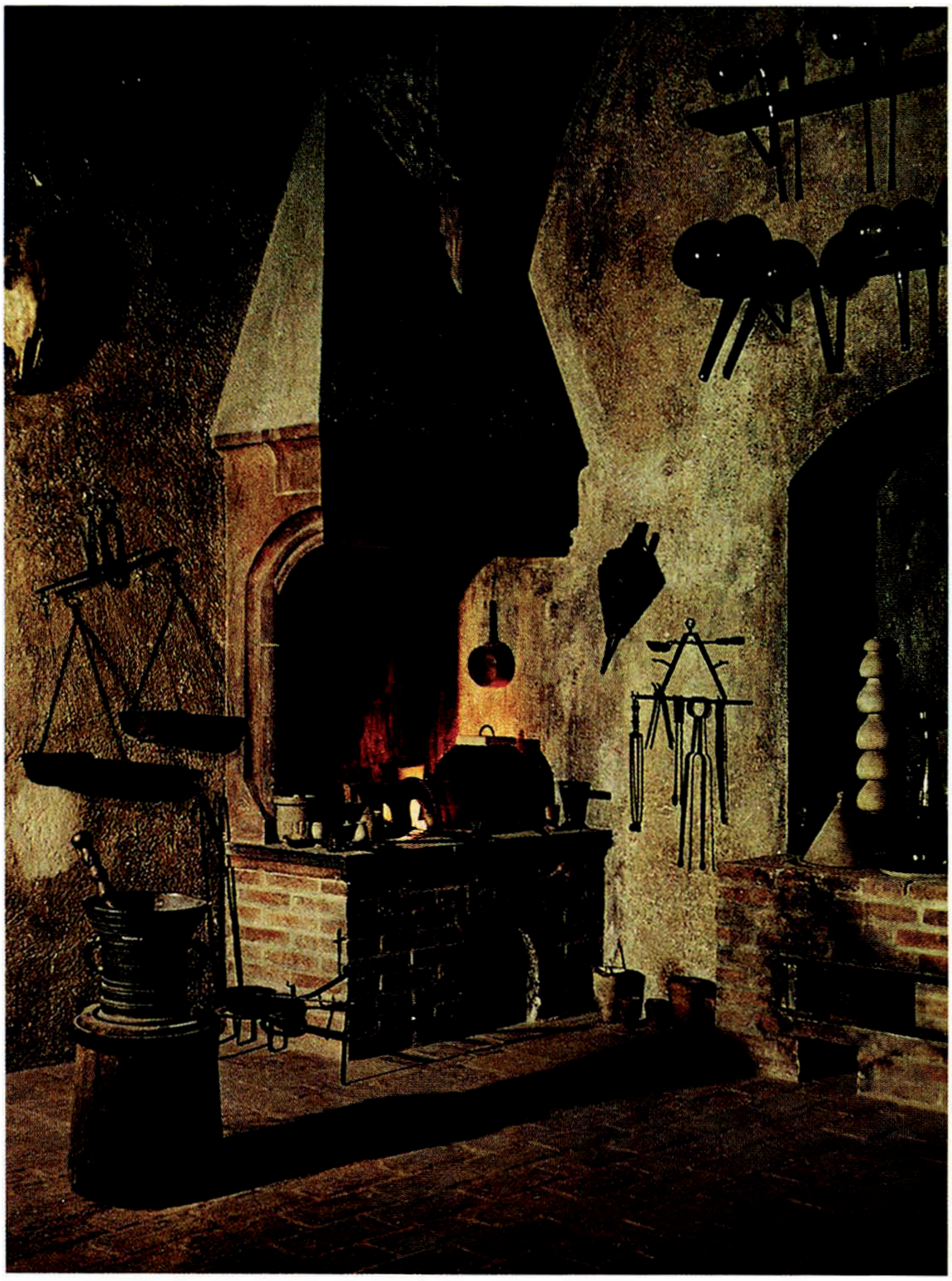
What is Chemistry?

Chemistry can be found in everything around us: in our own body, in all the things we can touch, in all objects our eyes can see. The growth of the flowers in spring, the brown colouring of the leaves in autumn, the baking of bread, the cooking of soup – really everything in this world is based upon chemical processes.
Nevertheless, we often experience chemistry as a strange thing, because its processes take place in tiny molecules and can be seen only when their products have accumulated to visible quantities. And the language of chemical formulae seems incomprehensible, even frightening, to the lay mind.
However, chemistry is absolutely omnipresent, and the number of identified existing compounds is estimated at about 15 million for organic chemical and at about 1 million for inorganic chemical compounds. Not a single day goes by without the discovery of several hundred new chemical compounds, either found in nature or synthesized in the laboratory. The task of chemistry is to study the substances of the animate and inanimate world, their composition and their properties, and to transform these types of matter into new substances with useful properties. The changes can be obtained by the exchange of atoms, or groups of atoms, in natural compounds (substitution), by decomposition of compounds, by assembling small and mini-molecules to bigger or comparatively gigantic molecules, or by suitable combination, repetition or variation of the processes mentioned above.
The prerequisites for such changes are: the knowledge of the composition and structure of the existing substances, which is sought by the methods of chemical analysis; quantitative ideas of the stability of the bonds to be dissolved or of the chemical valencies in the substance to be changed; and detailed study of the ways of reaction and of the laws ruling the production of a new substance with the desired properties.

