

## APPENDIX E • Nobel Prizes

All Nobel Prizes in physics are listed (and marked with a P), as well as relevant Nobel Prizes in Chemistry (C). The key dates for some of the scientific work are supplied; they often antedate the prize considerably.

- 1901** (P) *Wilhelm Roentgen* for discovering x-rays (1895).
- 1902** (P) *Hendrik A. Lorentz* for predicting the Zeeman effect and *Pieter Zeeman* for discovering the Zeeman effect, the splitting of spectral lines in magnetic fields.
- 1903** (P) *Antoine-Henri Becquerel* for discovering radioactivity (1896) and *Pierre* and *Marie Curie* for studying radioactivity.
- 1904** (P) *Lord Rayleigh* for studying the density of gases and discovering argon. (C) *William Ramsay* for discovering the inert gas elements helium, neon, xenon, and krypton, and placing them in the periodic table.
- 1905** (P) *Philipp Lenard* for studying cathode rays, electrons (1898–1899).
- 1906** (P) *J. J. Thomson* for studying electrical discharge through gases and discovering the electron (1897).
- 1907** (P) *Albert A. Michelson* for inventing optical instruments and measuring the speed of light (1880s).
- 1908** (P) *Gabriel Lippmann* for making the first color photographic plate, using interference methods (1891).  
(C) *Ernest Rutherford* for discovering that atoms can be broken apart by alpha rays and for studying radioactivity.
- 1909** (P) *Guglielmo Marconi* and *Carl Ferdinand Braun* for developing wireless telegraphy.
- 1910** (P) *Johannes D. van der Waals* for studying the equation of state for gases and liquids (1881).
- 1911** (P) *Wilhelm Wien* for discovering Wien's law giving the peak of a black-body spectrum (1893).  
(C) *Marie Curie* for discovering radium and polonium (1898) and isolating radium.
- 1912** (P) *Nils Dalén* for inventing automatic gas regulators for lighthouses.
- 1913** (P) *Heike Kamerlingh Onnes* for the discovery of superconductivity and liquefying helium (1908).
- 1914** (P) *Max T. F. von Laue* for studying x-rays from their diffraction by crystals, showing that x-rays are electromagnetic waves (1912).  
(C) *Theodore W. Richards* for determining the atomic weights of sixty elements, indicating the existence of isotopes.
- 1915** (P) *William Henry Bragg* and *William Lawrence Bragg*, his son, for studying the diffraction of x-rays in crystals.
- 1917** (P) *Charles Barkla* for studying atoms by x-ray scattering (1906).
- 1918** (P) *Max Planck* for discovering energy quanta (1900).
- 1919** (P) *Johannes Stark*, for discovering the Stark effect, the splitting of spectral lines in electric fields (1913).

- 1920** (P) *Charles-Édouard Guillaume* for discovering invar, a nickel-steel alloy with low coefficient of expansion.  
(C) *Walther Nernst* for studying heat changes in chemical reactions and formulating the third law of thermodynamics (1918).
- 1921** (P) *Albert Einstein* for explaining the photoelectric effect and for his services to theoretical physics (1905).  
(C) *Frederick Soddy* for studying the chemistry of radioactive substances and discovering isotopes (1912).
- 1922** (P) *Niels Bohr* for his model of the atom and its radiation (1913).  
(C) *Francis W. Aston* for using the mass spectrograph to study atomic weights, thus discovering 212 of the 287 naturally occurring isotopes.
- 1923** (P) *Robert A. Millikan* for measuring the charge on an electron (1911) and for studying the photoelectric effect experimentally (1914).
- 1924** (P) *Karl M. G. Siegbahn* for his work in x-ray spectroscopy.
- 1925** (P) *James Franck* and *Gustav Hertz* for discovering the Franck-Hertz effect in electron-atom collisions.
- 1926** (P) *Jean-Baptiste Perrin* for studying Brownian motion to validate the discontinuous structure of matter and measure the size of atoms.
- 1927** (P) *Arthur Holly Compton* for discovering the Compton effect on x-rays, their change in wavelength when they collide with matter (1922), and *Charles T. R. Wilson* for inventing the cloud chamber, used to study charged particles (1906).
- 1928** (P) *Owen W. Richardson* for studying the thermionic effect and electrons emitted by hot metals (1911).
- 1929** (P) *Louis Victor de Broglie* for discovering the wave nature of electrons (1923).
- 1930** (P) *Chandrasekhara Venkata Raman* for studying Raman scattering, the scattering of light by atoms and molecules with a change in wavelength (1928).
- 1932** (P) *Werner Heisenberg* for creating quantum mechanics (1925).
- 1933** (P) *Erwin Schrödinger* and *Paul A. M. Dirac* for developing wave mechanics (1925) and relativistic quantum mechanics (1927).  
(C) *Harold Urey* for discovering heavy hydrogen, deuterium (1931).
- 1935** (P) *James Chadwick* for discovering the neutron (1932).  
(C) *Irène* and *Frédéric Joliot-Curie* for synthesizing new radioactive elements.
- 1936** (P) *Carl D. Anderson* for discovering the positron in particular and antimatter in general (1932) and *Victor F. Hess* for discovering cosmic rays.  
(C) *Peter J. W. Debye* for studying dipole moments and diffraction of x-rays and electrons in gases.
- 1937** (P) *Clinton Davisson* and *George Thomson* for discovering the diffraction of electrons by crystals, confirming de Broglie's hypothesis (1927).
- 1938** (P) *Enrico Fermi* for producing the transuranic radioactive elements by neutron irradiation (1934–1937).
- 1939** (P) *Ernest O. Lawrence* for inventing the cyclotron.
- 1943** (P) *Otto Stern* for developing molecular-beam studies (1923), and using them to discover the magnetic moment of the proton (1933).
- 1944** (P) *Isidor I. Rabi* for discovering nuclear magnetic resonance in atomic and molecular beams.  
(C) *Otto Hahn* for discovering nuclear fission (1938).
- 1945** (P) *Wolfgang Pauli* for discovering the exclusion principle (1924).
- 1946** (P) *Percy W. Bridgman* for studying physics at high pressures.
- 1947** (P) *Edward V. Appleton* for studying the ionosphere.

