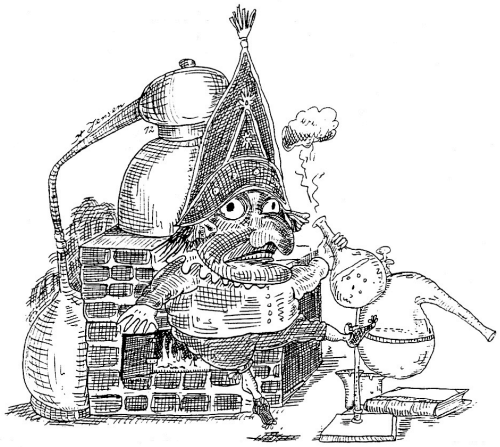
CHYMISTS:
THAT STRANGE CLASS OF MORTALS

Caricatures of Famous Chemists with a Few Physicists and Biologists Added

BY

WILLIAM B. JENSEN



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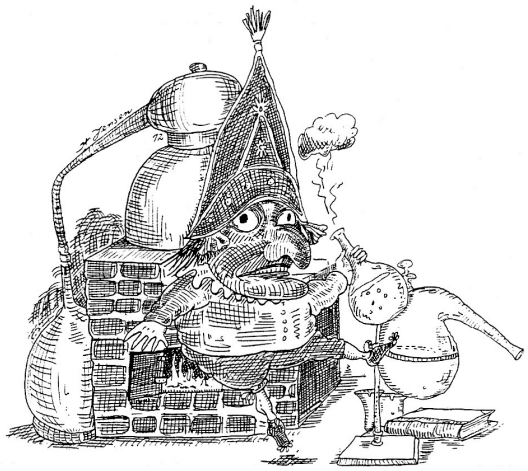

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"The chymists are a strange class of mortals, impelled by
an almost insane impulse to seek their pleasures amid
smoke and vapor, soot and flame, poisons and
poverty. Yet among all these evils I seem to
live so sweetly that may I die if I were to
changes places with the Persian King."

Johann Joachim Becher
Physica Subterranea, 1667

INTRODUCTION

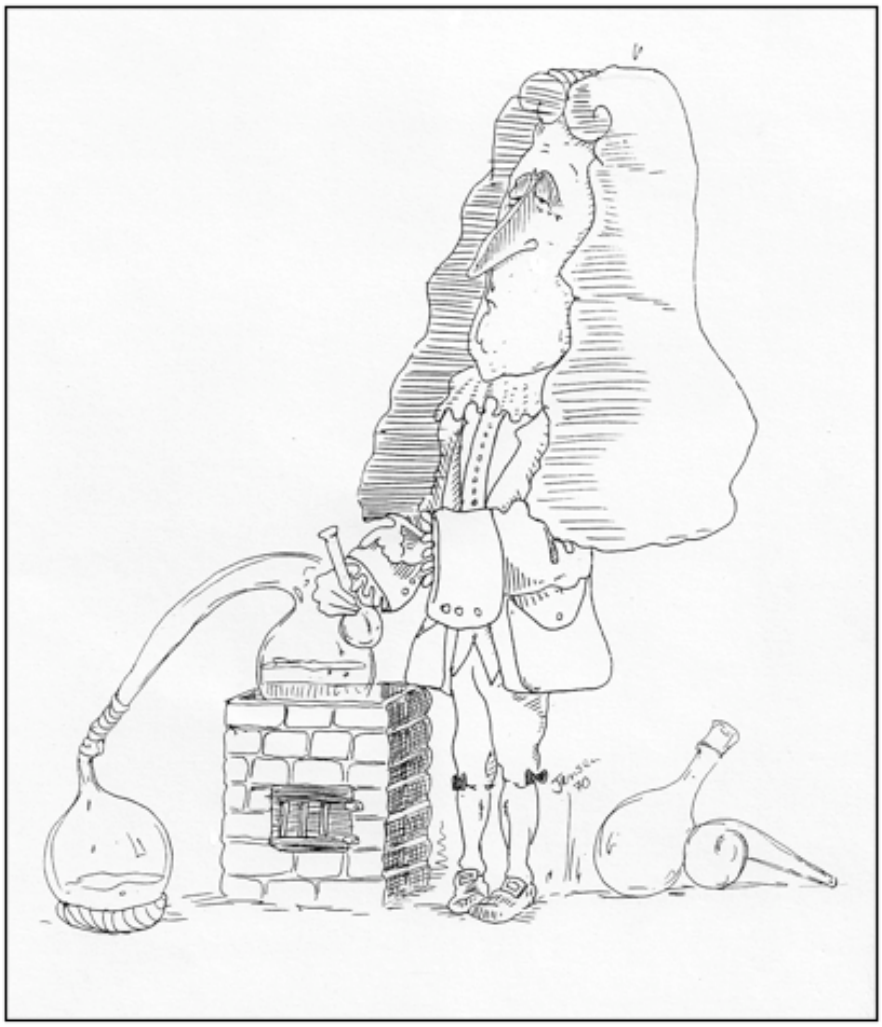
The majority of the following caricatures were done more than 40 years ago when I was a junior at the University of Wisconsin-Madison and attending Aaron Ihde's lectures on the history of chemistry. Each week, rather than taking lecture notes, I would instead select one of the chemists that Ihde was lecturing on and do a caricature based on the portraits found in Ihde's textbook, *The Development of Modern Chemistry* (1964). This original set has since been supplemented by about another half-dozen caricatures prompted by requests over the years from various individuals and journals. In the 1970s there was little interest in these drawings, but with the passage of time, a sort of underground demand for them has spontaneously arisen among teachers and students of chemistry and many have since been reproduced on coffee mugs, T-shirts, and on various internet sites. More recently I was informed that one of them (Robert Bunsen) was even being used as the logo for a rock band. In any case, I thought it was about time to collect and present them in a more permanent and convenient format by supplementing each drawing with a short biographical sketch of the subject in question, as well as with an occasional hint concerning the symbolism used.

Also included as an appendix is a short piece of chemical doggerel which I first published in 1972 under the title of "A Chemist's Annotated Mother Goose of Chemical Bonding Theory," in which I coupled variants of well-known nursery rhymes with caricatures of noted physicists and chemists connected in some fashion with the history of chemical bonding. Two of these (Langmuir and Pauling) already appear among the individual caricatures, but since these, unlike the nursery rhymes, also come with short biographical sketches, I hope readers are willing to forgive the redundancy.

William B. Jensen
April 2010

I
SCEPTICAL CHYMIST

Robert Boyle (1627-1691). Irish chemist and natural philosopher. As a son of the Earl of Cork, Boyle was independently wealthy and so was able to live the life of a private scientific "virtuoso." Best known for his advocacy of a mechanical corpuscular or particulate approach to physics and chemistry, as opposed to the older hylomorphic doctrines of Aristotle and Paracelsus, Boyle authored numerous books, of which his most famous was perhaps *The Sceptical Chymist*, first published in 1661. He is known to students of introductory chemistry today largely through his discovery of Boyle's law (1662), which states that the volume of a gas varies inversely with applied pressure at constant temperature.



SCEPTICAL CHYMIST

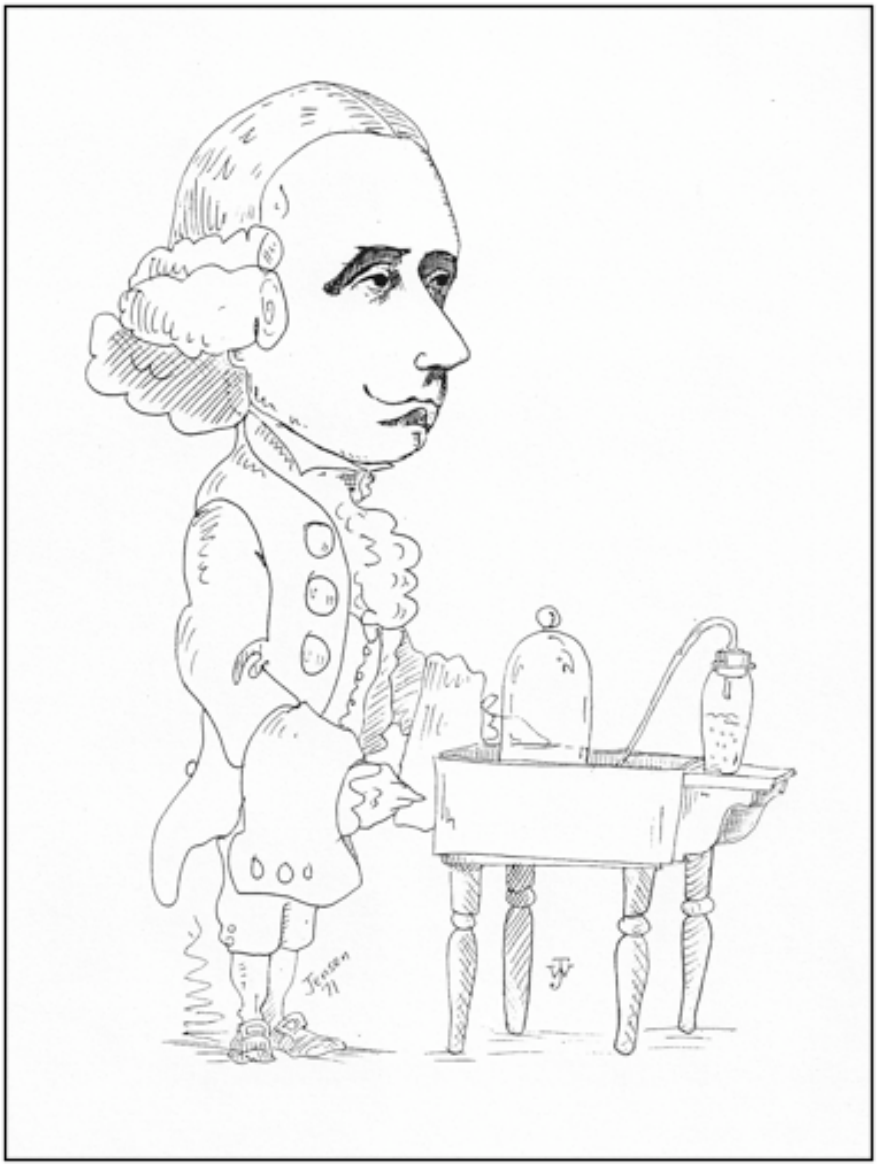
II

AIRS

Joseph Priestley (1733-1804). English chemist and unitarian minister. Priestley earned his living as a minister and as a teacher at various dissenting academies. His work in chemistry was done in his spare time and largely during the period when he served as private librarian to Lord Shelburne. It dealt almost exclusively with the use of the pneumatic trough to discover a large number of new "airs" or gases, including nitrogen oxide, nitrogen dioxide, dinitrogen oxide, ammonia, hydrogen chloride, sulfur dioxide and, most famously of all, dioxygen (1774), all of which were described in the various editions of his multi-volume work *Experiments and Observations on Different Kinds of Air*.

He also investigated the processes of brewing, photosynthesis, and respiration, and invented soda water. Priestley was a prolific writer, not only on chemistry, but also on the subjects of theology, history, geography, natural philosophy, and electricity. Due to his liberal political and religious opinions, his home and laboratory were destroyed by a Birmingham mob in 1791, and he spent his final years in the small village of Northumberland, Pennsylvania, where he wrote several pamphlets defending the outdated phlogiston theory against Lavoisier's newer oxygen theory of combustion.

CHYMISTS
THAT STRANGE CLASS OF MORTALS



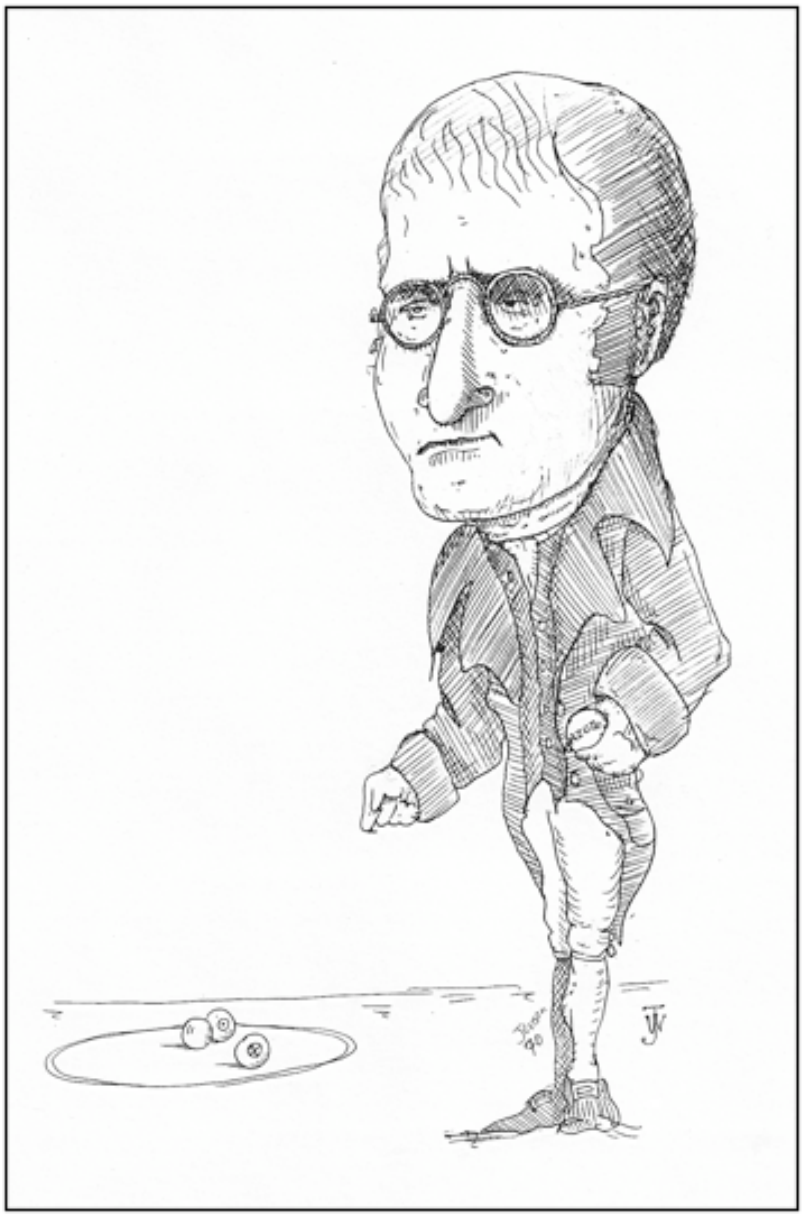
AIRS

III

ATOMIC MARBLES

John Dalton (1766-1844). English chemist and natural philosopher. A self-educated Quaker, Dalton was born in the village of Eaglesfield in northwest England and worked as a school teacher much of his life. Originally interested in meteorology, he kept detailed records of the local weather for many decades. This resulted in his first book, *Meteorological Observations and Essays* (1793) and eventually led to an interest in the chemistry and physics of mixed gases, to the discovery of his famous law of partial pressures, and ultimately to his chemical atomic theory.

Whereas 17th-century corpuscularism had focused on atomic shape and the 18th-century dynamic atomism of Newton on interatomic forces as the keys to chemical behavior, Dalton focused instead on atomic weight. In 1805 he published his first table of atomic weights and in 1808 he summarized his new atomistic approach to chemistry in the first volume of his book, *A New System of Chemical Philosophy*. Unfortunately Dalton's procedures for extracting atomic weights from gravimetric composition, via his so-called rules of simplicity, were flawed and virtually all of his reported atomic weights are now known to be incorrect. The result was almost 50 years of confusion in which chemists used a variety of competing atomic and equivalent weight scales. Not until the publication of Cannizzaro's work in 1858 was this problem finally resolved. Dalton is also known for having given (1794) the first accurate description of color blindness or "Daltonism."



ATOMIC MARBLES

IV

EQUAL VOLUMES

Amedeo Avogadro (1776-1856). Italian physicist. Initially a law student, Avogadro did not begin the study of physics until 1800, eventually becoming Professor of Physics at the Royal College at Vercelli (1809) and then at the University of Turin (1820,1834). He is best known for his essay of 1811 in which he attempted to reconcile Dalton's atomic theory with Gay-Lussac's law of combining volumes. His solution rested on two assumptions: 1) equal volumes of gases at the same temperature and pressure contain equal numbers of molecules, and 2) the molecules of simple substances could be polyatomic. The first assumption allowed one to determine molecular weights by measuring gas densities, and the second allowed one to extract atomic weights from the molecular weights of simple substances given a knowledge of the volumetric stoichiometries of their gas-phase reactions.

Unfortunately Avogardro's second assumption was at variance with the chemical theory of the time, which assumed that all simple substances were inherently monoatomic, and his procedure for extracting atomic weights from molecular weights could only be applied to a few elements. As a consequence, his work was largely ignored during his lifetime. It was only in 1858, when the second assumption was no longer in conflict with accepted theory, that Cannizzaro was able to reawaken an interest in Avogadro's work through his discovery of a more general method for extracting atomic weights from the resulting molecular weights.

CHYMISTS
THAT STRANGE CLASS OF MORTALS

EQUAL VOLUMES

V

FOND DICTATOR

Jöns Jacob Berzelius (1779-1848). Swedish chemist. Originally trained as a physician, Berzelius was largely self-taught as a chemist and spent most of his adult life as a professor at the Karolinska Medical Institute in Stockholm. A superb analytical chemist, he is credited with the discovery of the elements cerium (1803), thorium (1815), and selenium (1817) and with being the first to isolate the elements silicon, titanium, and zirconium. He is also responsible for having almost single-handedly generated the first comprehensive table of accurate atomic weights (though several of his values are now known, for theoretical reasons, to be either multiples or fractions of our current values).

However, Berzelius is perhaps best known for his electrochemical or dualistic theory of chemical combination, which dominated chemical theory during much of the first half of the 19th century, and for his introduction of our current chemical symbolism based on the use of letter abbreviations for each atom type and numerical subscripts to represent their combining ratios. He was also the author of an influential multi-volume textbook, monographs on blowpipe analysis and the chemical classification of minerals, and of an annual review of chemical research (the *Jahres-Bericht*) which he published between 1822-1848. Through this latter medium he was able to "dictate" much of what happened in European chemistry and to coin much of our present-day chemical vocabulary, including such terms as halogen, isomer, polymer, catalyst, and protein.

