

TIMELINE

- c. 600 B.C.E:** Thales of Miletus speculates that water is the common principle out of which all matter is made.
- c. 540 B.C.E:** Pythagoras and his pupils claim that all of nature is bound together by numbers.
- c. 540 B.C.E:** Anaximenes suggests air as the primary matter of all things, whereas Heraclitus (c. 480 B.C.E) favors fire.
- c. 450 B.C.E:** Democritus develops an atomic theory that may have been first suggested by his teacher Leucippus. According to Democritus, everything consists of atoms—hard, indivisible and indestructible particles—within a vacuum. At about the same time, Empedocles proposes his theory of the four elements, water, air, earth, and fire.
- c. 350 B.C.E:** Aristotle rejects atomism and adopts the four-element theory. He maintains a strict separation between terrestrial matter and the substance of the heavenly bodies, later known as *quinta essentia* or the fifth element.
- c. 50 B.C.E:** Lucretius, in his *De Rerum Natura* (On the Nature of Things), gives a full exposition of philosophical atomism based on Democritus and Epicurus.
- c. 1200:** Following the Arabian philosopher Averroës, medieval thinkers develop the Aristotelian notion of *minima naturalia*, a corpuscular theory of matter.
- c. 1530:** In Paracelsus's chemical philosophy, all matter and changes are explainable in terms of three principles called salt, sulfur, and mercury.
- 1661:** In *The Sceptical Chymist*, Robert Boyle bases chemistry on the theory of atoms. He rejects the Aristotelian four-element theory and Paracelsian ideas.
- 1704:** Isaac Newton, in his *Opticks*, conceives light as a stream of tiny particles and suggests that matter is explained by forces acting between primary particles.
- 1718:** Georg Stahl proposes a theory according to which all combustible bodies include *phlogiston*, a hypothetical principle.
- 1758:** Rudjer Boscovich develops a dynamic conception of matter based on point-atoms.
- 1789:** Antoine-Laurent Lavoisier's *Treatise of Chemistry* signals the coming of a new, antiphlogistic chemistry based on the principle of mass conservation. In his table of chemical elements, Lavoisier includes imponderable (weightless) bodies such as light and heat.
- 1808:** In his *New System of Chemical Philosophy*, John Dalton revises the atomic theory. Dalton's atoms

- are characterized by their weights, with one kind of atom corresponding to one kind of chemical element.
- 1811:** Amedeo Avogadro introduces compound atoms, or molecules.
- 1815:** William Prout suggests that all atomic weights are multiples of hydrogen's atomic weight and that hydrogen may be the common element, or prototype, of all matter.
- 1847:** The law of energy conservation receives its full formulation by Hermann von Helmholtz, who draws upon earlier work by Robert Mayer, James Joule, and others.
- 1859:** Gustav Kirchhoff introduces the concept of a black body. Together with Robert Bunsen, he invents the spectroscope for chemical analysis and discovers two new elements, cesium and rubidium.
- c. 1860:** The ether becomes an important concept in many physical theories, in particular in electrodynamics where it serves as the medium for transmission of signals. The ether is only abandoned around 1910, after the acceptance of Albert Einstein's special theory of relativity.
- 1864:** James Clerk Maxwell publishes his *Dynamical Theory of the Electromagnetic Field* in which the laws of electromagnetism are presented in terms of fields, but with no room for electrified particles.
- 1865:** Johann Loschmidt makes the first calculation of the number of molecules in a volume of gas, corresponding to Avogadro's number.
- 1867:** William Thomson (later, Lord Kelvin) suggests that atoms are vortical modes of motion in a primitive, perfect, and all-pervading fluid. The vortex atomic theory, a truly unified theory of all matter, is developed during the following decades but abandoned in the 1890s.
- 1868:** Based on a few unidentified lines in the solar spectrum, Norman Lockyer suggests the existence of a new element, helium, in the sun.
- 1869:** Dmitri Mendeleev publishes his periodic system in which the chemical elements are ordered according to their atomic weights and arranged in periods and groups.
- 1886:** William Crookes suggests that the periodic system reflects a compound structure of atoms and that the basic unity of matter may be helium, supposed to have an atomic weight of one-half.
- 1891:** George Johnstone Stoney introduces the term electron as a measure of an atomic unit charge. During the following years, electron theories are developed by Hendrik Lorentz, Joseph Larmor, and others.
- 1895:** Wilhelm Röntgen discovers a new kind of rays, called X rays or Röntgen rays.
- 1896:** Henri Becquerel announces the discovery of radioactivity, a radiation produced by uranium.
- 1896:** Pieter Zeeman discovers the effect of magnetism on spectral lines, and Hendrik Lorentz deduces from it that atoms contain oscillating negative charges of a mass that is perhaps 1,000 times as small as that of a hydrogen atom.
- 1897:** Joseph John Thomson demonstrates that cathode rays are corpuscular in nature. He calls the particles *corpuscles* and determines their charge-to-mass ratio. Thomson's corpuscles are soon known as electrons.
- 1898:** Marie and Pierre Curie discover two strongly radioactive elements, radium and polonium. It is gradually recognized that radioactivity is a spontaneous process, a disintegration of atoms.
- 1900:** Max Planck suggests that radiation energy is quantized. Planck's law of blackbody radiation is announced.
- 1904:** Joseph John Thomson develops a quantitative electron theory of atomic structure. In the Thomson model, a large number of electrons move in a hypothetical fluid of positive electricity.
- 1905:** Albert Einstein proposes that light and other electromagnetic radiation is not only emitted and absorbed in quanta, but consists of such quanta, later (1926) called photons. In his theory of relativity, he shows that energy and matter are equivalent according to $E = mc^2$.
- 1908:** Ernest Rutherford and Thomas Royds show conclusively that alpha particles are doubly charged helium ions. During the next two decades, alpha