- 1948** (P) *Patrick M. S. Blackett* for studying nuclear physics with cloud-chamber photographs of cosmic-ray interactions.
- 1949** (P) *Hideki Yukawa* for predicting the existence of mesons (1935).
- 1950** (P) *Cecil F. Powell* for developing the method of studying cosmic rays with photographic emulsions and discovering new mesons.
- 1951** (P) *John D. Cockcroft* and *Ernest T. S. Walton* for transmuting nuclei in an accelerator (1932).  
(C) *Edwin M. McMillan* for producing neptunium (1940) and *Glenn T. Seaborg* for producing plutonium (1941) and further transuranic elements.
- 1952** (P) *Felix Bloch* and *Edward Mills Purcell* for discovering nuclear magnetic resonance in liquids and gases (1946).
- 1953** (P) *Frits Zernike* for inventing the phase-contrast microscope, which uses interference to provide high contrast.
- 1954** (P) *Max Born* for interpreting the wave function as a probability (1926) and other quantum-mechanical discoveries and *Walther Bothe* for developing the coincidence method to study subatomic particles (1930–1931), producing, in particular, the particle interpreted by Chadwick as the neutron.
- 1955** (P) *Willis E. Lamb, Jr.*, for discovering the Lamb shift in the hydrogen spectrum (1947) and *Polykarp Kusch* for determining the magnetic moment of the electron (1947).
- 1956** (P) *John Bardeen*, *Walter H. Brattain*, and *William Shockley* for inventing the transistor (1956).
- 1957** (P) *T.-D. Lee* and *C.-N. Yang* for predicting that parity is not conserved in beta decay (1956).
- 1958** (P) *Pavel A. Čerenkov* for discovering Čerenkov radiation (1935) and *Ilya M. Frank* and *Igor Tamm* for interpreting it (1937).
- 1959** (P) *Emilio G. Segrè* and *Owen Chamberlain* for discovering the antiproton (1955).
- 1960** (P) *Donald A. Glaser* for inventing the bubble chamber to study elementary particles (1952).  
(C) *Willard Libby* for developing radiocarbon dating (1947).
- 1961** (P) *Robert Hofstadter* for discovering internal structure in protons and neutrons and *Rudolf L. Mössbauer* for discovering the Mössbauer effect of recoilless gamma-ray emission (1957).
- 1962** (P) *Lev Davidovich Landau* for studying liquid helium and other condensed matter theoretically.
- 1963** (P) *Eugene P. Wigner* for applying symmetry principles to elementary-particle theory and *Maria Goeppert Mayer* and *J. Hans D. Jensen* for studying the shell model of nuclei (1947).
- 1964** (P) *Charles H. Townes*, *Nikolai G. Basov*, and *Alexandr M. Prokhorov* for developing masers (1951–1952) and lasers.
- 1965** (P) *Sin-iti Tomonaga*, *Julian S. Schwinger*, and *Richard P. Feynman* for developing quantum electrodynamics (1948).
- 1966** (P) *Alfred Kastler* for his optical methods of studying atomic energy levels.
- 1967** (P) *Hans Albrecht Bethe* for discovering the routes of energy production in stars (1939).
- 1968** (P) *Luis W. Alvarez* for discovering resonance states of elementary particles.
- 1969** (P) *Murray Gell-Mann* for classifying elementary particles (1963).
- 1970** (P) *Hannes Alfvén* for developing magnetohydrodynamic theory and *Louis Eugène Félix Néel* for discovering antiferromagnetism and ferrimagnetism (1930s).