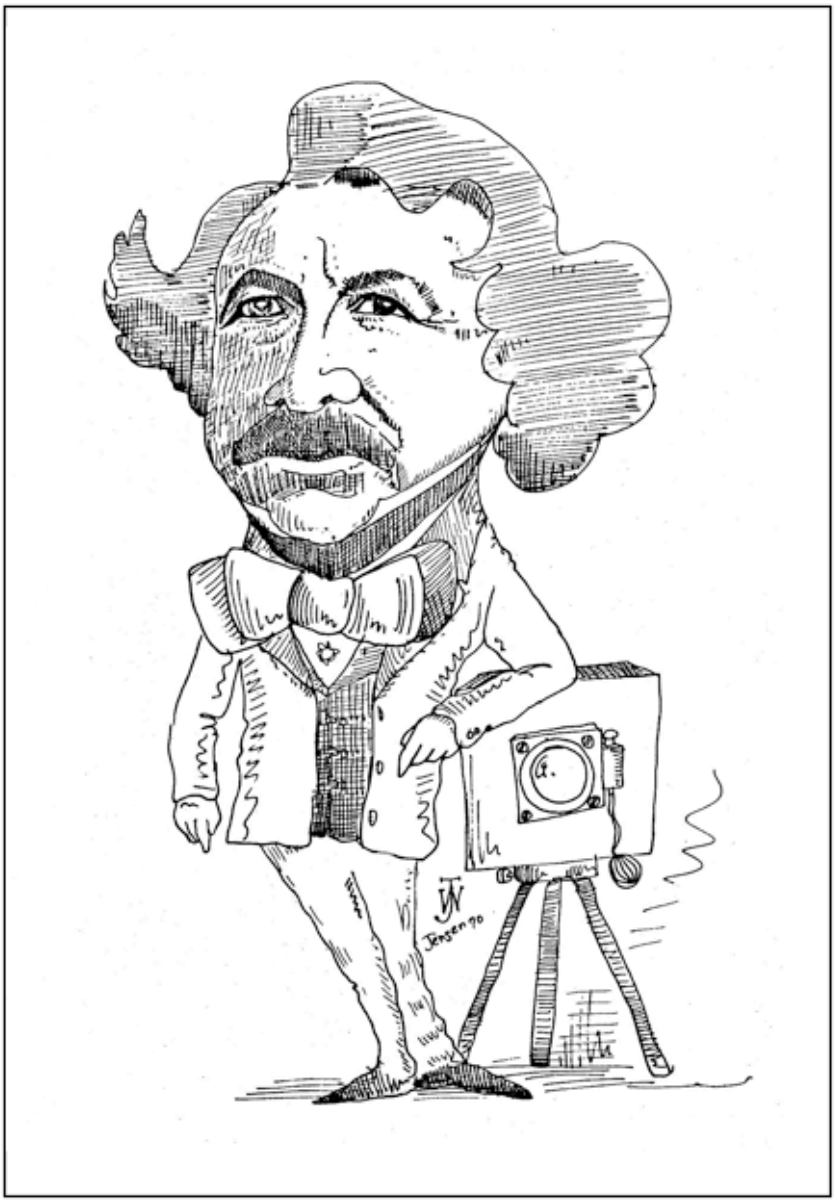
FOND DICTATOR

VI

PHOTO

Louis Jacques Mandé Daguerre (1789-1851). French artist and inventor. Born in Cormeilles near Paris, Daguerre worked as a painter of opera scenery and dioramas. These activities led to a interest in the artistic possibilities of permanently capturing optical images on chemically-sensitized surfaces. Starting in 1826 he collaborated with Joseph Nicéphore Niepce on various attempts to develop a practical photographic system and, after the death of Niepce in 1833, continued these efforts on his own. By 1839 he had achieved success and formally presented his process to the French Academy of Sciences as a gift to the world. Known in his honor as the "daguerrotype," it consisted of exposing copper plates coated with a mixture of silver bromide and iodide to the light image in question and in developing the resulting latent image using mercury vapor – a process which gave the resulting images a silvery mirror-like appearance. Though Daguerre was not a chemist and his original process would, by the 1860s, be largely replaced by alternative photographic systems, his discovery nevertheless represents not only a revolutionary breakthrough in photochemistry – but one which was destined to have profound historical and cultural consequences.

CHYMISTS
THAT STRANGE CLASS OF MORTALS



PHOTO

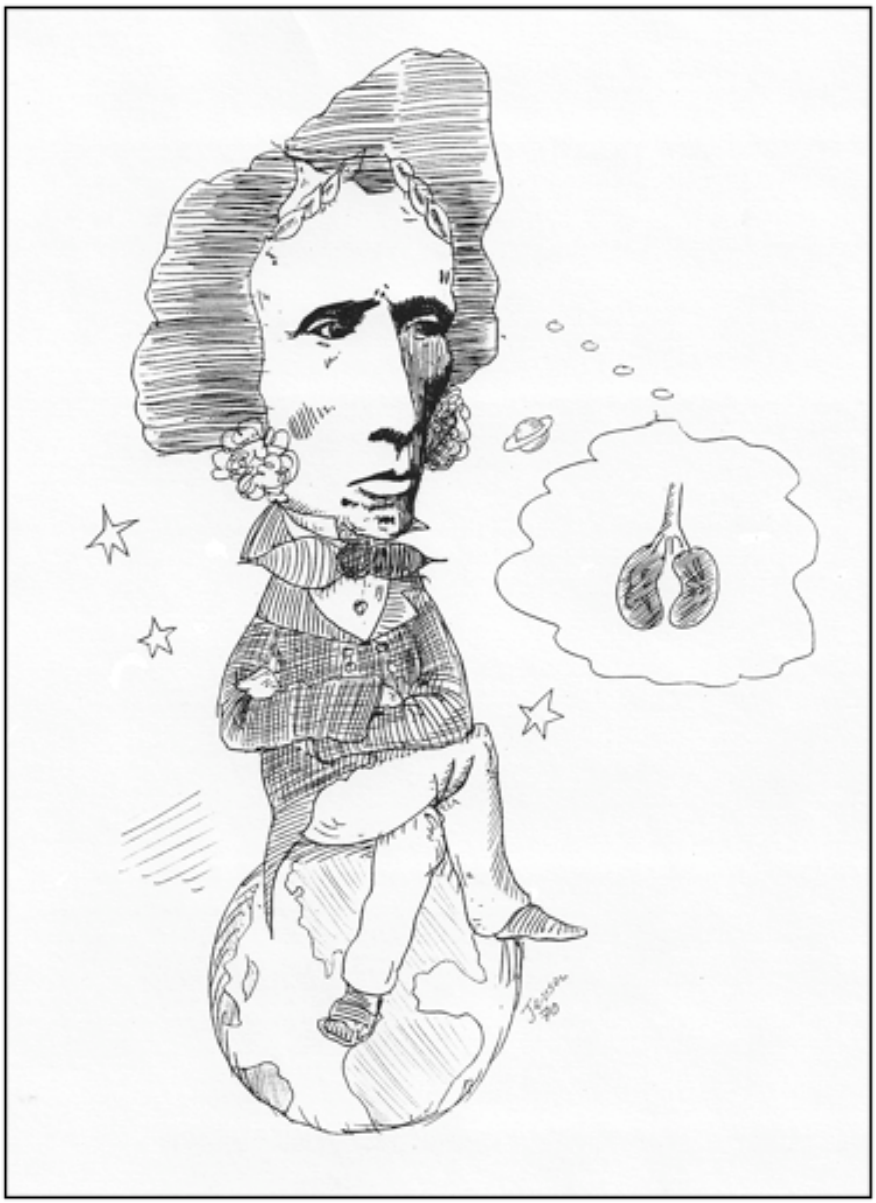
VII
THE ATTITUDE OF AN ALCHEMIST

Christian Friedrich Schönbein (1799-1868). German-Swiss chemist. Born in Metzingen Germany and trained at the Universities of Tübingen and Erlangen, Schönbein served as Professor of Chemistry at the University of Basel from 1828 until his death in 1868. Best known for his discovery of ozone (1840) and of both guncotton (1846) and collodion, he also did important work on the passivity of metals. His somewhat bizarre attempts to theoretically rationalize the differences between dioxygen gas, ozone gas, and hydrogen peroxide using electrochemical dualism, and his disregard for the finer points of the atomic theory and the law of constant composition, later led the German physical chemist, Wilhelm Ostwald, to comment that, "of all modern chemists, Schönbein most retained the mental attitude of an alchemist."

THE ATTITUDE OF AN ALCHEMIST

VIII
IN THE BEGINNING WAS A DOG KIDNEY

Friedrich Wöhler (1800-1882). German chemist. A student of Leopold Gmelin at Heidelberg and of the great Berzelius at Stockholm, Wöhler held teaching positions at Berlin and Kassel before accepting the chair in chemistry at Göttingen in 1836, where he remained for the rest of his life. An eclectic chemist, he is best known in the field of organic chemistry for his collaborative work with Liebig on the isomerism of the fulminates and cyanates (1823-1824) and on the chemistry of the benzoyl radical (1832), and for his synthesis of urea from ammonium cyanate (1828), which was later interpreted as a decisive blow against the doctrine of vitalism. In the field of inorganic chemistry he is best known for his isolation of the elements aluminum (1827) and beryllium (1828) and, in the field of chemical education, for the many 19th-century American chemists who came to study in his laboratory. The caricature is obviously a reference to Wöhler's synthesis of urea and a remark which he made to Berzelius to the effect that he could now perform in a test tube what had previously been possible only in the kidney of a dog.



IN THE BEGINNING WAS A DOG KIDNEY

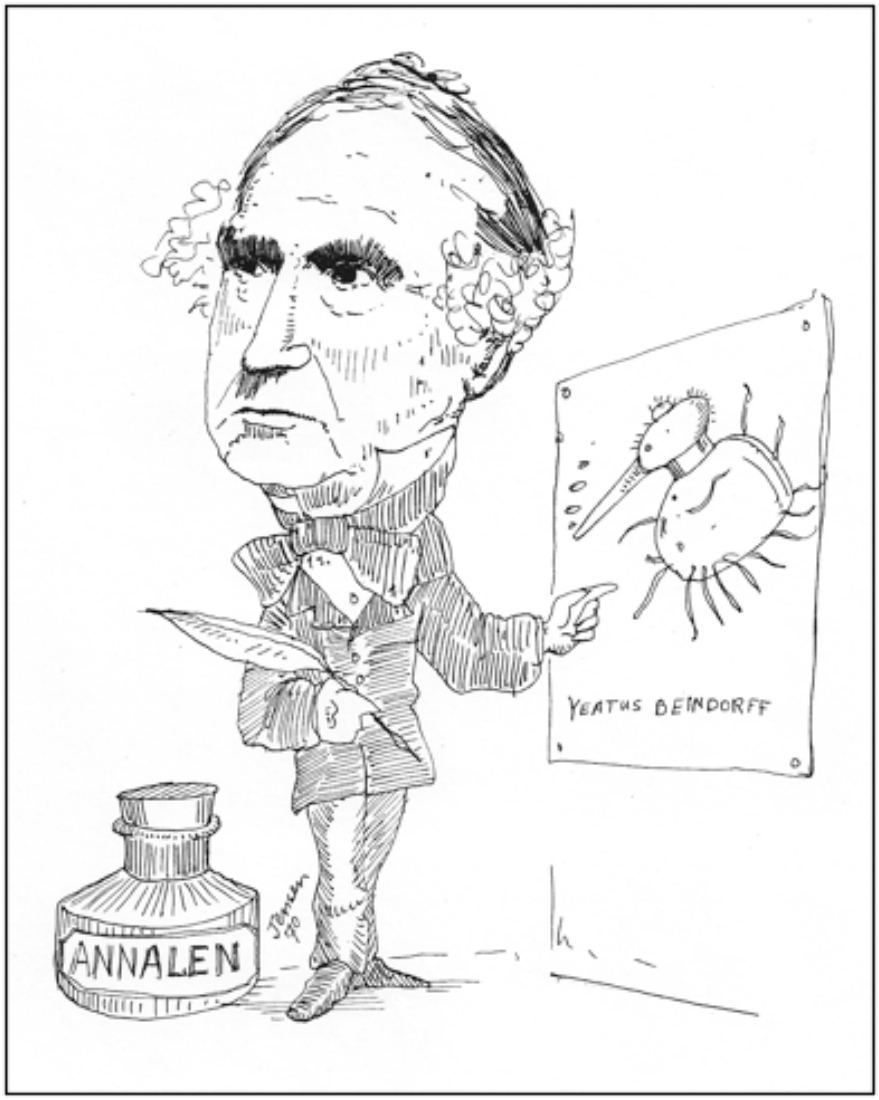
IX

ANNALEN

Justus von Liebig (1803-1873). German chemist. Professor at Giessen (1824) and Munich (1852), Liebig's teaching laboratory at Giessen served as the model for the advanced training of chemists in the first half of the 19th century and included many foreign students from Great Britain and the United States. Through his editorship (starting in 1832) of the journal, *Annalen der Chemie und Pharmacie* (which is still published under the title of *Liebig's Annalen*), he exercised enormous influence on the early development of organic chemistry, agricultural chemistry, and physiology. He perfected organic combustion analysis (1837) and the counter-current laboratory condenser (1843), and, in collaboration with his close friend, Friedrich Wöhler, did pioneering work on the isomerism of fulminates and cyanates (1823-1826) and on the chemistry of the benzoyl radical (1832). He also made important contributions to the theory of polybasic acids (1838).

Liebig often conducted polemics in his journal and even went so far as to publish satires of chemical views that he opposed. The caricature makes reference to one of these satires involving a dispute over the nature of fermentation. For details see P. de Mayo, A. Stoessi, M. Usselman, "The Liebig/Wöhler Satire on Fermentation," *J. Chem. Educ.*, **1984**, *61*, 552-553.

CHYMISTS
THAT STRANGE CLASS OF MORTALS



ANNALEN

X

BURNER

Robert Wilhelm Bunsen (1811-1899). German chemist. Professor of Chemistry at the Universities of Kassel (1836), Marburg (1841) and Heidelberg (1852), Bunsen is perhaps best known for his work on spectrum analysis (1860), done in collaboration with the German physicist, Gustav Kirchhoff, and their subsequent spectroscopic discovery of the elements cesium (1860) and rubidium (1861). He also did notable work on the chemistry of organoarsenic compounds (1837-1842), the laws of photochemistry (1855-1867), and the refinement of gas analysis (1857). Known to students of general chemistry for his introduction of the tubular laboratory gas burner in 1855, Bunsen was a prolific inventor of chemical apparatus, including the Bunsen carbon battery (1841), the grease-spot photometer (1843), the hydrogen chloride actinometer (1857), and an improved ice calorimeter (1870).

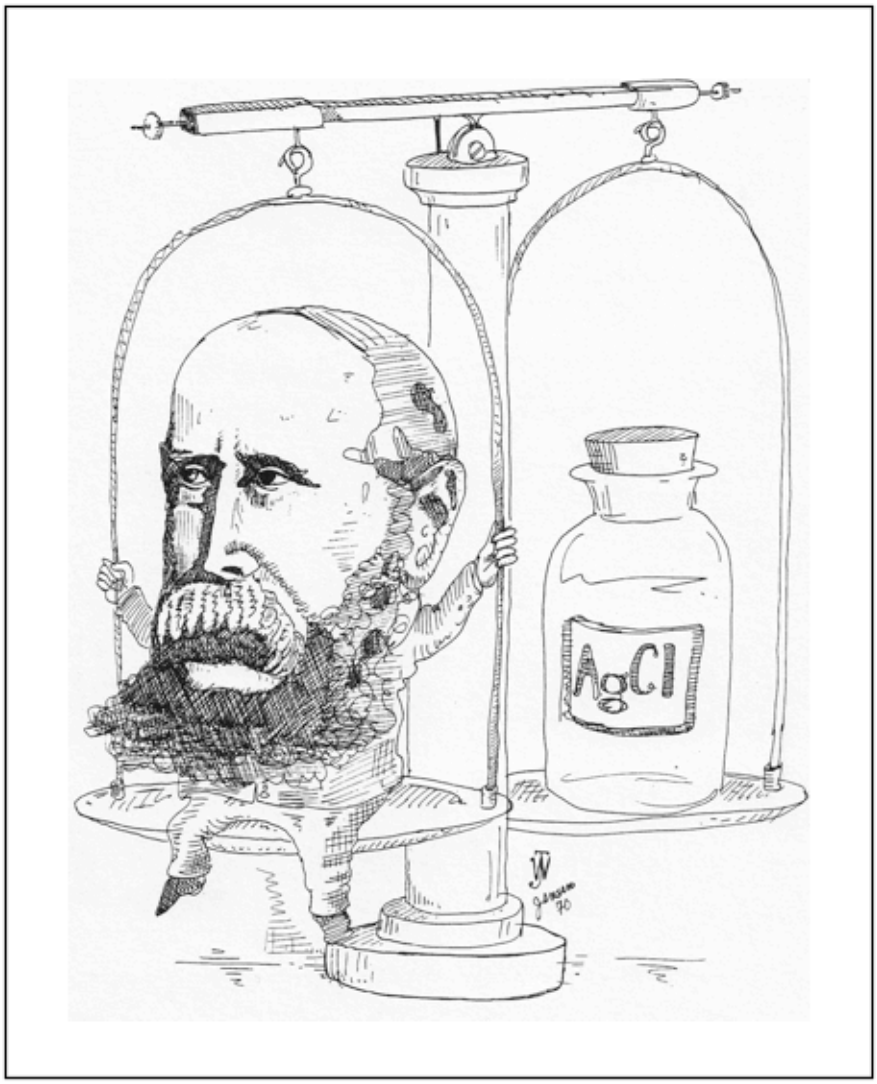
BURNER

XI

ATOMIC WEIGHT

Jean Servais Stas (1813-1891). Belgian chemist. Born in Louvain, Stas was originally trained as a physician before switching to chemistry and serving as an assistant to the famous French chemist, Jean Dumas. From 1840-1869 he served as Professor of Chemistry at the Royal Military School in Brussels and from 1869-1872 as Commissioner of the Mint. Best known for his painstaking and highly accurate determinations of various atomic weights, usually employing a series of conversions that ultimately led to a final precipitation and gravimetric determination of silver chloride, Stas began his work as a supporter of Prout's hypothesis that all atomic weights were whole number multiples of that of hydrogen. However he soon discovered cases, such as chlorine, for which the fractional residues failed to disappear no matter how refined the determinations and so ended in vigorously opposing Prout's original suggestion.