The exhibition is divided into a historic section with 3 laboratories (alchemy, Lavoisier, Liebig) and an experimental section, in which the modern methods of chemistry are explained and demonstrated.

Alchemy

The task of alchemy was the refining and transformation of metals and other substances. The visible sign for the successful activity of the master was the purification of the disciple's soul. Thus alchemy was also a ritual act of worship which found its expression in ritual dress, in liturgical prayers and hymns. Alchemy originated in Hellenistic Egypt, about the



Alchemist's laboratory (R)
For many centuries, chemistry had to manage with very simple means. The resemblance with a kitchen is striking.

2nd century A.D., and represented a combination of various kinds of scientific, philosophic, mystic-religious and technical thought, into which also Gnostic, neo-Platonic and Stoic theories had been integrated. The alchemical methods not only had a symbolic character; the alchemist's activity also included experiments. He owned a laboratory, fitted with hearths, flasks, melting pots and distillation apparatus – besides an altar –, and he was familiar with the laboratory techniques and with the properties of the different types of materials.

Alchemy from the aspect of natural science was less important than from the aspect of human self-understanding. The laboratory work, the attempts of producing gold from base metals – such as lead, for example, – were not undertaken as an end in itself, anyway not by serious alchemists. While endeavouring to perfect metals, the alchemist simultaneously tried to achieve the perfection of his own soul. The lead therefore was a symbol for the unsaved soul, gold symbolized the redemption. The alchemist struggled to discover the self and to take possession of it in the belief that by doing so he would be able to redeem matter from its imperfect state. Thus he endeavoured to prepare the *philosophers' stone* which would be able to transform imperfect bodies into perfect ones by mere touch, like silver into gold. At the same time, the philosophers' stone was a symbol of the spirit of redemption, able to free the soul from all impurities. In Latin alchemy, the philosophers' stone was often identified with Jesus Christ.

Looking at the alchemical laboratory, the visitor can see different types of hearths. A showcase illustrates the evolution of the art of distillation from Antiquity up to the *moor's head* which was in use up until the 18th century. Alchemists believed that some mixtures had to be kept boiling over years, so they developed special receptacles for this purpose: the *pelican* and the *circulatory.*

In addition, the exhibition shows a *gallery furnace* for pharmaceutical work and a *Lazy Henry,* a special furnace construction for slow and uniform distillation. Glass fragments from the laboratory of the alchemist Johann Kunckel von Löwenstern, found during the excavation of his laboratory on the Pfaueninsel of Berlin, which was destroyed in 1686, complete the display on alchemy.

Chemical Laboratory at the Time of Lavoisier

In the 18th century, physical equipment, such as electrostatic generators, air pumps, pneumatic troughs and burning lenses, was also used in chemical laboratories. Important discoveries in the field of gas chemistry were achieved with these instruments.

As an example, a large lens manufatured by Ehrenfried Walter von Tschirnhaus about 1700 is on display here. At the right wall of the laboratory, there is an apparatus for the analysis of water on glowing iron. Standing in the niche of the right wall there is a small electrostatic generator similar to those then in use for the analysis of air by means of an electric spark. The centre of the room is dominated by a pharmacist's table from the monastic pharmacy of Andechs. On this table, there is a pneumatic trough of polished marble, of the type used by Lavoisier, as well as a simple burning lens for the ignition of substances in the interior

View of the laboratory at the time of Lavoisier (R)
18th century chemistry is characterized by the slow penetration of physical implements, such as lenses and electrostatic generators, into the chemical laboratories.

of the glass bell jars, which themselves stand in a pneumatic trough. At the rear of the laboratory, a mighty hearth with chimney hood recalls the type of hearth common in the second half of the 18th century, especially in France. Remarkable are the large bellows suspended under the ceiling, from which the air was directed by pipes to the surface of the furnace in order to produce particularly high temperature in the glowing fire on the plate.

18th century chemistry mainly dealt with the study of gases. In 1782, the English scientist Joseph Priestley discovered the so-called *nitrous air* by pouring nitric acid over brass cuttings. He discovered that this new type of air was able to "imbibe" part of the normal air, namely the part which supports breathing. So it was possible to determine whether the air was breathable by this chemical reaction. This method was refined by Felice Fontana who devised a special instrument for this reaction, the *eudiometer,* which was very popular. In 1805, Joseph Louis Gay-Lussac and Alexander von Humboldt established the true oxygen content of the air.