- 1971** (P) *Dennis Gabor* for developing holography (1947).  
(C) *Gerhard Herzberg* for studying the structure of molecules spectroscopically.
- 1972** (P) *John Bardeen*, *Leon N. Cooper*, and *John Robert Schrieffer* for explaining superconductivity (1957).
- 1973** (P) *Leo Esaki* for discovering tunneling in semiconductors, *Ivar Giaever* for discovering tunneling in superconductors, and *Brian D. Josephson* for predicting the Josephson effect, which involves tunneling of paired electrons (1958–1962).
- 1974** (P) *Anthony Hewish* for discovering pulsars and *Martin Ryle* for developing radio interferometry.
- 1975** (P) *Aage N. Bohr*, *Ben R. Mottelson*, and *James Rainwater* for discovering why some nuclei take asymmetric shapes.
- 1976** (P) *Burton Richter* and *Samuel C. C. Ting* for discovering the J/psi particle, the first charmed particle (1974).
- 1977** (P) *John H. Van Vleck*, *Nevill F. Mott*, and *Philip W. Anderson* for studying solids quantum-mechanically.  
(C) *Ilya Prigogine* for extending thermodynamics to show how life could arise in the face of the second law.
- 1978** (P) *Arno A. Penzias* and *Robert W. Wilson* for discovering the cosmic background radiation (1965) and *Pyotr Kapitsa* for his studies of liquid helium.
- 1979** (P) *Sheldon L. Glashow*, *Abdus Salam*, and *Steven Weinberg* for developing the theory that unified the weak and electromagnetic forces (1958–1971).
- 1980** (P) *Val Fitch* and *James W. Cronin* for discovering CP (charge-parity) violation (1964), which possibly explains the cosmological dominance of matter over antimatter.
- 1981** (P) *Nicolaas Bloembergen* and *Arthur L. Schawlow* for developing laser spectroscopy and *Kai M. Siegbahn* for developing high-resolution electron spectroscopy (1958).
- 1982** (P) *Kenneth G. Wilson* for developing a method of constructing theories of phase transitions to analyze critical phenomena.
- 1983** (P) *William A. Fowler* for theoretical studies of astrophysical nucleosynthesis and *Subramanyan Chandrasekhar* for studying physical processes of importance to stellar structure and evolution, including the prediction of white dwarf stars (1930).
- 1984** (P) *Carlo Rubbia* for discovering the W and Z particles, verifying the electroweak unification, and *Simon van der Meer*, for developing the method of stochastic cooling of the CERN beam that allowed the discovery (1982–1983).
- 1985** (P) *Klaus von Klitzing* for the quantized Hall effect, relating to conductivity in the presence of a magnetic field (1980).
- 1986** (P) *Ernst Ruska* for inventing the electron microscope (1931), and *Gerd Binnig* and *Heinrich Rohrer* for inventing the scanning-tunneling electron microscope (1981).
- 1987** (P) *J. Georg Bednorz* and *Karl Alex Müller* for the discovery of high temperature superconductivity (1986).
- 1988** (P) *Leon M. Lederman*, *Melvin Schwartz*, and *Jack Steinberger* for a collaborative experiment that led to the development of a new tool for studying the weak nuclear force, which affects the radioactive decay of atoms.
- 1989** (P) *Norman Ramsay* (U.S.) for various techniques in atomic physics; and *Hans Dehmelt* (U.S.) and *Wolfgang Paul* (Germany) for the development of techniques for trapping single charge particles.

- 1990** (P) *Jerome Friedman, Henry Kendall* (both U.S.), and *Richard Taylor* (Canada) for experiments important to the development of the quark model.
- 1991** (P) *Pierre-Gilles de Gennes* for discovering that methods developed for studying order phenomena in simple systems can be generalized to more complex forms of matter, in particular to liquid crystals and polymers.
- 1992** (P) *George Charpak* for developing detectors that trace the paths of evanescent subatomic particles produced in particle accelerators.
- 1993** (P) *Russell Hulse* and *Joseph Taylor* for discovering evidence of gravitational waves.
- 1994** (P) *Bertram N. Brockhouse* and *Clifford G. Shull* for pioneering work in neutron scattering.
- 1995** (P) *Martin L. Perl* and *Frederick Reines* for discovering the tau particle and the neutrino, respectively.
- 1996** (P) *David M. Lee, Douglas C. Osheroff*, and *Robert C. Richardson* for developing a superfluid using helium-3.
- 1997** (P) *Steven Chu, Claude Cohen-Tannoudji*, and *William D. Phillips* for developing methods to cool and trap atoms with laser light.
- 1998** (P) *Robert B. Laughlin, Horst L. Störmer*, and *Daniel C. Tsui* for discovering a new form of quantum fluid with fractionally charged excitations.