CHYMISTS
THAT STRANGE CLASS OF MORTALS



ATOMIC WEIGHT

XII

TYPE

Charles Frédéric Gerhardt (1816-1856). French chemist. A student of Liebig at Giessen and an assistant to Dumas at Paris, Gerhardt became professor of chemistry first at Montpelier (1844-1848) and, shortly before his premature death at age 50, at the University of Strasbourg (1855). Best known for his attempts to systematize the newly emerging field of organic chemistry – much of which was done in collaboration with his fellow French chemist, Auguste Laurent – he is considered as one of the founders of type theory and as one of the pioneers in the application of both the functional group and the homologous series concepts to organic chemistry – approaches which formed the foundations of his influential textbooks *Précis de chimie organique* (1844) and *Introduction á l'etude de la chimie par le système unitaire* (1848).

CHYMISTS
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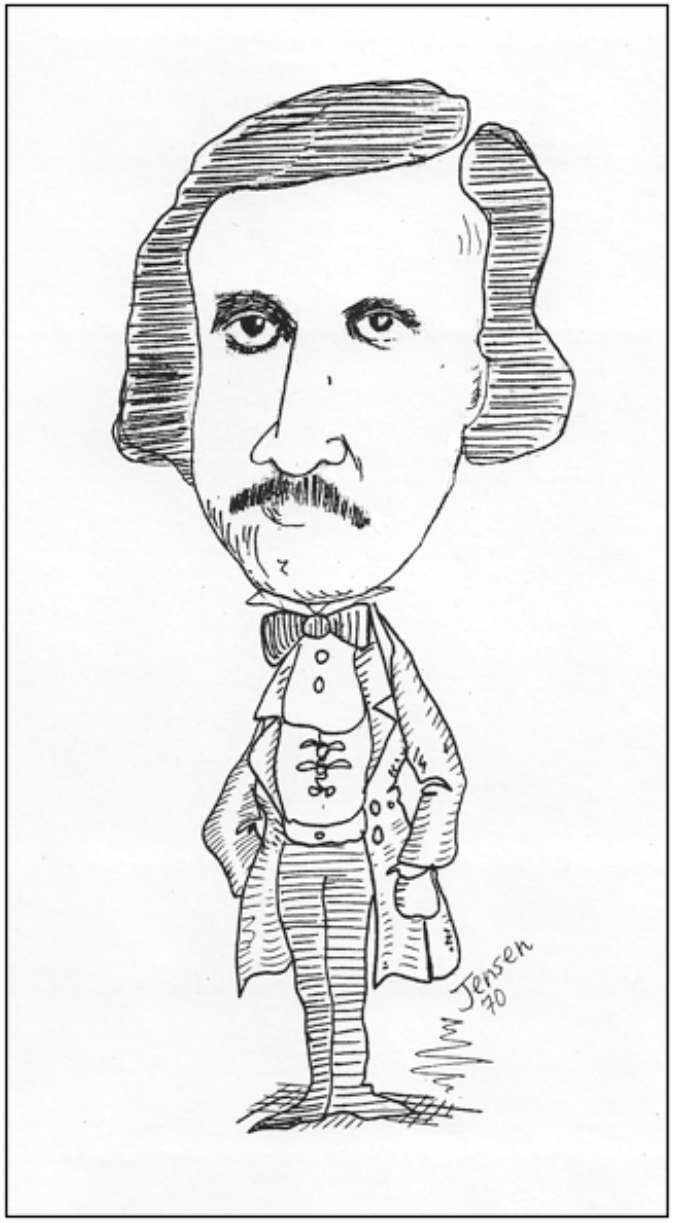

TYPE

XIII

HISTORIAN

Hermann Kopp (1817-1892). German chemist and historian. Professor of Chemistry at Giessen (1843-1862) and Heidelberg (1863-1892), Kopp did pioneering work on the correlations between chemical composition and structure and the physical properties of organic compounds, such as the relationship between hydrocarbon chain lengths and boiling points. His discovery that the molar heat capacities of solids are the approximate additive sum of the molar heat capacities of their component atoms is known as Kopp's rule. Today, however, he is largely remembered for his pioneering contributions to the history of chemistry, including his epic four-volume *Geschichte der Chemie* (1843-1847), and his monographs: *Beiträge zur Geschichte der Chemie* (1871-1873), *Die Entwicklung der Chemie in der neueren Zeit* (1875), and *Die Alchemie in älterer und neuere Zeit* (1886).


TINTE
GESCHICHTE DER CHEMIE
KOPP
BAND I
GESCHICHTE DER CHEMIE
KOPP
BAND II

HISTORIAN

XIV

AMINE

Charles Adolphe Wurtz (1817-1884). French chemist. Educated at Strasbourg in medicine, Wurtz received his chemical training at Giessen under Liebig and at Paris under Dumas, and served as Professor of Chemistry at the École de Médecine (1853) and at the Sorbonne (1874). Best known for his contributions to type theory through his studies of the amines as primary examples of the ammonia type (1849) and his discovery of the Wurtz reaction (1855) for the extension of hydrocarbon chains, he also did important work on the polyalcohols or glycols.

A prolific writer of textbooks and monographs, of which the most successful was probably his popular account of the evolution of the atomic theory – *La théorie atomique* (1879) – Wurtz also served as editor of the *Annales de chimie et physique* and of the important *Dictionnaire de chimie pure et appliquée* (1868-1878). For the latter he wrote a lengthy historical introduction which was simultaneously released as a separate book (*Histoire des doctrines chimiques depuis Lavoisier jusqu'à nos jours,* 1868), and which opens with the infamous chauvinist remark: "Chemistry is a French science. It was founded by Lavoisier of immortal memory."

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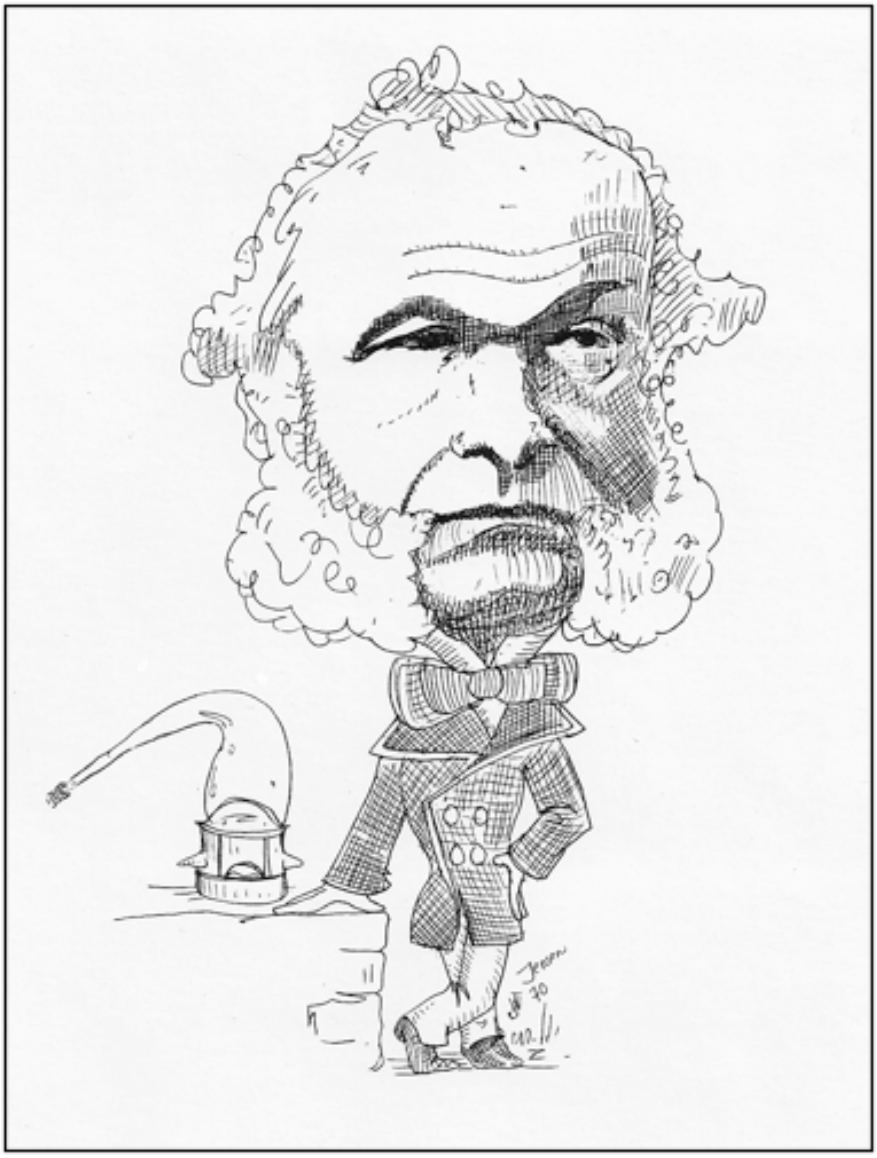


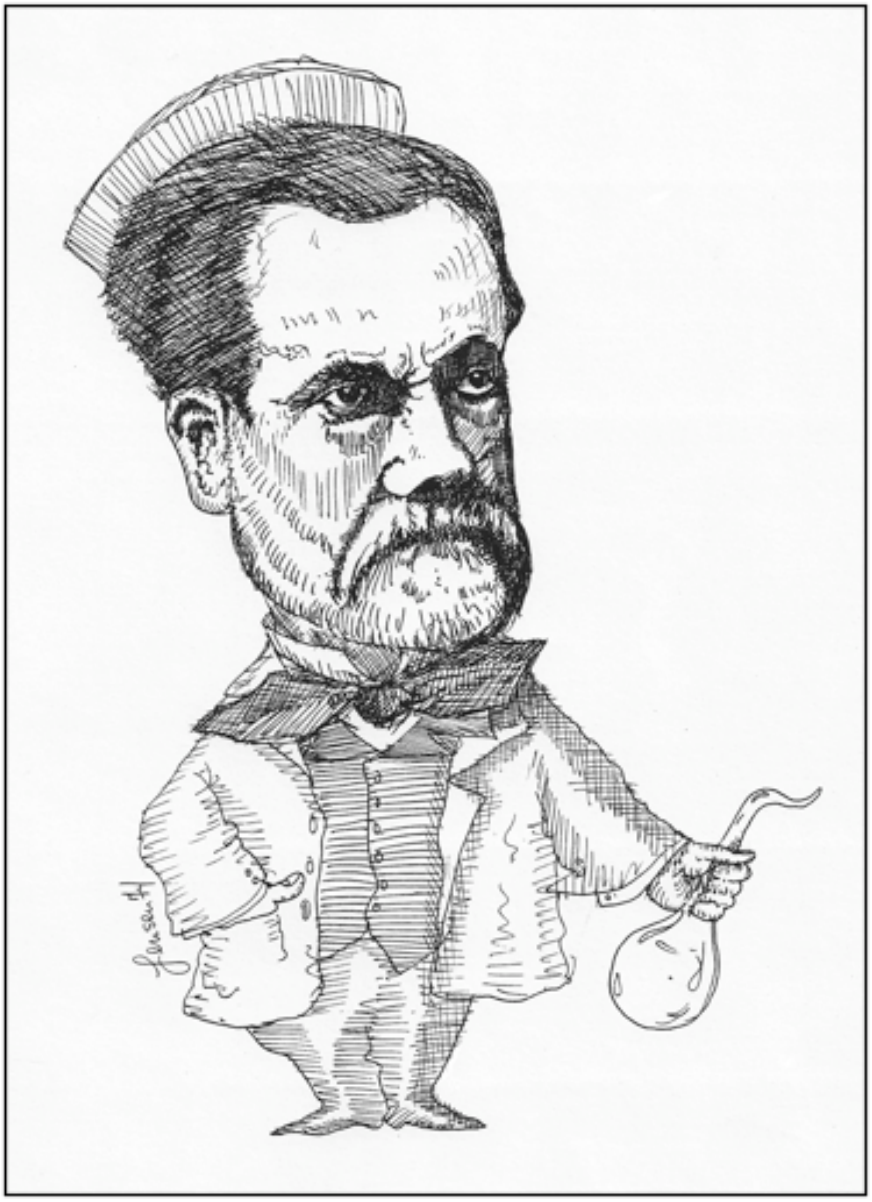
AMINE

XV

ASYMMETRIC

Louis Pasteur (1822-1895). French chemist and microbiologist. Born in Dole, the son of a tanner, Pasteur was trained as a chemist at the École Normale Supérieure in Paris. He served as Professor of Chemistry at Strasbourg (1849), Lille (1854), the École Normale (1857), and the Sorbonne (1867) before becoming head of the physiological chemistry laboratory at the École Normale in 1874. From 1888 until his death in 1895 he served as director of the Pasteur Institute.

Pasteur is best known to the general public for his work in the field of microbiology, including his studies of fermentation and "pasteurization" (1856), spontaneous generation (1862), silkworm disease (1865), anthrax (1877), and rabies (1885). His equally significant contributions to chemistry date from his doctoral work in 1848 and his discovery that the optical activity of solutions of tartaric acid salts correlated with a fundamental asymmetry in the crystal forms of the corresponding solids and his subsequent suggestion (1860) that such asymmetry may extend to the molecular level as well – an idea which became one the cornerstones of van't Hoff's theory of the tetrahedral carbon atom and of modern stereochemistry.

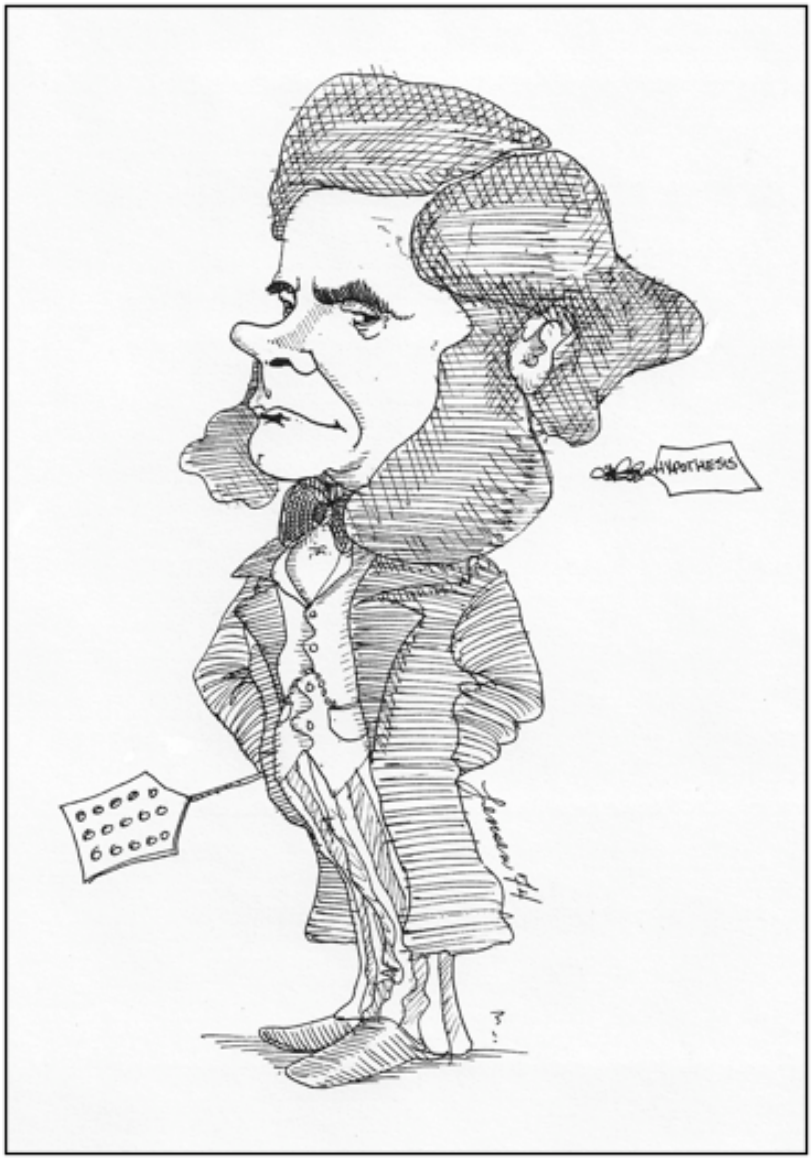


ASYMMETRIC

XVI

NASTY LITTLE FACT

Thomas Henry Huxley (1825-1895). British biologist. Educated as a medical doctor at Charing Cross Hospital, Huxley found his first employment as the surgeon aboard the vessel *HMS Rattlesnake,* which had been assigned the task of surveying the Torres Strait between Australia and Papua New Guinea. While aboard, he conducted a detailed study of the jellyfish and related species which eventually led to his election to the Royal Society (1851). In 1856 he became a lecturer in natural history at the Royal School of Mines in London. Though he did numerous important studies on the comparative anatomy of various animal species, he is today best remembered for his vigorous defense of Darwin's theory of evolution, for which he earned the title of "Darwin's Bulldog," and for his coining of the word "agnosticism." The caricature refers to remark of Huxley's concerning his friend – the English speculative philosopher, Herbert Spencer – to the effect that Spencer's idea of tragedy was "the disproof of a beautiful hypothesis by a nasty little fact."