One of the great topics of 18th century chemistry was the attempt to explain the phenomena of combustion. In the left niche of the rear wall of the laboratory, two experiments made by Priestley and Scheele are therefore referred to: the exhaustion of oxygen by the respiration of a living mouse in a pneumatic trough and the burning of a candle in such a trough. By means of a weighing instrument it is shown that the com-

bustion products of a candle are heavier than the candle itself. In 1789, Lavoisier decomposed mercuric oxide into mercury and oxygen in a goose-necked retort, then let the oxygen react with the mercury and thus obtained mercuric oxide again. Thus he clarified the role of oxygen in processes of oxidation and reduction. The terms of oxygen, reduction and oxidation were coined by him, as well as the nomenclature used in inorganic chemistry even today.

Liebig's Laboratory

The great rise of German chemistry began with the research work of Justus von Liebig. Liebig (1803–1873) was professor of chemistry in Giessen until 1852 and then lived in Munich until he died. Liebig completed the analysis of the elements, founded chemical teaching in the laboratory in Germany and worked out the theory of artificial fertilizing, in addition to numerous other studies. The exhibition shows a rather idealistic reconstruction of the Giessen laboratory fitted out with instruments from Liebig's laboratory in Munich. A Liebig drying apparatus, a small laboratory stove, a gasometer and two Liebig condensers, used by the scientist himself, can be seen there. The flat-bottomed flasks come from the laboratory of Liebig's friend Wöhler.

Old pharmacy, of about 1800 (R)
As an example of an old pharmacy, the monastic pharmacy of St. Emmeram's at Regensburg was reconstructed here. Its equipment combines originals from different pharmacies and is one of the most valuable collections of the Deutsches Museum.

Uranium in everyday household
Uranium was rediscovered in 1789 by Martin Heinrich Klaproth, after it had been used in the late Roman period to colour mosaics. Until Antoine Henri Becquerel discovered natural radioactivity in 1896, and since then up to the present day, uranium has found uses in the form of its compounds (uranyl salts, uranium oxide) as an ingredient in orange-yellow and black glazes, and as an additive to glass flux.
The yellow-green fluorescence of uranyl-ion which occurs in daylight and even more so in long wave ultraviolet light is a characteristic of the electron configuration around the actinide atom, uranium, and makes it thus – unintentionally – into a radioactive element common in everyday life.

A portrait of Liebig by the painter Wilhelm Trautschold dominates the room. The famous – and somewhat idealistic – representation of the laboratory, hanging at the left of the entrance, was painted by the same artist in 1842.
Three showcases show typical chemical instruments of the first third of the past century. They belong to the estate of Johann B. Trommsdorf. Among them, there are such instruments as a large travel oxhydrogen eudiometer as used by Alessandro Volta, an equivalent slide rule of the William Hyde Wollaston type and a pycnometer from the workshop of Goethe's friend Christian Gottfried Körner of Jena.
In the large wall showcase, instruments from the estate of Eilhard Mitscherlich are shown: among these, the goniometer which he successfully used for the discovery of isomorphism, and the remains of an apparatus for the determination of vapour density, which he used for disproving the law of A. Avogadro; nevertheless, this law is correct. The other half of the showcase is dedicated to equipment formerly owned by R. W. Bunsen: it shows some adsorptiometers, an indigo prism and his eudiometer.

Experiments Section

The experimental part of the department is divided into sections corresponding to a few important fundamentals: the structure of matter, atom and molecule, chemical reaction, analysis and synthesis, biochemistry. In every room, the visitor may activate a variety of push-botton reactions and demonstrations.
A lecture hall in the centre of the department provides the visitors with a short lecture with experiments (at 11.00 a. m. on weekdays). In addition to that, lectures on special subjects can be held upon request for large groups (please contact the management of the department for a list of lecture subjects and an appointment).
Among the historical highlights of this section is the table on which Otto Hahn set up an arrangement of original instruments such as he and Fritz Strassmann had used in December 1938 for the discovery of nuclear fission of uranium. The counterpart of this table is the laboratory bench with original instruments from the estate of Hermann Staudinger, the founder of the theory of macromolecular chemistry. The end and culminating point of the department is the historic pharmacy, a reconstruction of the monastic pharmacy of St. Emmeram at Regensburg. Part of the pharmaceutical containers on display came from St. Emmeram (blue and yellow coat of arms on white ground), the others from famous former pharmacies of Munich, Regensburg and Nuremberg. Nearly all vessels and drawers are still filled with original preparations. Portable and ship's medicine cases as well as a collection of particularly curious medicines, such as mandrake and Spanish flies, complete the display. In front of the pharmacy, there is a pharmaceutical hearth of the type which was commonly used in the second half of the past century, fitted with a water bath, distillation apparatus, drying closet, ointment mixer etc.

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