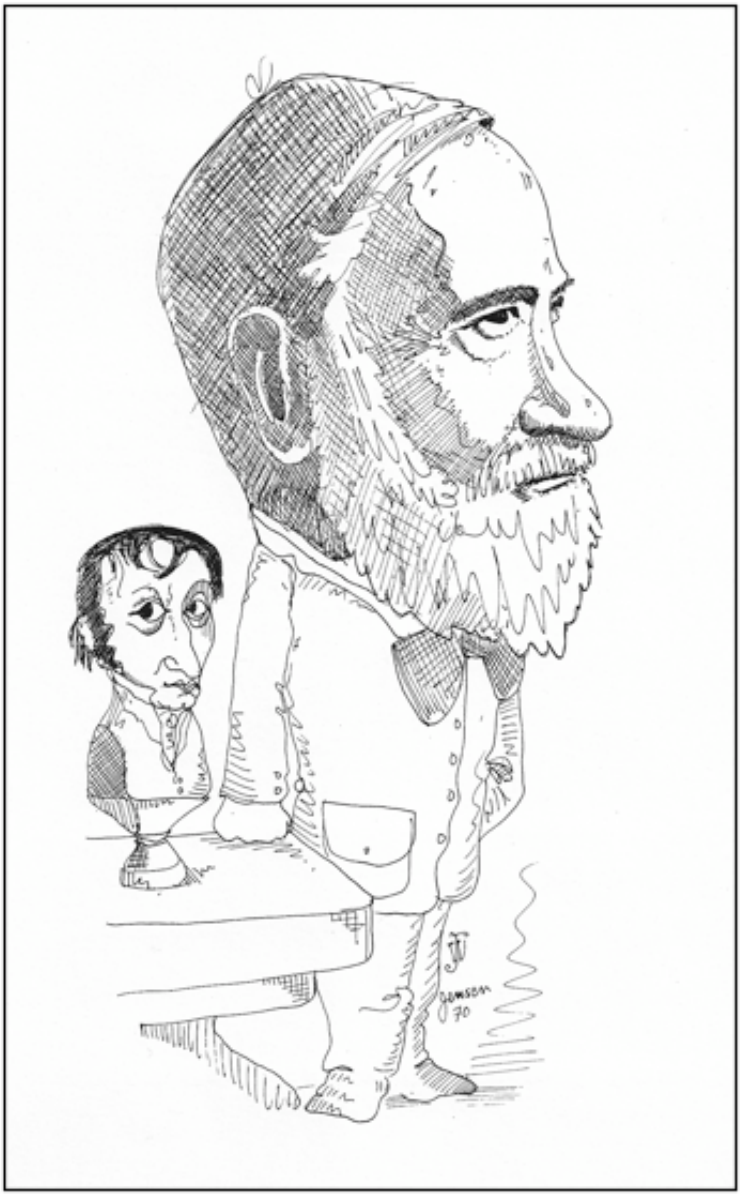
NASTY LITTLE FACT

XVII

MOLECULAR WEIGHT

Stanislao Cannizzaro (1826-1910). Italian chemist. Professor at Alessandria (1851-1854), Genoa (1855-1859), Palermo (1860-1869) and Rome (1870-1910), Cannizzaro is best known for his discovery of the Cannizzaro reaction in organic chemistry for the conversion of aromatic aldehydes into the corresponding acids and alcohols, and for his successful resolution of the atomic weight problem.

Though Dalton had introduced the idea of extracting atomic weights from gravimetric data in 1803, he was unable to do this in a completely unambiguous fashion and, as a result, 50 years of chaos followed during which chemists used a variety of competing atomic and equivalent weight values. In 1858 Cannizzaro published a small pamphlet in which he reasserted Avogadro's earlier hypothesis (1811) that gas densities at equal pressures and temperatures were directly proportional to molecular weights. Whereas Avogadro had attempted to extract atomic weights from the resulting molecular weights by using the volumetric stoichiometries of gas reactions – a procedure that could be applied only to a few elements – Cannizzaro showed how this same information could be extracted by using the gravimetric composition of an element's volatile compounds – a procedure that was virtually universal. With Cannizzaro's advance, chemists finally acquired a standard set of atomic weights and were able to determine unambiguous and universally accepted compositional formulas for their compounds.



MOLECULAR WEIGHT

XVIII

ALCHEMY

Marcellin Pierre Eugène Berthelot (1827-1907). French chemist. A student of Balard at the Collége de France, Berthelot served as Professor of Chemistry at the École Supériere de Pharmacie (1859) and at the Collége de France (1864), as well as holding various governmental positions, including Minister of Higher Education (1881), Senator (1886), and French Foreign Minister (1895). Remembered today primarily for his classic studies with Pèan de Saint Gilles on the kinetics of the esterification reaction (1862), Berthelot was also a prolific writer of books, and published more than two dozen during his lifetime dealing with such diverse areas as the direct synthesis of organic compounds from inorganic precursors, the chemistry of sugars, the chemistry of explosives, thermo-chemistry, agricultural chemistry, philosophy of science, and the history of alchemy and early chemistry. The caricature is obviously a reference to his contributions to the later area, which included reproductions, translations and commentaries on some of the earliest surviving chemical recipe books and alchemical manuscripts – some dating as far back as 4th-century Greco-Roman Egypt.

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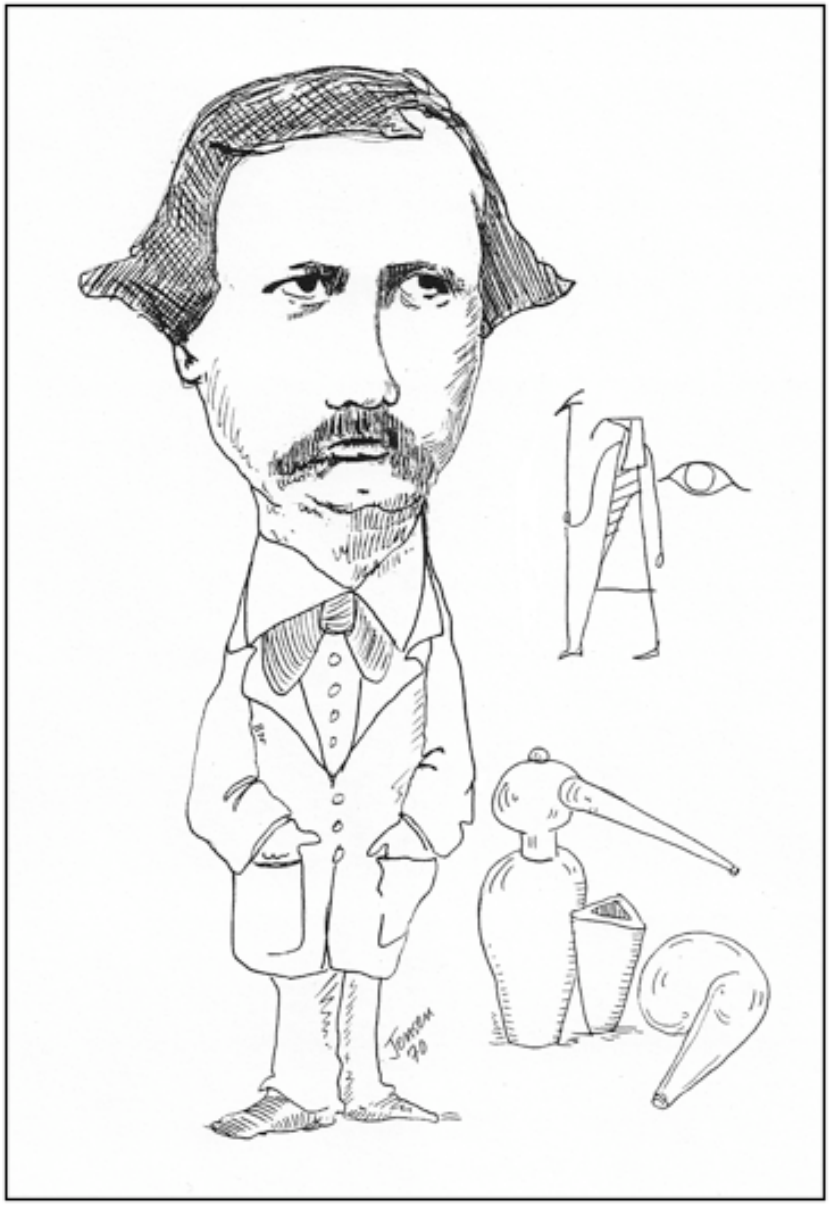
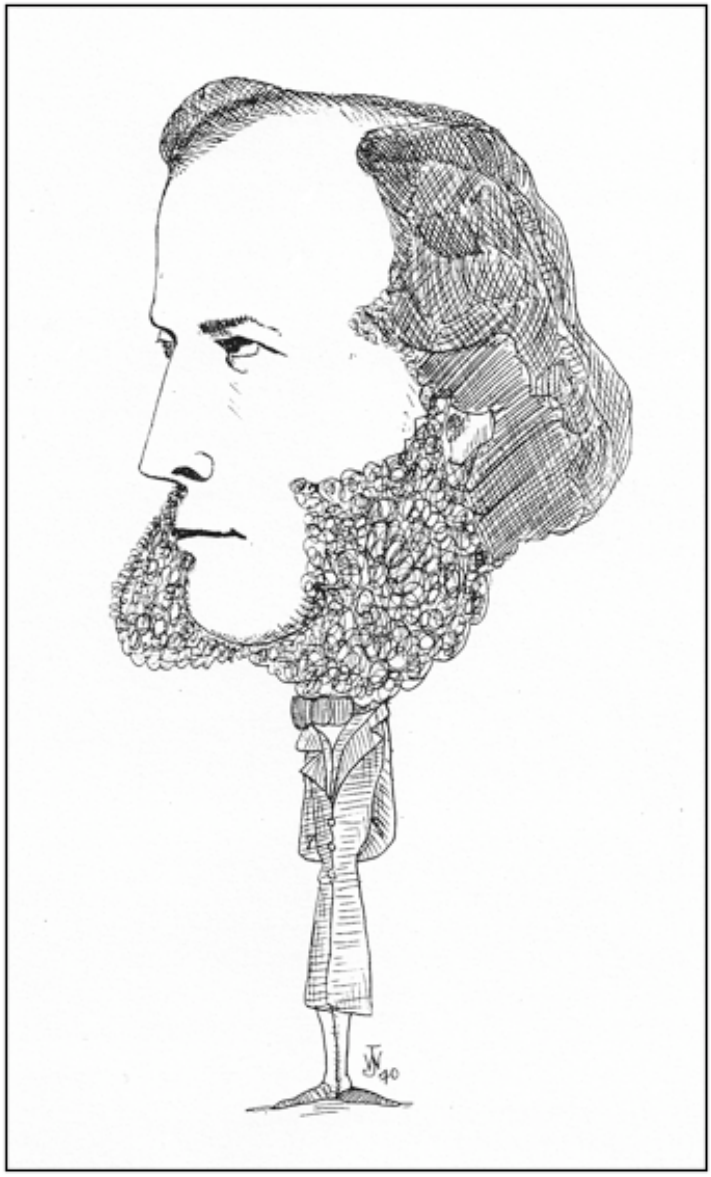


ALCHEMY

XIX

BENZENE

Friedrich August Kekulé (1829-1896). German chemist. Initially a student of architecture, Kekulé studied chemistry under Liebig at Giessen and under Dumas in Paris. After brief periods in Switzerland and England (1854), and at the University of Heidelberg (1856), he became Professor of Chemistry at the Universities of Ghent (1859) and Bonn (1867). Acknowledged as one of the founders of classical molecular structure theory, Kekulé is best known for his proposal (also independently made by the Scottish chemist, Archibald Scott Couper) that tetravalent carbon can undergo self-linkage to form homo-catenated chains and rings (1858), and for his hexagonal cyclic structure for the benzene molecule (1865).

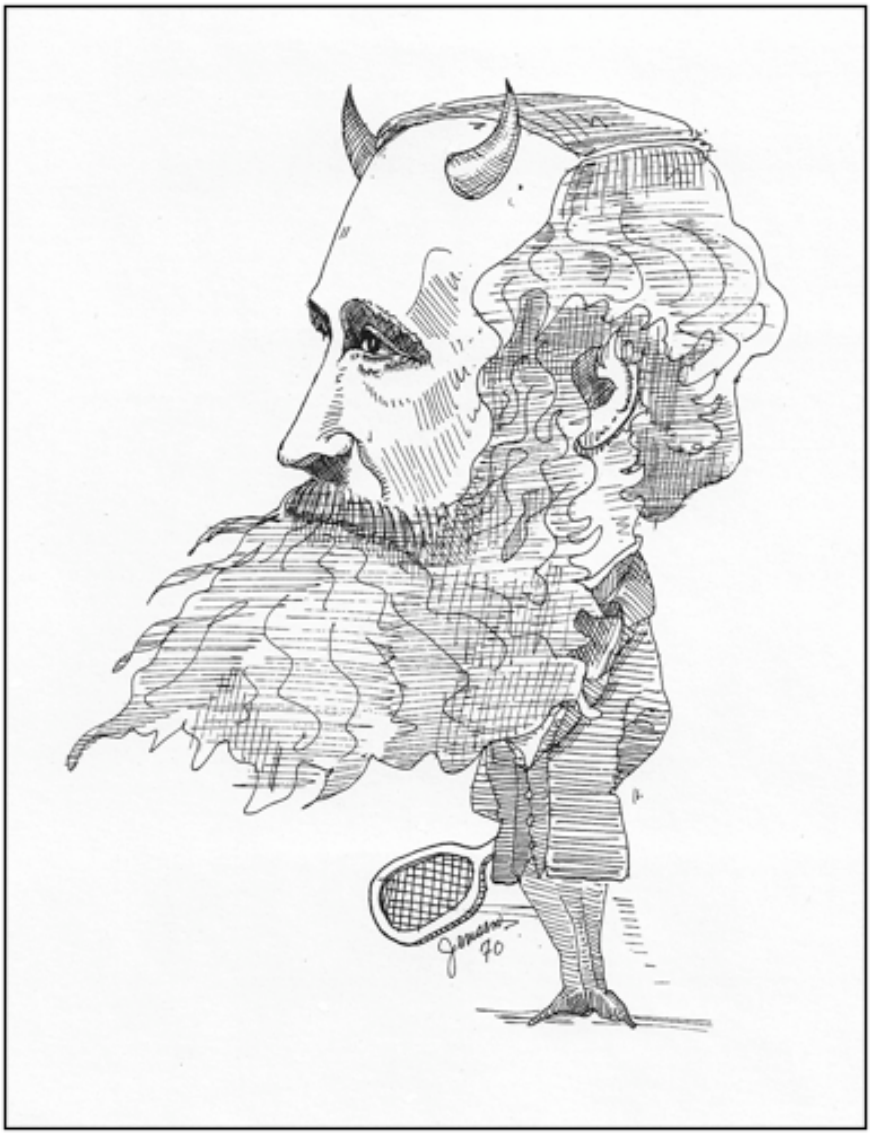


BENZENE

XX

DEMON

James Clerk Maxwell (1831-1879). British Physicist. Educated at the Universities of Edinburgh and Cambridge, Maxwell held positions at Marishal College in Aberdeen (1856), King's College in London (1860), and Cambridge University (1874). Something of a child prodigy, he is best remembered for his work on color theory (1855); his theory that the rings of Saturn are particulate (1857); his important contributions to the kinetic theory of gases, including the well-known Maxwell distribution; and his electromagnetic theory of light, which he summarized in his 1873 magnum opus, *Treatise on Electricity and Magnetism*. The caricature is an obvious reference to the well-known hypothetical molecular "sorting demon" which Maxwell introduced in 1871 in order to illustrate the statistical nature of the second law of thermodynamics.



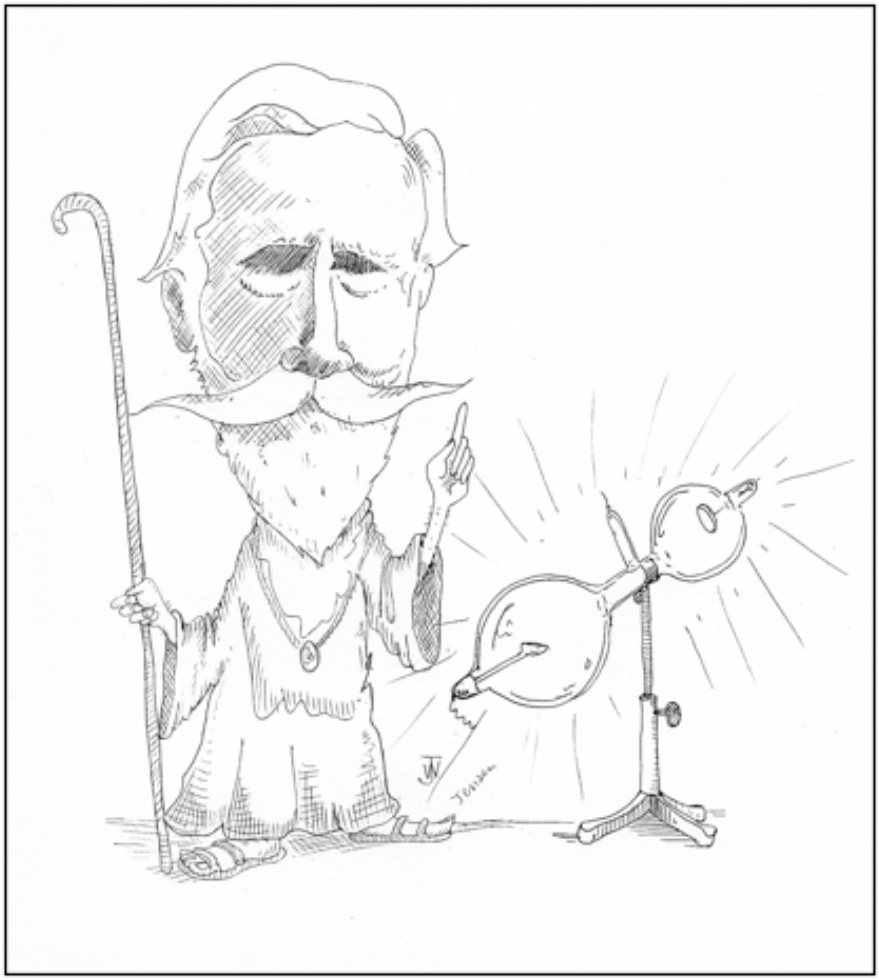
DEMON

XXI

LIKE MOSES AND HIS BURNING BUSH

William Crookes (1832-1919). British chemist. Educated in London at the Royal College of Chemistry under August Hofmann, Crookes spent his early years in the employ of the Radcliffe Observatory in Oxford and the Chester College of Science. In 1856, however, he moved to London, where he devoted his life to consulting work, private research, and to the publication of his weekly journal, *The Chemical News*, which he began in 1860. He also translated and published numerous books on industrial chemistry, as well as stenographic accounts of several of Michael Faraday's popular juvenile lectures at the Royal Institution, including *The Various Forces of Nature* (1860) and *The Chemical History of the Candle* (1861).

Best known for his spectroscopic discovery of the element thallium (1861) and his invention of the radiometer (1875) and spinthariscope (1903), Crookes also made substantial improvements in the design of gaseous discharge tubes and in the investigation of cathode rays, which he identified with a "fourth state of matter." Many of his tube designs were used as standard demonstrations until the 1980s. Beginning in the 1870s, Crookes also became increasingly interested in psychic phenomena and began to devote a substantial amount of his time to the investigation of various mediums. The caricature refers to a period characterization of Crookes and his speculations on a fourth state of matter and the nature of the periodic law by comparing the revelations of his discharge tubes to the burning bush of Moses.

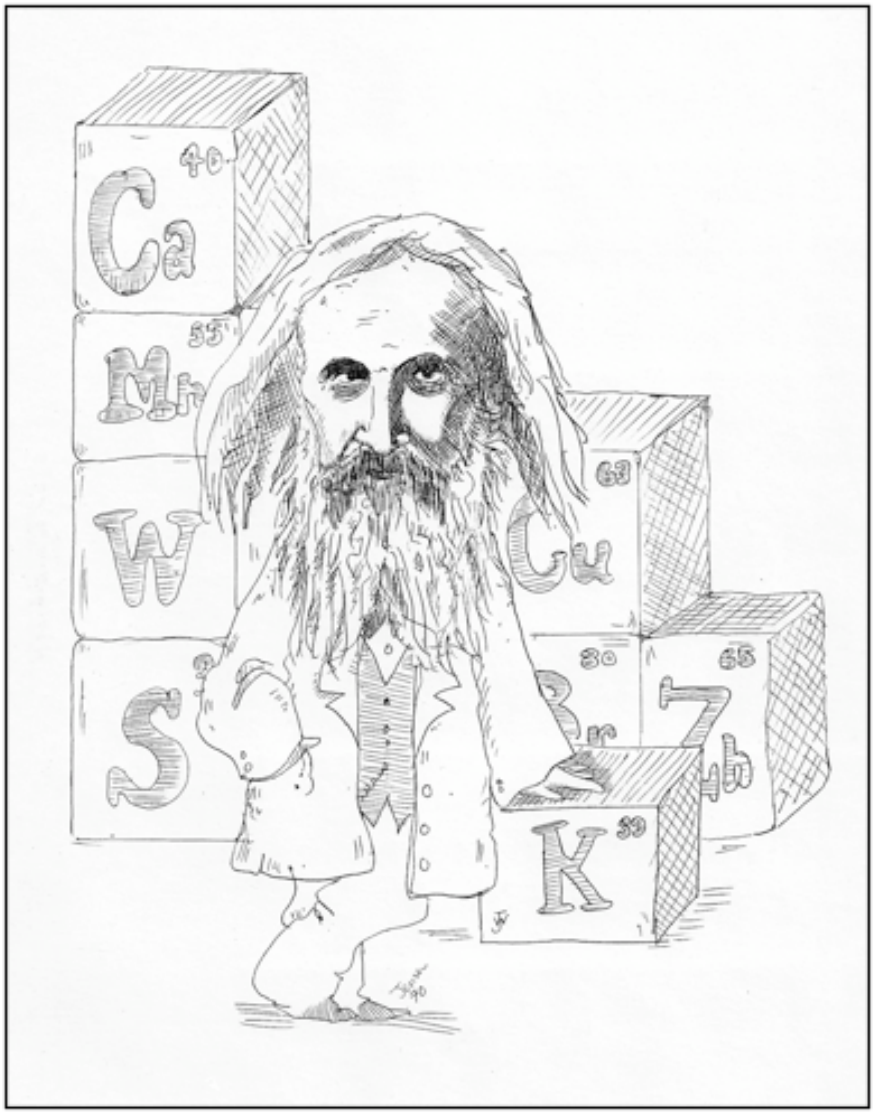


LIKE MOSES AND HIS BURNING BUSH

XXII

BUILDING BLOCKS

Dmitri Ivanovich Mendeleev (1834-1907). Russian chemist. Born in Siberia, the youngest of 14 children of an impoverished school teacher, Mendeleev was educated at the Teachers' College in St. Petersburg. After briefly serving as a gymnasium teacher, he went on to complete his graduate training at the University of St. Petersburg, after which he served as Professor of Chemistry at the St. Petersburg Technological Institute (1865) and at the University of St. Petersburg (1866), as well as Director of the Russian Central Board of Weights and Measures (1893). Best known for his discovery in 1869 of the periodic law, which stated that the chemical and physical properties of the elements were periodic functions of their atomic weights, Mendeleev also did important work on molar volumes and isomorphism, the critical temperatures of organic liquids, the behavior of gases under extremely low pressures, the hydrate theory of solutions, and the geochemistry of petroleum.

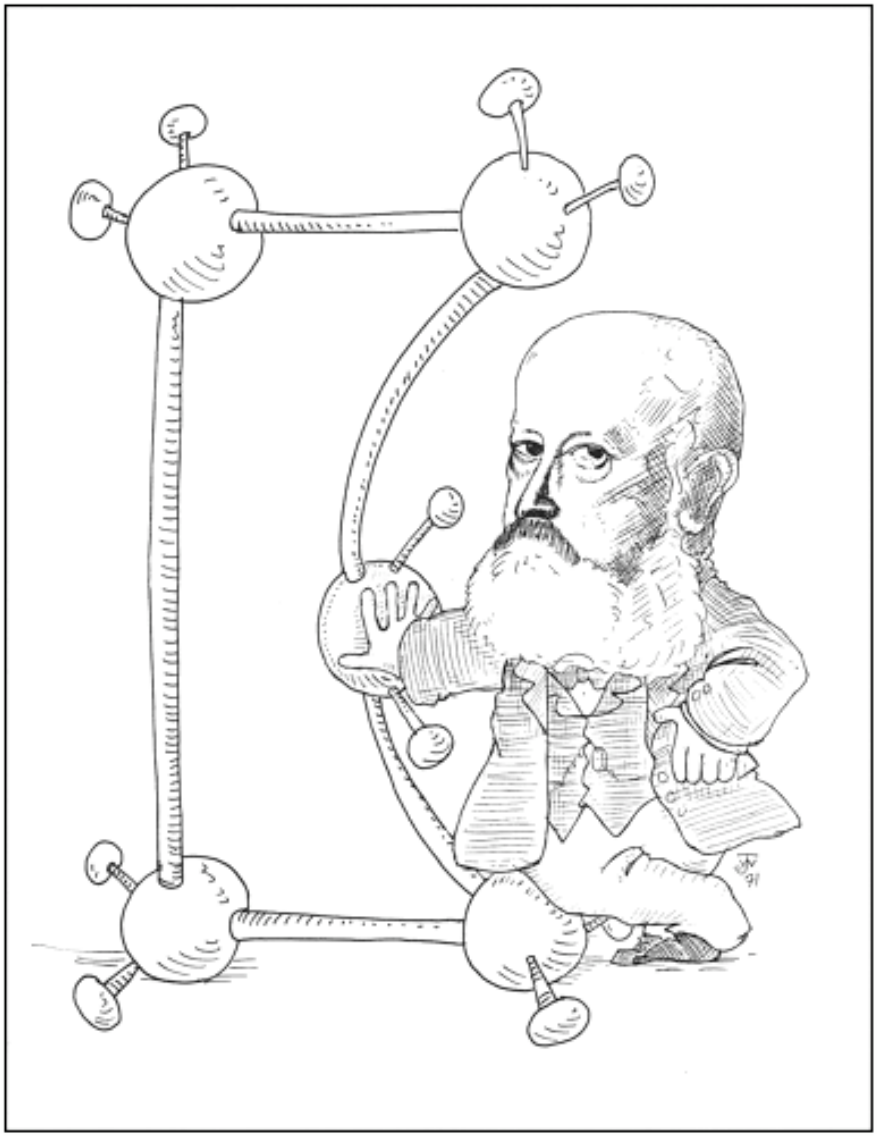


BUILDING BLOCKS

XXIII

STRAIN

Johann Friedrich Adolph von Baeyer (1835-1917). German chemist and Nobel Prize winner (1905). A student of Kekulé and Bunsen at Heidelberg, von Baeyer held positions at the Gewerbe-Institut in Berlin (1860), and at the Universities of Strasbourg (1872) and Munich (1875). Known for his studies of uric acid derivatives, which included the discovery of barbituric acid (named in honor of a girl friend named Barbara), and of the triphenylmethane dyes, including phenolphthalein and fluorescein, his most famous work involved his 20-year (1865-1885) study of the structure and synthesis of indigo. Other contributions of note include his experimental studies of the origins of aromaticity and his famous "strain theory" of ring formation, to which the caricature is an obvious reference.



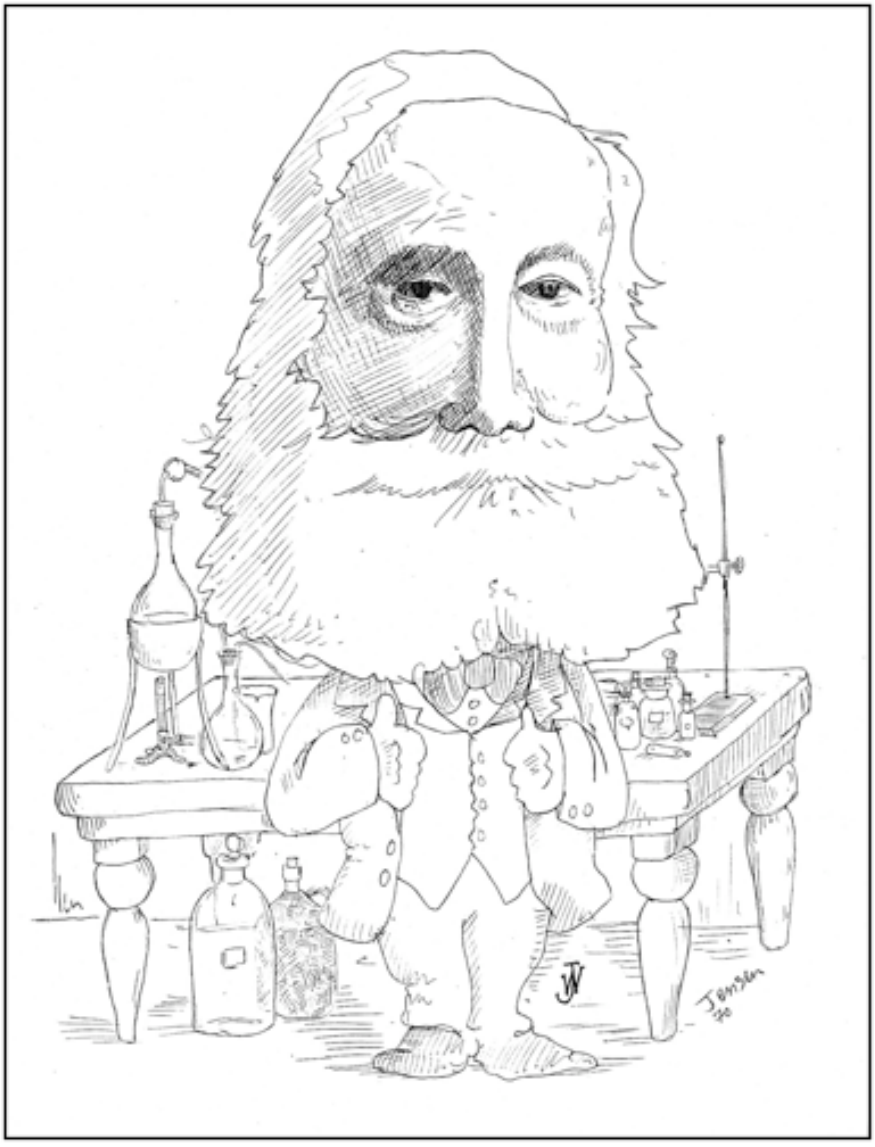
STRAIN

XXIV

GET THE MAUVE ON

William Henry Perkin (1838-1907). British chemist. A student of August Hofmann at the Royal College of Chemistry in London, Perkin is best known for his accidental discovery in 1856, while still a student, of the purple aniline dye *mauve* during a failed attempt to synthesize quinine. Having the presence of mind to recognize the commercial potential of this discovery, Perkin dropped out of school, obtained the proper patents, and in 1857 opened the first factory for the industrial-scale production of synthetic coal-tar dyes in Greenford Green. By 1874 he was able to sell his factory and retire a rich man. He devoted the rest of his life to pure research, specializing in the chemical applications of the Faraday effect (magnetic optical rotary power). The caricature is a play on a popular pun of the time in which people were encouraged to join the fad for mauve colored clothing by telling them to "get the mauve [move] on."

CHYMISTS
THAT STRANGE CLASS OF MORTALS



GET THE MAUVE ON

XXV

SUGAR

Emil Herman Fischer (1852-1919). German chemist and Nobel Prize winner (1902). A student of Kekulé at Bonn and of von Baeyer at Strasbourg and Munich, Fischer held professorships at Munich (1879), Erlangen (1882), Würzburg (1885) and Berlin (1892). He did key work on the structural elucidation and synthesis of the purines, the sugars, the tannins, and the amino acids and polypeptides, including the first successful synthesis of a 14-unit protein in 1907. He was also the first to propose the well-known "lock and key" model of enzyme interactions. His discovery (1884) and extensive use of the reagent phenyl-hydrazine to characterize the sugars is thought to have led to his eventual cancer and subsequent suicide.

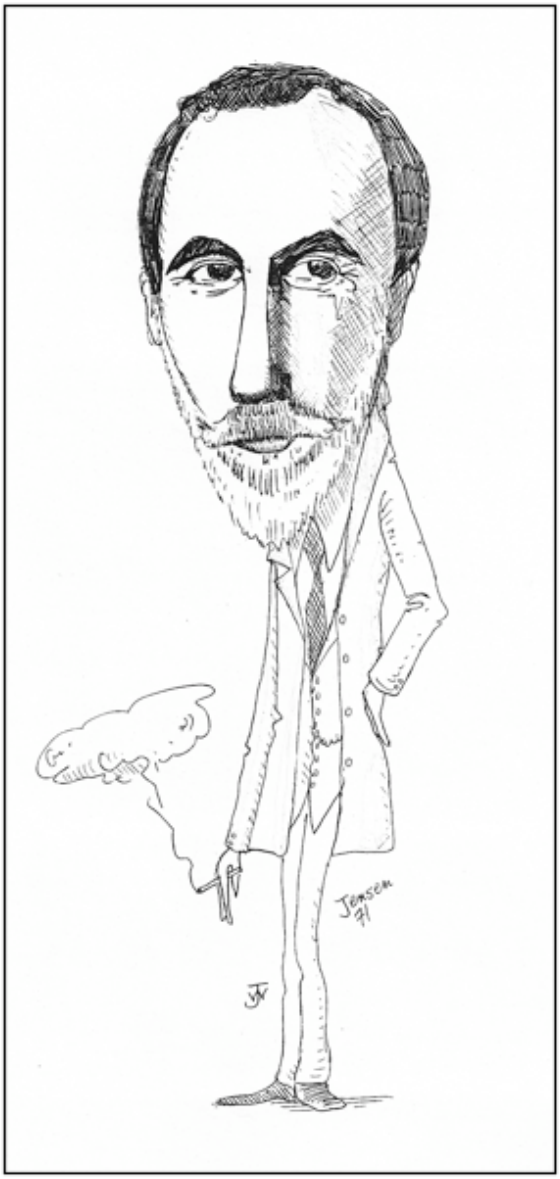
CHYMISTS
THAT STRANGE CLASS OF MORTALS

SUGAR

XXVI

INERT

William Ramsay (1852-1916). British chemist and Nobel Prize winner (1904). Educated at the Universities of Glasgow and Tübingen, Ramsay held positions at Anderson College (1872), the University of Glasgow (1874), University College-Bristol (1880), and University College-London (1887). Best known for his discovery and isolation (1894-1898), in collaboration with Lord Rayleigh and later with Morris Travers, of the noble gases, Ramsay also did important work on the vaporization and dissociation of liquids, and on the generation of helium during radioactive decay. Long thought to be chemically unreactive until the discovery of the compound xenon hexafluoroplatinate in 1962, the noble gases were originally known as the "inert gases" – whence the title of the caricature.



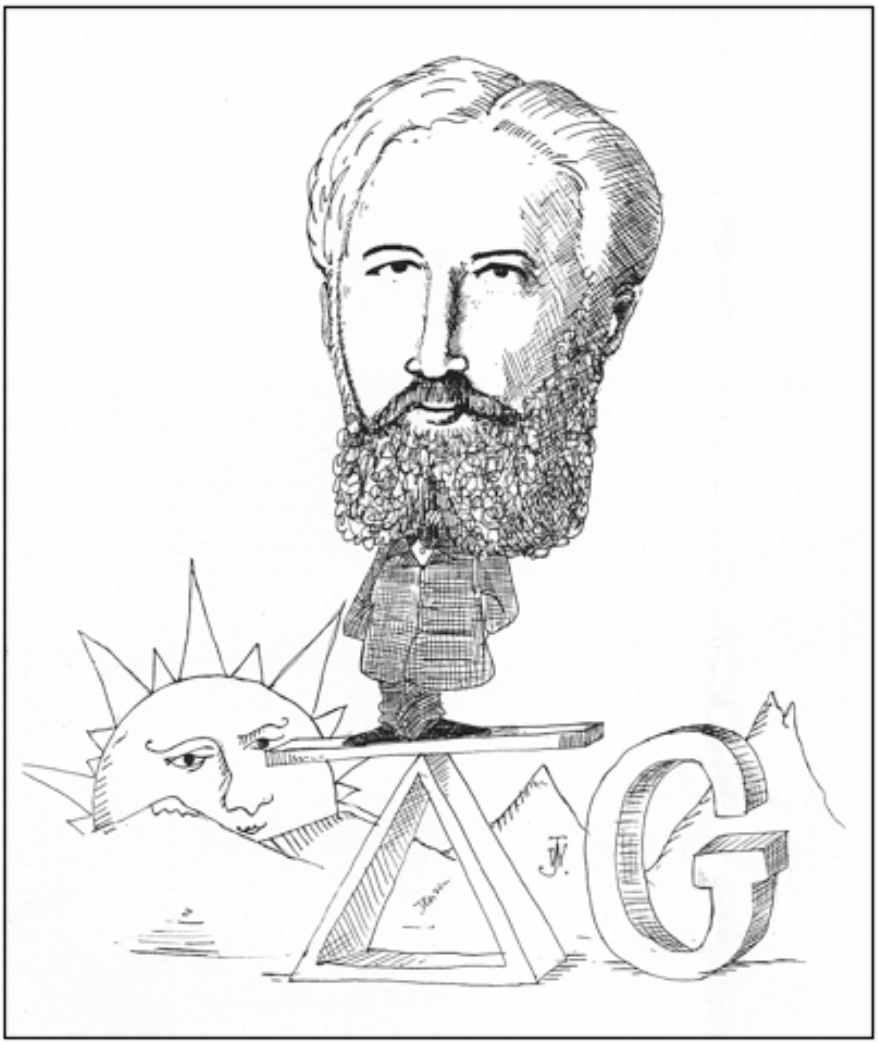
INERT

XXVII

ENERGY IS REALITY

Friedrich Wilhelm Ostwald (1852-1932). German chemist and Nobel Prize winner (1909). Born in Latvia of German parents, Ostwald was Professor at the Universities of Riga (1881) and Leipzig (1887). Because of his early recognition of the work of Arrhenius on the theory of ionic dissociation, of van't Hoff on colligative properties, and of Gibbs on chemical thermodynamics, as well as the publication of his famous multi-volume textbook, *Lehrbuch der allgemeinen Chemie* (1885-1887), and his founding of the *Zeitschrift für physikalische Chemie* (1887), he is widely considered to be the father of the modern discipline of physical chemistry. Other chemical achievements of note include his famous dilution law (1888), his elucidation of the kinetic nature of catalysis (1894), and his catalytic industrial process for the oxidation of ammonia to nitric acid (1902).

He is also credited with having written the first book to theoretically rationalize traditional analytical chemistry using the principles of modern physical chemistry (1894). Deeply interested in the history and philosophy of chemistry, Ostwald also attempted to replace the atomic theory with a more operational set of concepts based on the phase rule and the concept of energy (1907). After his early retirement in 1909, he devoted his life to the development of a universal technical language, the study of the role of energy in human history and society, and to the formulation of a more scientific classification of colors known as the Ostwald Color System.

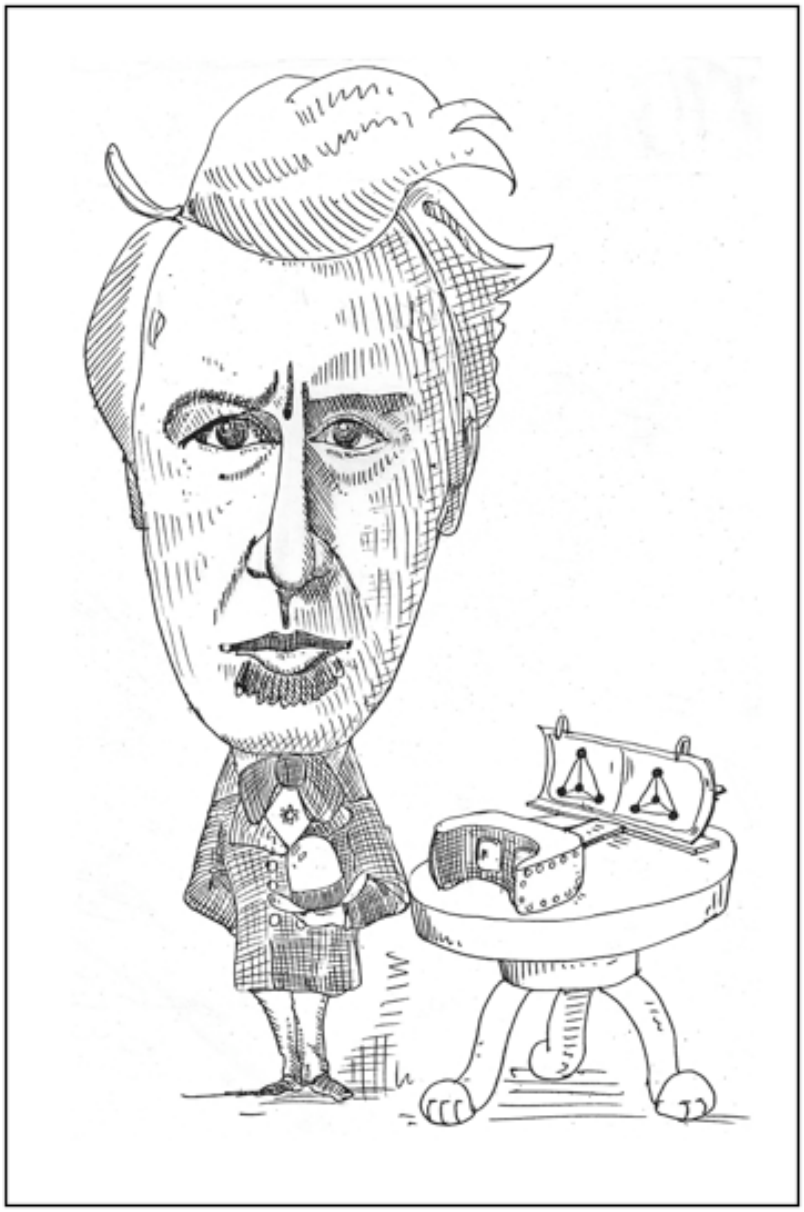


ENERGY IS REALITY

XXVIII

STEREO

Jacobus Henricus van't Hoff (1852-1911). Dutch chemist and the winner of the first Nobel Prize in Chemistry (1901). Educated at the Delft Polytechnikum and at the University of Leiden, van't Hoff also worked in the laboratories of Kekulé in Bonn and Wurtz in Paris. He held positions at the University of Utrecht Veterinary School (1874), the University of Amsterdam (1877), and as director of a special government-funded laboratory in Berlin (1896) for the study of the famous Stassfurt salt deposits. Best known for his theory of the tetrahedral carbon atom (1874), which, in conjunction with the work of Pasteur and Le Bel on molecular asymmetry, serves as the foundation of modern stereochemistry, and for his work on osmotic pressure (1885), he is also credited with having written the first modern monograph on chemical kinetics, *Études de dynamic chimique,* in 1884. Among his numerous contributions to chemical thermodynamics and kinetics are the van't Hoff isochore equation for the prediction of the temperature-dependence of equilibrium constants, the concept of reaction order, and an anticipation of Arrhenius' later concept of activation energy.

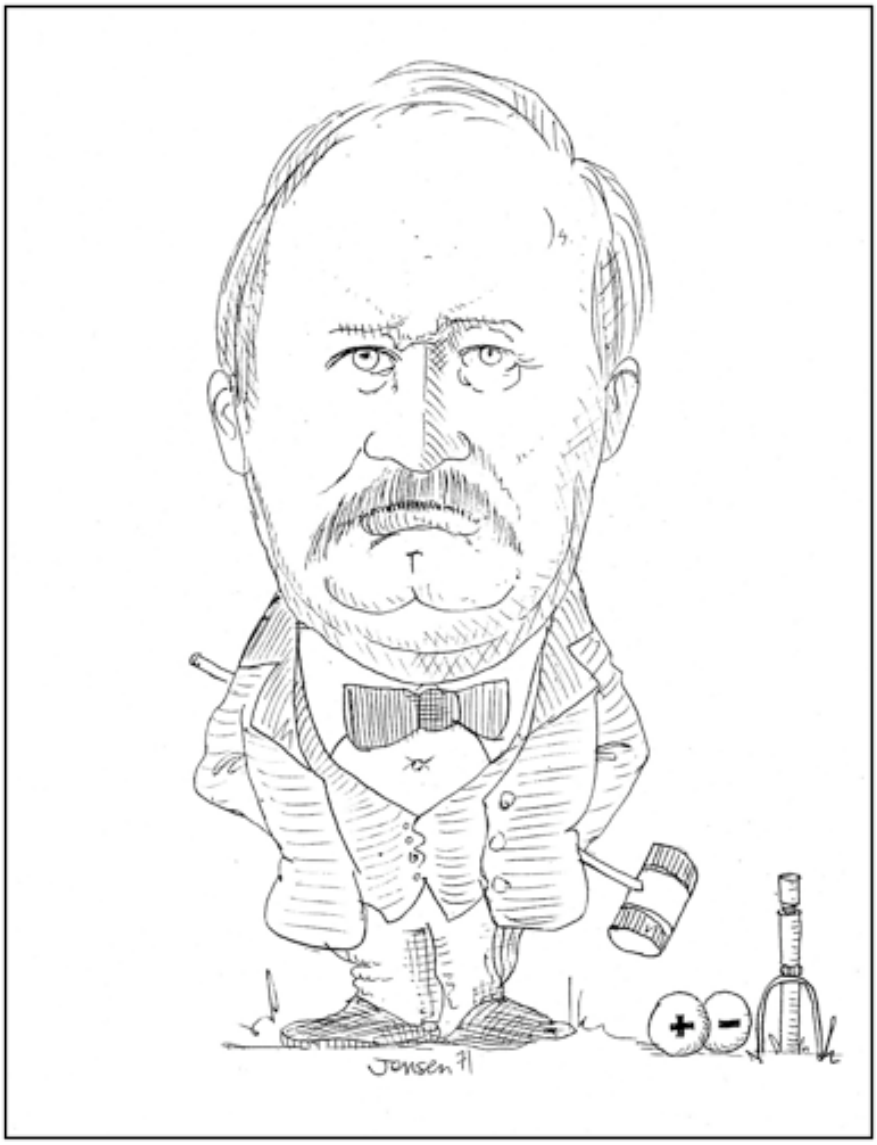


STEREO

XXIX

CHARGED CROQUET BALLS

Svante August Arrhenius (1859-1927). Swedish chemist and Nobel Prize winner (1903). Lecturer and Professor at the Technical Institute in Stockholm (1891) and later Director of the Nobel Institute (1905), Arrhenius is best known for his theory of ionic dissociation, which evolved out of his doctoral thesis of 1884, his ionic acid-base definitions (1887), and his introduction of the concept of activation energy in chemical kinetics (1889). He later did pioneering work on the physical chemistry of serums, ecology (where he is responsible for much of our early understanding of the greenhouse effect), and cosmology.



CHARGED CROQUET BALLS

XXX

COORDINATED

Alfred Werner (1866-1919). German-Swiss chemist and Nobel Prize winner (1913). Born the son of an ironworker in Mulhouse, Werner studied chemistry under Arthur Hantzsch at the Zürich Polytechnikum and collaborated with him on his first important paper (1890), which dealt with the stereochemistry of trivalent nitrogen compounds and represented a significant extension of the van't Hoff theory of the tetrahedral carbon atom. In 1893 Werner was appointed to a professorship at the University of Zürich, where he remained until his death. That same year he published his famous coordination theory of complex inorganic salts which was destined to revolutionize inorganic chemistry in much the same way as the earlier classical structure theory of Kekulé, Couper, and van't Hoff had revolutionized organic chemistry. The rest of Werner's career was spent in experimentally testing the predictions of his theory, as summarized in his seminal monographs, *Lehrbuch der Stereochemie* (1904) and *Neuere Anschauungen auf dem Gebiete der anorganischen Chemie* (1905). The caricature shows Werner as the central atom of an octahedral coordination complex.

COORDINATED

XXXI

AMMONIA

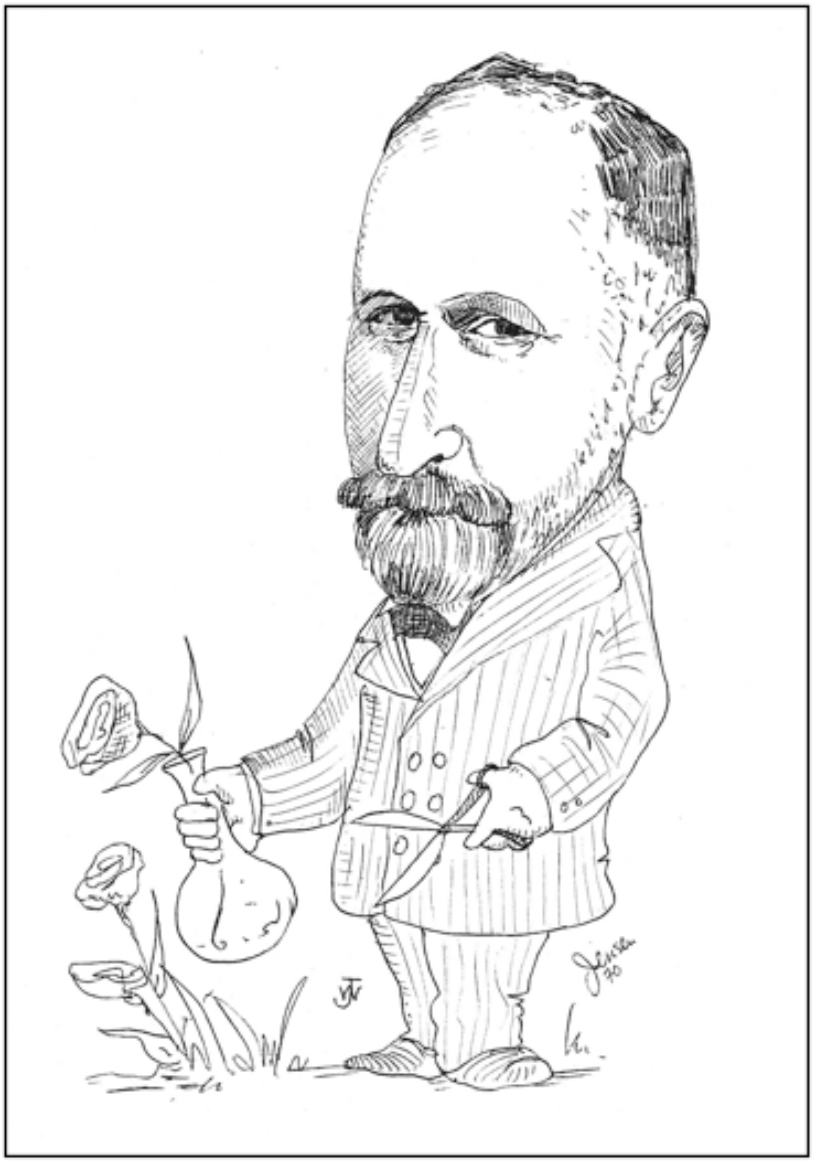
Fritz Haber (1868-1934). German physical chemist and Nobel Prize winner (1918). Professor at Karlsruhe (1894) and Director of the Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry at Dahlem outside of Berlin (1911), Haber is best known for his successful development, along with Carl Bosh, of the high-pressure, catalytic synthesis of ammonia on an industrial scale from dinitrogen and dihydrogen gas, and for his introduction, as head of the German Warfare Service, of gas warfare at the battle of Ypres in April of 1915. Other activities of note include his work on the electrochemical synthesis of organic compounds (1904-1910), his work on the glass electrode in connection with pH determinations (1909), his introduction of the Born-Haber cycle for the visual simplification of lattice calculations (1919), and his unsuccessful attempt to repay Germany's war debts by extracting gold from sea water (1922-1927). Ostracized as a war criminal in some scientific circles after World War I for his introduction gas warfare, Haber, who was of Jewish descent, resigned his position after Hitler came to power in 1933. He died in exile a year later in a hotel room in Basel Switzerland.

AMMONIA

XXXII

ROSES ARE RED
VIOLETS ARE BLUE

Richard Willstätter (1872-1942). German chemist and Nobel Prize winner (1915). Born in Karlsruhe, the son of a textile merchant, Willstätter was educated at the University of Munich and held positions at the ETH in Zürich (1905), the Kaiser Wilhelm Institute and University of Berlin (1912), and the University of Munich (1916), where he remained until his resignation in 1924 in protest over the growing anti-Semitism of the faculty. Best known for his structural elucidation and synthesis of various alkaloids, including cocaine and atropine, and especially for his studies of chlorophyl and various plant pigments of the anthocyanin class, he also did work on enzymes but failed to recognize that they were proteins. Also of interest is his synthesis of cyclooctatetraene (1905) and his proof of its nonaromatic character, which dealt a blow to Thiele's well-known partial-valence theory of aromaticity. Forced to flee Germany in 1939, he died in exile in Switzerland in 1942.

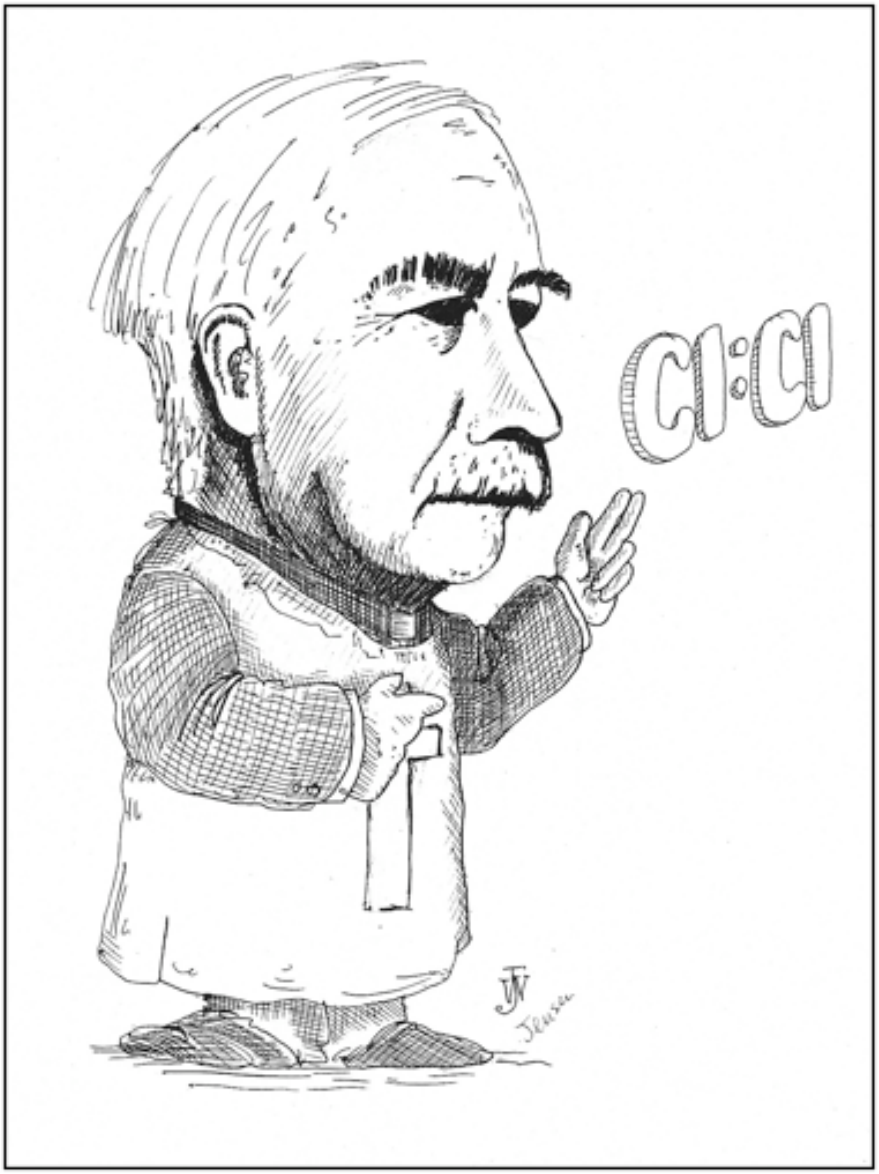


ROSES ARE RED, VIOLETS ARE BLUE

XXXIII

THE PAIRING OF THE ELECTRONS

Gilbert Newton Lewis (1876-1946). American chemist. Born in Weymouth, Massachusetts, and raised in Lincoln, Nebraska, Lewis received his B.S., M.S. and Ph.D degrees from Harvard – the latter for work done on the electrochemistry of zinc and cadmium amalgams under the direction of Theodore Richards. Following postdoctoral study in Germany and a year as the Superintendent of Weights and Measures for the Philippines, Lewis was appointed Professor of Chemistry at MIT (1905). In 1912 he was appointed Professor and permanent Dean of the College of Chemistry at the University of California-Berkeley, a position which he held until his death in 1946. In the field of chemical bonding he is best remembered today for his introduction of the shared electron-pair model of the covalent bond (1916), his electron-dot diagrams, and his electron-pair donor-acceptor definitions of acids and bases (1923). He and his associates are also responsible for much of the quantification of 20th-century thermodynamics and for the introduction of such concepts as fugacity, activity, and ionic strength. In addition, Lewis also did important work on the chemistry of deuterium and on the nature of phosphorescence and the triplet state.



THE PAIRING OF THE ELECTRONS

XXXIV

RELATIVE

Albert Einstein (1879-1955). German physicist and Nobel Prize winner (1921). Educated at the ETH in Zürich, Einstein began his career as a clerk in the Swiss Patent Office (1902), but eventually came to hold academic positions at the University of Berne (1908), the University of Zürich (1909), the Karl-Ferdinand University in Prague (1911), the ETH in Zürich (1912), the Kaiser Wilhelm Institute and University of Berlin (1914), and the Institute for Advanced Study in Princeton (1933), where he remained until his death in 1955. Best known for his work on Brownian motion (1905), his quantum rationalization of the photoelectric effect and the particulate nature of light (1905), and, of course, for both his special (1905) and general (1916) theories of relativity, Einstein's importance to chemistry lies in his lesser known enunciation (1912) of the law of photochemical equivalence (also independently proposed somewhat earlier by the German physicist, Johannes Stark), which revolutionized 20th-century photochemistry.

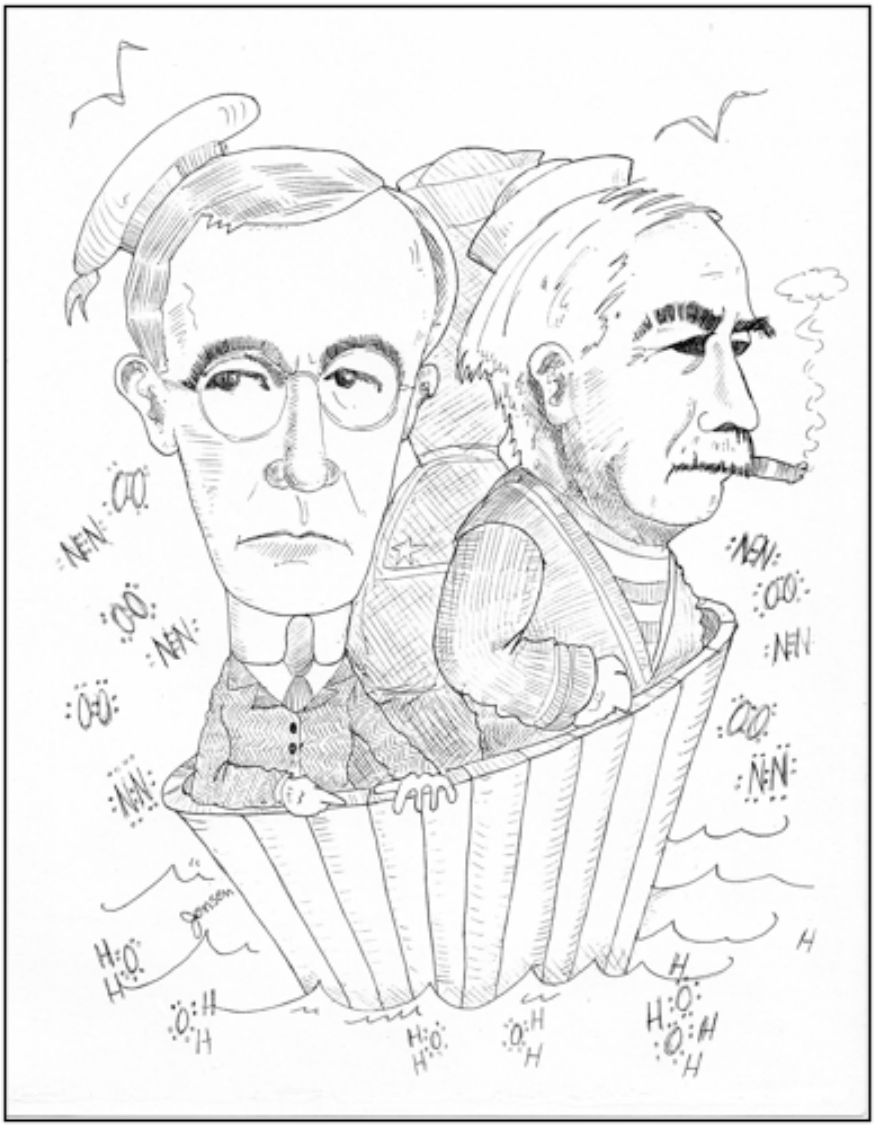
RELATIVE

XXXV

THREE MEN IN A TUB

Irving Langmuir (1881-1957). American chemist and Nobel Prize winner (1932). Educated at the Columbia School of Mines and at the University of Göttingen under the tutelage of Walther Nernst, Langmuir briefly taught chemistry at the Stevens Intitute of Technology (1906) before leaving academia to work as a research scientist for the General Electric Company in Schnectady, New York (1909), where he remained until his retirement in 1950. He did important work on the improvement of the tungsten filament light bulb, on surface chemistry, on the electron-pair theory of the chemical bond, and on the seeding of rain clouds, and is probably best remembered for the Langmuir adsorption isotherm (1918) in the field of surface chemistry, and for his introduction of the isoelectronic principle (1919), the term "octet" theory (1919), the electroneutrality principle (1921), and the 18-electron rule (1921) in the field of chemical bonding.

Langmuir was also a successful designer of chemical apparatus, including the mercury diffusion pump, the Langmuir-Blodgett surface trough (1906, 1935), and a new form of the hydrogen blowtorch (1927). In the caricature Langmuir is pictured along with the other two pioneers of the modern electronic theory of bonding – the American chemist, G. N. Lewis, and the German physicist, Walther Kossel – in a world filled with molecules containing shared electron-pair bonds. (See also the "Annotated Mother Goose" in the appendix).



THREE MEN IN A TUB

XXXVI

RESONANCE IN EVERY POSITION

Linus Carl Pauling (1901-1994). American chemist. Professor at the California Institute of Technology (1927-1962) and Nobel Prize winner for both chemistry (1954) and peace (1962), Pauling began his career as a crystallographer, but is best known today for his work on the electronic theory of the chemical bond, as summarized in his 1939 monograph, *The Nature of the Chemical Bond*, and for his later work on the molecular and electronic structures of large biomolecules. His name is most often associated with his table of ionic radii (1927), his rules for rationalizing the most stable structures for complex ionic crystals (1929), his extensive use of both the resonance (1928) and hybridization (1931) concepts in chemical bonding, his thermochemical electronegativity scale (1932), and his tables of covalent (1934) and metallic (1939) radii. He also gained considerable notoriety during the 1950s for his political activism in support of nuclear disarmament and, in later years, for his controversial advocacy of the supposed medical benefits of megadoses of vitamin C. (See also the "Annotated Mother Goose" in the appendix).

RESONANCE IN EVERY POSITION

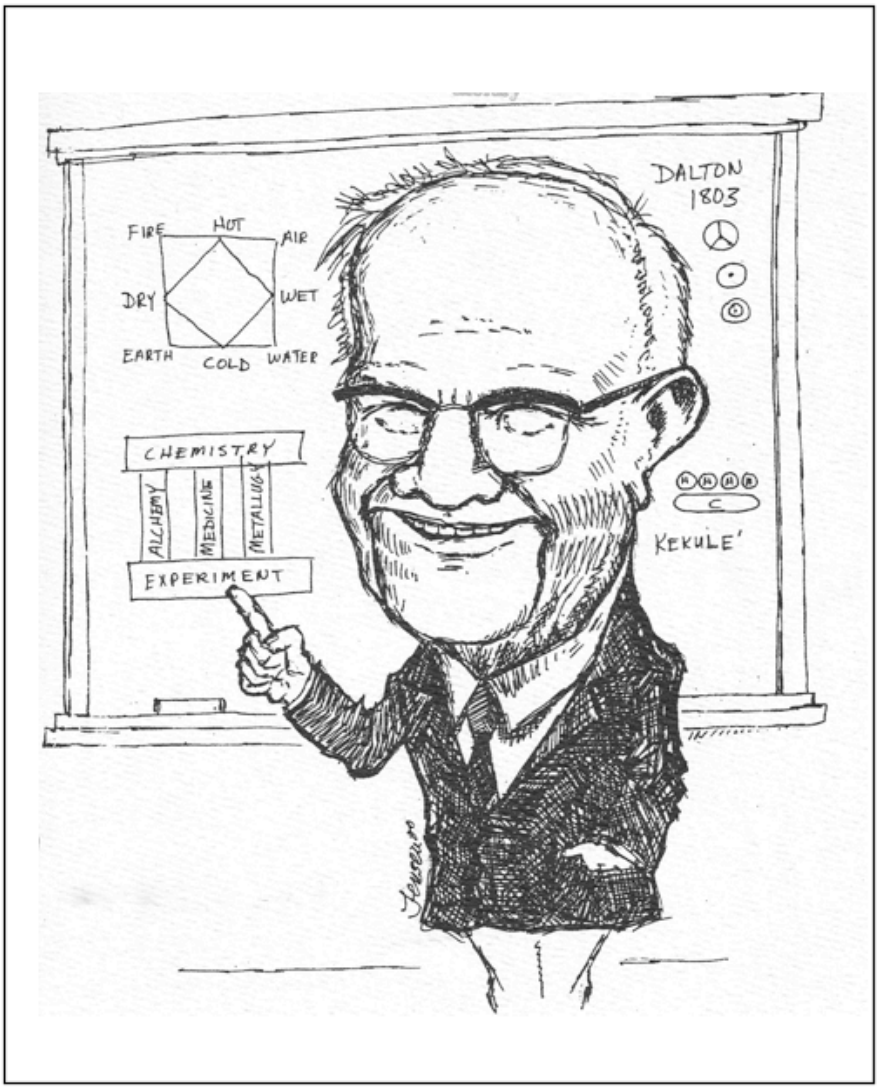
XXXVII

IHDEL THOUGHTS

Aaron John Ihde (1909-2000). American chemist and historian. Born on a farm near Neenah Wisconsin, Ihde was trained at the University of Wisconsin-Madison, from which he received his doctorate degree in 1941 for work in the field of food chemistry done under the supervision of Professor Henry Schuette. After a year of teaching at Butler University, Ihde returned to the University of Wisconsin as an Instructor, but was soon moved to a tenure track position. In 1946 he was given permission to revive a defunct history of chemistry course. This eventually led to the publication in 1964 of his influential textbook, *The Development of Modern Chemistry*. This book dominated the field for the remainder of the 20th century and has still not been surpassed for either its breath of coverage or its depth of documentation.

In 1957 Ihde received a joint appointment in both the chemistry and history of science departments at Wisconsin, which provided him with the opportunity to supervise doctoral students in the history of science and to eventually train a generation of chemical historians. Many of Ihde's 342 publications dealt with the history of nutritional and biochemistry, with chemical biography, and with the history of the chemistry department at Wisconsin. This latter interest culminated in his final book, *Chemistry as Viewed from Bascom Hill*, which was published in 1990.

CHYMISTS
THAT STRANGE CLASS OF MORTALS

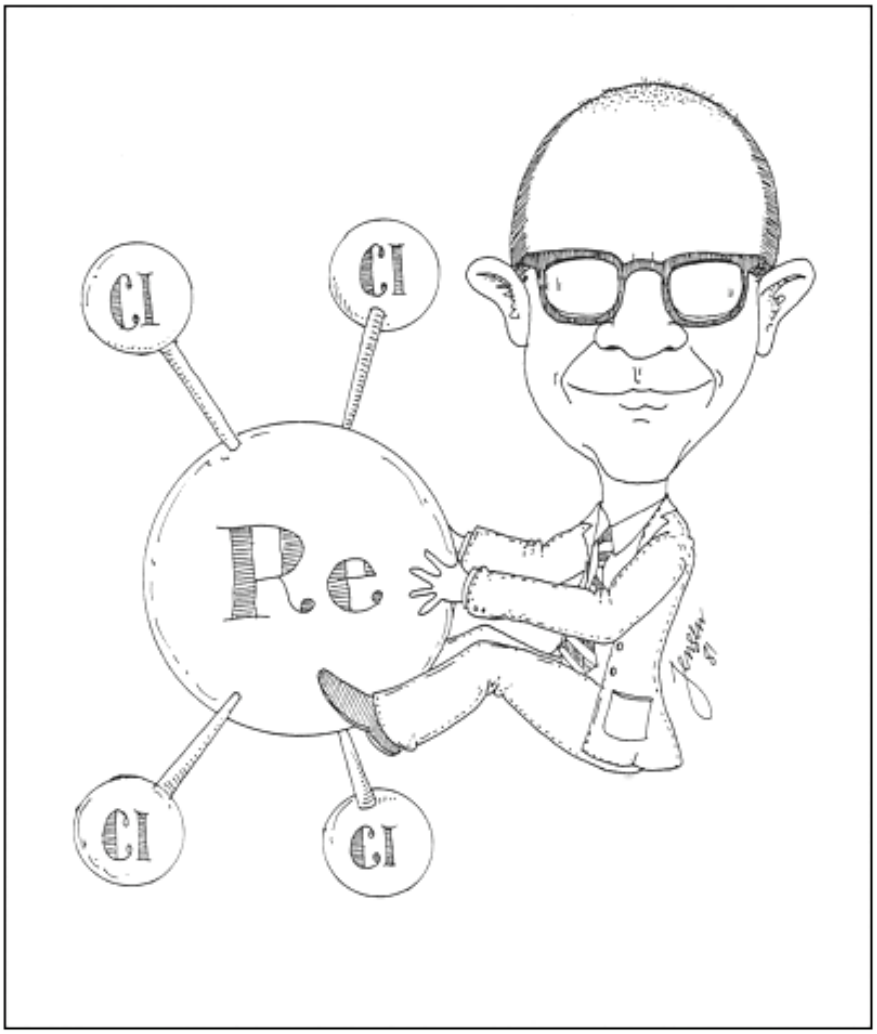


IHDEL THOUGHTS

XXXVIII

QUADRUPLE EMBRACE

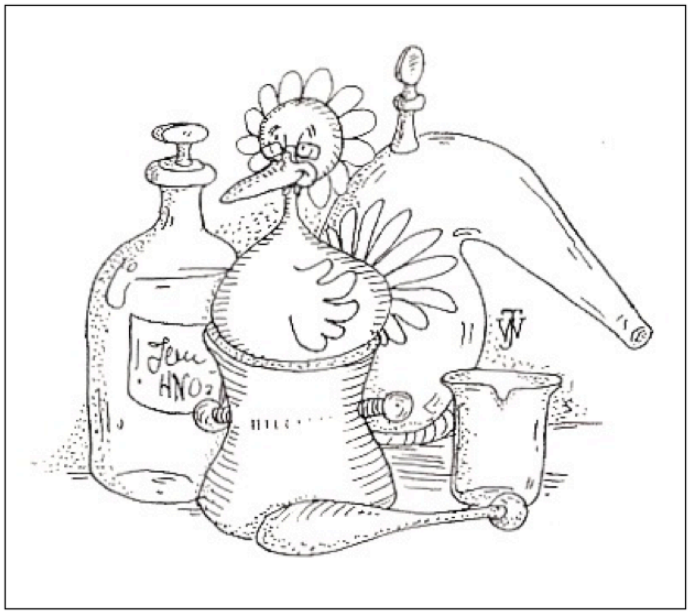
Frank Albert Cotton (1930-2007). American chemist. Educated at Drexel University, Temple University and Harvard, where he worked with Geoffrey Wilkinson, Cotton held professorships at MIT (1961) and Texas A&M University (1972). A prolific organometallic chemist with hundreds of publications, Cotton is today best remembered for his proposal (1964) of the quadruple Re-Re bond in the complex anion $Re_2Cl_8^{2-}$ – the first significant extension of the bond concept beyond the traditional single, double, and triple bonds that had dominated chemical thought since the mid-19th century. His extensive work on transition-metal multiple bonds was eventually summarized in his 1982 monograph, *Multiple Bonds Between Metal Atoms* (coauthored by Richard Walton). Cotton's inorganic chemistry textbook, *Advanced Inorganic Chemistry* (1962), which he coauthored with his mentor, Geoffrey Wilkinson, has passed through many editions and has played a major role in shaping the training of chemists in the last half of the 20th century, as has his smaller textbook, *Chemical Applications of Group Theory*, first published in 1963.



QUADRUPLE EMBRACE

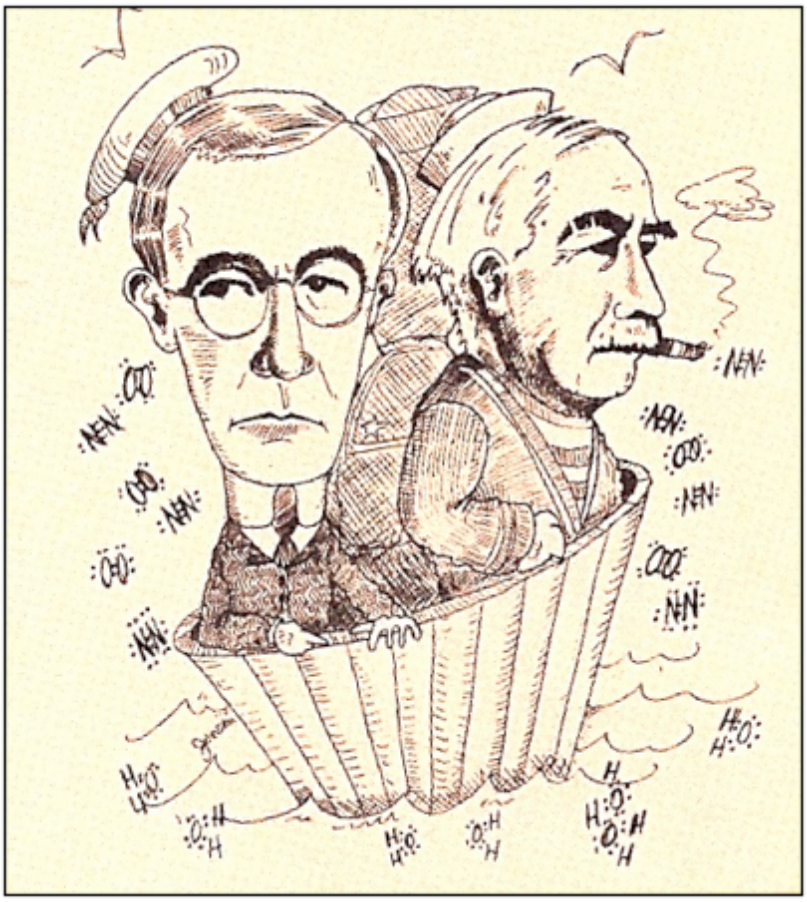
Appendix

A Chemist's Annotated Mother Goose of Modern Bonding Theory



Dalton and Chemistry,
Attraction and affinity,
Davy and Berzelius,
Charges and Arrhenius,
Couper and A. Kekulé,
Electrons and old J. J.,
van't Hoff and 3D,
Werner and valency.
Alas we could give rhymes galore,
But we do not wish to Bohr (i).

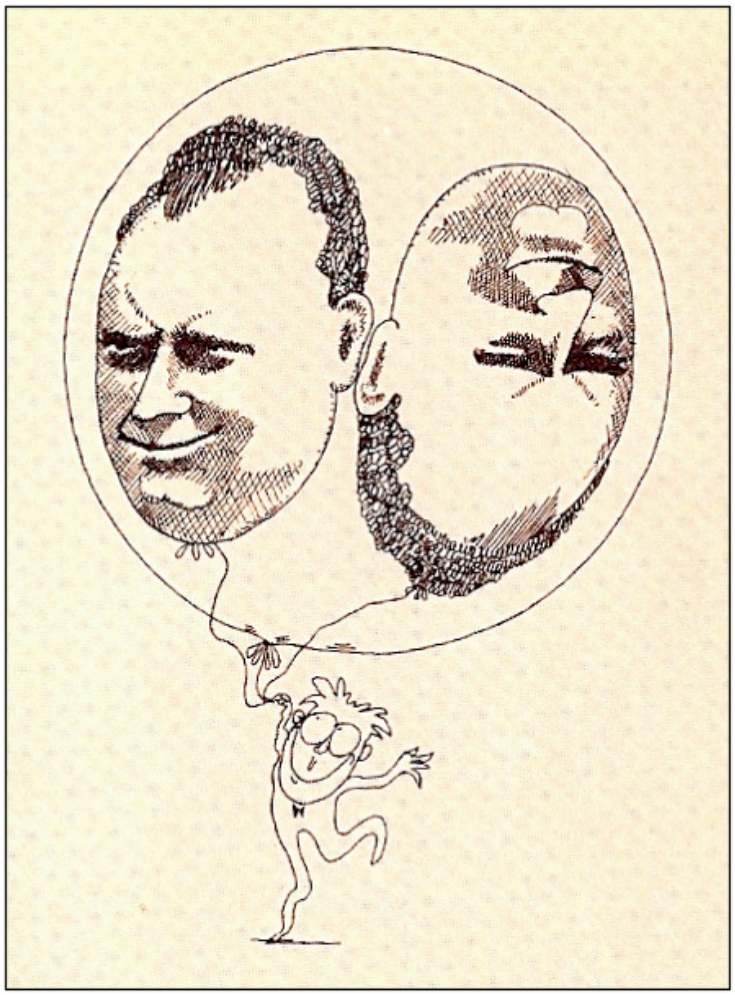
CHYMISTS
THAT STRANGE CLASS OF MORTALS



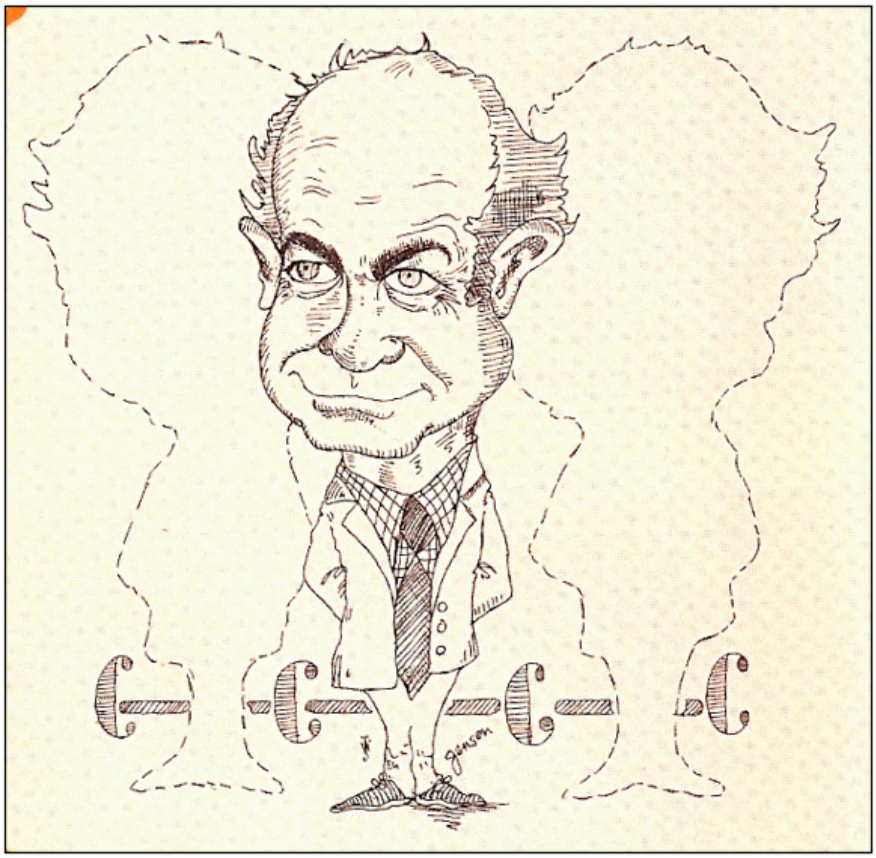
Rub-a-dub-dub,
Three men in a tub;
Lewis, Langmuir, Kossel – not four.
The electrons will pair,
For each atom to share,
Save ions, which need no more (2).

Hey diddle diddle,
With waves from a fiddle,
de Broglie our physics did save;
And Schrödinger affirms,
With differential-like terms,
That matter is really a wave (3).

CHYMISTS
THAT STRANGE CLASS OF MORTALS

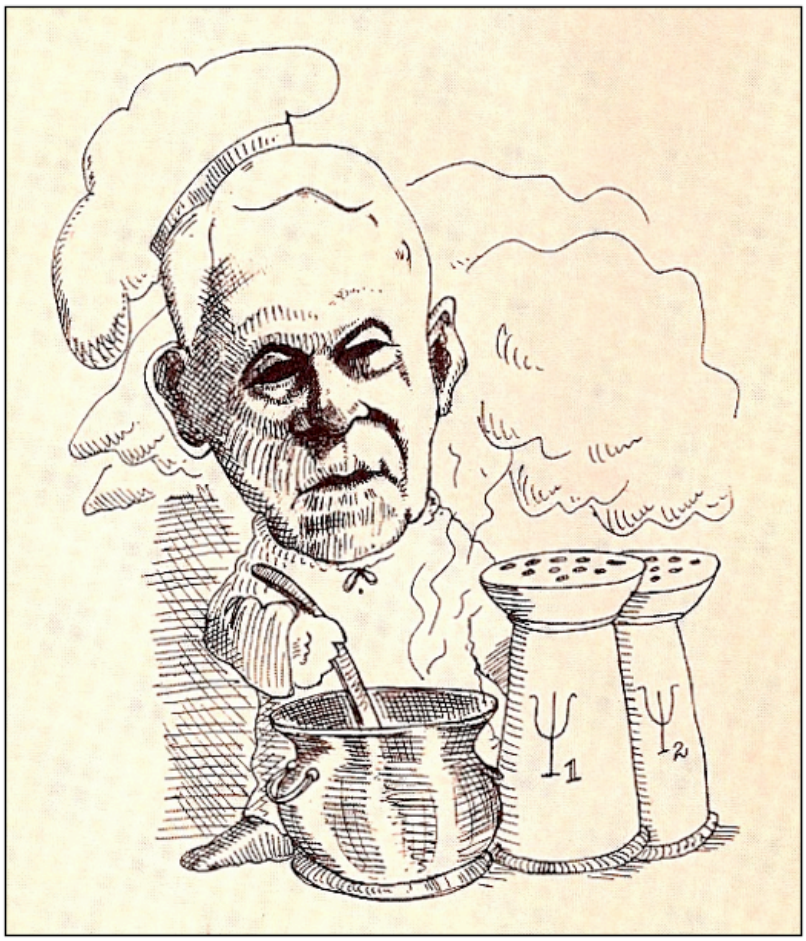


Pauli, Pauli, quite contrary,
How do your spins arrange?
"Opposites together,
But identicals never,
A phenomenon very strange" (4).

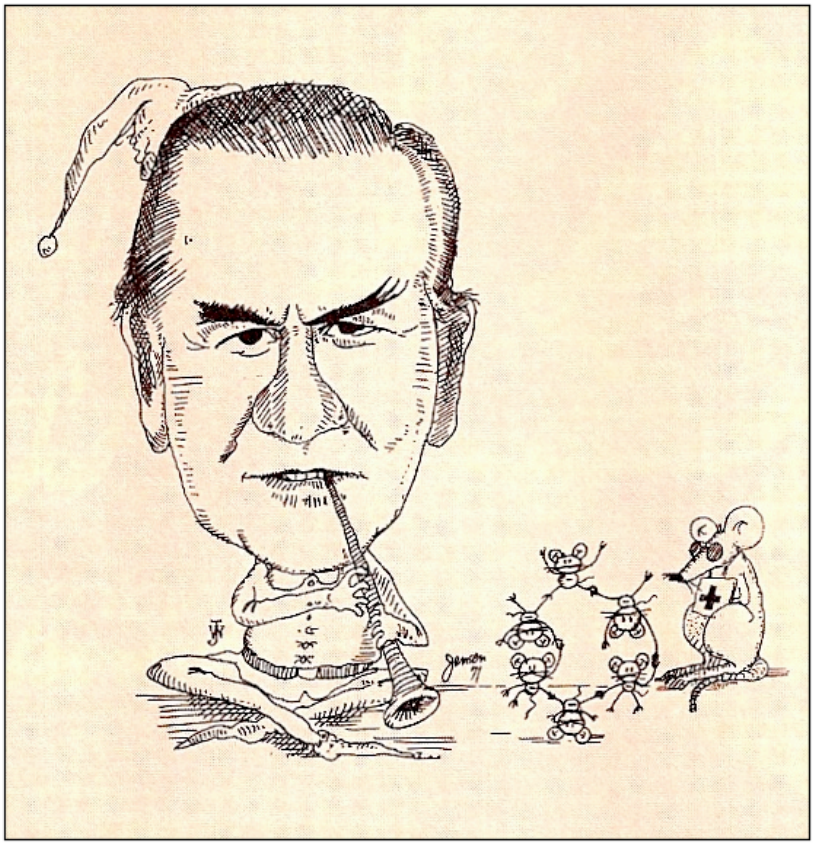


See saw,
Pauling et al.
Resonance in every position;
The electron is there,
But also elsewhere,
I have a dialectic suspicion (5).

CHYMISTS
THAT STRANGE CLASS OF MORTALS

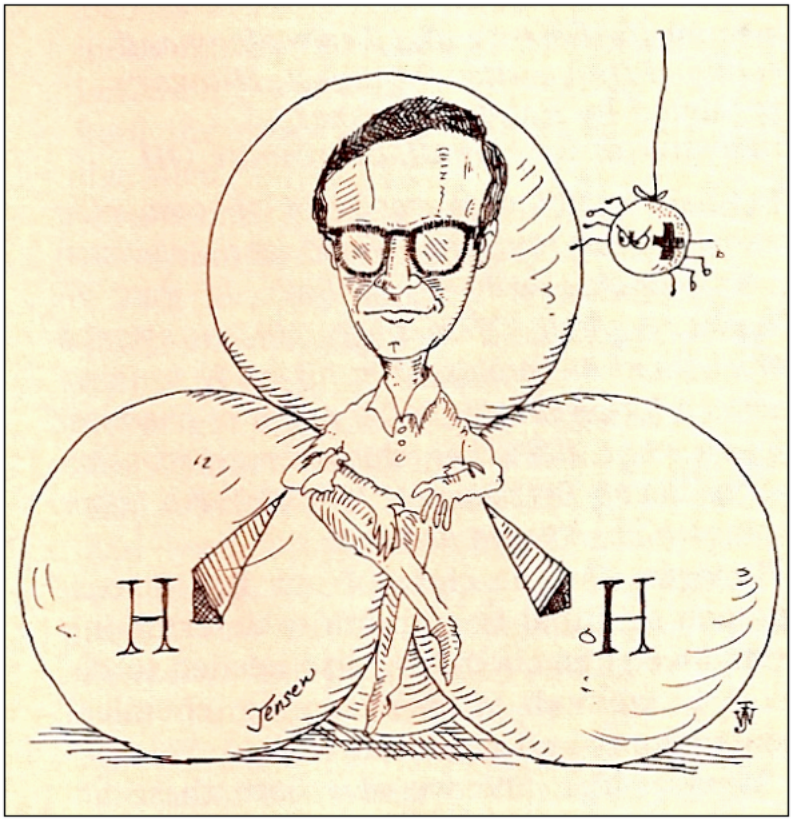


Mulliken, Mulliken, what are you doing?
"M.O.'s from A.O.'s I'm orthogonally brewing.
Pi bonds, sigma bonds, symmetric or not;
Excited or ground state, that's what I've got.
I have psi's and phi's, and pi's galore,
And with linear combinations, several millions more (6).



Six extra electrons!
See how they correlate!
They all formed into bonds by Linnett,
Where their close-paired positions were all upset.
The problem of resonance they conquered and met;
Those six extra electrons (7).

CHYMISTS
THAT STRANGE CLASS OF MORTALS



Little Henry Bent,
Sits in the dent,
At the center of tangent spheres,
In fermions close packed,
And electrostatically stacked,
As the neighboring nucleus leers (8).

WILLIAM B. JENSEN

Hints for the Perplexed

1. A brief summary of classical atomic theory and bonding theory from John Dalton to Niels Bohr.

2. A play on "Rub-A-Dub-Dub" and the early qualitative electronic theory of the ionic and covalent bonds in terms of electron transfer and electron-pair sharing as developed by G. N. Lewis, Irving Langmuir and Walther Kossel.

3. A play on "Hey Diddle Diddle" and the introduction of both matter waves by Louis de Broglie and the wave equation by Erwin Schrödinger.

4. A play on "Mary, Mary, Quite Contrary" and the pairing of electrons of opposite spin in keeping with the Pauli exclusion principle – a result often symbolized by means of paired arrows enclosed within either a circle or a box.

5. A play on "See Saw Margery Daw" depicting Linus Pauling as a resonating pi-electron in a conjugated bond system. The phrase "dialectic suspicion" refers to Russian attacks on resonance theory during the 1950s.

6. A play on "Mary, Mary, Quite Contrary" depicting Robert Mulliken as a chef employing atomic orbitals to brew up molecular orbitals using the technique of linear combinations.

7. A play on "Three Blind Mice" and John Linnett's representation of the bonding in benzene in terms of

six nonclose-paired, three-electron bonds, which eliminated the necessity for resonance.

8. A play on "Little Miss Muffet" and Henry Bent's development of the tangent-sphere model, which represented the various electron-pairs of a typical 2D Lewis-dot diagram in terms of mutually repulsive 3D spherical electron-pair domains and provided a simple rationale for the VSEPR rules for predicting molecular shapes.

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