

# DEFINITIONS OF SCIENTIFIC TERMS

Brief definitions of selected terms of importance in chemistry, physics, and related fields of science are given in this section. The selection process emphasizes the following types of terms:

- ◆ Physical quantities
- ◆ Units of measure
- ◆ Classes of chemical compounds and materials
- ◆ Important theories, laws, and basic concepts.

Individual chemical compounds are not included.

Definitions have taken wherever possible from the recommendations of international or national bodies, especially the International Union of Pure and Applied Chemistry (IUPAC) and International Organization for Standardization (ISO). For physical quantities and units, the recommended symbol is also given. The source of such definitions is indicated by the reference number in brackets following the definition. In many cases these official definitions have been edited in the interest of stylistic consistency and economy of space. The user is referred to the original source for further details.

An asterisk (\*) following a term indicates that further information can be found by consulting the index of this handbook under the entry for that term.

**Ab initio method** - An approach to quantum-mechanical calculations on molecules which starts with the Schrödinger equation and carries out a complete integration, without introducing empirical factors derived from experimental measurement.

**Absorbance (A)** - Defined as  $-\log(1-\alpha) = \log(1/\tau)$ , where  $\alpha$  is the absorptance and  $\tau$  the transmittance of a medium through which a light beam passes. [2]

**Absorbed dose (D)** - For any ionizing radiation, the mean energy imparted to an element of irradiated matter divided by the mass of that element. [1]

**Absorptance ( $\alpha$ )** - Ratio of the radiant or luminous flux in a given spectral interval absorbed in a medium to that of the incident radiation. Also called absorption factor. [1]

**Absorption coefficient (a)** - The relative decrease in the intensity of a collimated beam of electromagnetic radiation, as a result of absorption by a medium, during traversal of an infinitesimal layer of the medium, divided by the length traversed. [1]

**Absorption coefficient, molar ( $\epsilon$ )** - Absorption coefficient divided by amount-of-substance concentration of the absorbing material in the sample solution ( $\epsilon = a/c$ ). The SI unit is  $\text{m}^2/\text{mol}$ . Also called extinction coefficient, but usually in units of  $\text{mol}^{-1}\text{dm}^2\text{cm}^{-1}$ . [2]

**Acceleration** - Rate of change of velocity with respect to time.

**Acceleration due to gravity ( $g$ )\*** - The standard value ( $9.80665 \text{ m/s}^2$ ) of the acceleration experienced by a body in the earth's gravitational field. [1]

**Acenes** - Polycyclic aromatic hydrocarbons consisting of fused benzene rings in a rectilinear arrangement. [5]

**Acid** - Historically, a substance that yields an  $\text{H}^+$  ion when it dissociates in solution, resulting in a  $\text{pH} < 7$ . In the Brønsted definition, an acid is a substance that donates a proton in any type of reaction. The most general definition, due to G.N. Lewis,

classifies any chemical species capable of accepting an electron pair as an acid.

**Acid dissociation constant ( $K_a$ )\*** - The equilibrium constant for the dissociation of an acid HA through the reaction  $\text{HA} + \text{H}_2\text{O} \rightleftharpoons \text{A}^- + \text{H}_3\text{O}^+$ . The quantity  $\text{p}K_a = -\log K_a$  is often used to express the acid dissociation constant.

**Actinides** - The elements of atomic number 89 through 103, e.g., Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr. [7]

**Activation energy\*** - In general, the energy that must be added to a system in order for a process to occur, even though the process may already be thermodynamically possible. In chemical kinetics, the activation energy is the height of the potential barrier separating the products and reactants. It determines the temperature dependence of the reaction rate.

**Activity** - For a mixture of substances, the absolute activity  $\lambda$  of substance B is defined as  $\lambda_B = \exp(\mu_B/RT)$ , where  $\mu_B$  is the chemical potential of substance B,  $R$  the gas constant, and  $T$  the thermodynamic temperature. The relative activity  $a$  is defined as  $a_B = \exp[(\mu_B - \mu_B^\circ)/RT]$ , where  $\mu_B^\circ$  designates the chemical potential in the standard state. [2]

**Activity coefficient ( $\gamma$ )\*** - Ratio of the activity  $a_B$  of component B of a mixture to the concentration of that component. The value of  $\gamma$  depends on the method of stating the composition. For mole fraction  $x_B$ , the relation is  $a_B = \gamma_B x_B$ ; for molarity  $c_B$ , it is  $a_B = \gamma_B c_B/c^\circ$ , where  $c^\circ$  is the standard state composition (typically chosen as 1 mol/L); for molality  $m_B$ , it is  $a_B = \gamma_B m_B/m^\circ$ , where  $m^\circ$  is the standard state molality (typically 1 mol/kg). [2]

**Activity, of radioactive substance (A)** - The average number of spontaneous nuclear transitions from a particular energy state occurring in an amount of a radionuclide in a small time interval divided by that interval. [1]

## References

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- Acyl groups** - Groups formed by removing the hydroxy groups from oxoacids that have the general structure  $RC(=O)(OH)$  and replacement analogues of such acyl groups. [5]
- Adiabatic process** - A thermodynamic process in which no heat enters or leaves the system.
- Admittance ( $Y$ )** - Reciprocal of impedance.  $Y = G + iB$ , where  $G$  is conductance and  $B$  is susceptance. [1]
- Adsorption** - A process in which molecules of gas, of dissolved substances in liquids, or of liquids adhere in an extremely thin layer to surfaces of solid bodies with which they are in contact. [10]
- Albedo\*** - The ratio of the light reflected or scattered from a surface to the intensity of incident light. The term is often used in reference to specific types of terrain or to entire planets.
- Alcohols** - Compounds in which a hydroxy group,  $-OH$ , is attached to a saturated carbon atom. [5]
- Aldehydes** - Compounds  $RC(=O)H$ , in which a carbonyl group is bonded to one hydrogen atom and to one R group. [5]
- Aldoses** - Aldehydic parent sugars (polyhydroxyaldehydes  $H[CH(OH)]_nC(=O)H$ ,  $n > 1$ ) and their intramolecular hemiacetals. [5]
- Aldoximes** - Oximes of aldehydes:  $RCH=NOH$ . [5]
- Alfvén number ( $Al$ )** - A dimensionless quantity used in plasma physics, defined by  $Al = v(\rho\mu)^{1/2}/B$ , where  $\rho$  is density,  $v$  is velocity,  $\mu$  is permeability, and  $B$  is magnetic flux density. [2]
- Alfvén waves** - Very low frequency waves which can exist in a plasma in the presence of a uniform magnetic field. Also called magnetohydrodynamic waves.
- Alicyclic compounds** - Aliphatic compounds having a carbocyclic ring structure which may be saturated or unsaturated, but may not be a benzenoid or other aromatic system. [5]
- Aliphatic compounds** - Acyclic or cyclic, saturated or unsaturated carbon compounds, excluding aromatic compounds. [5]
- Alkali metals** - The elements lithium, sodium, potassium, rubidium, cesium, and francium.
- Alkaline earth metals** - The elements calcium, strontium, barium, and radium. [7]
- Alkaloids** - Basic nitrogen compounds (mostly heterocyclic) occurring mostly in the plant kingdom (but not excluding those of animal origin). Amino acids, peptides, proteins, nucleotides, nucleic acids, and amino sugars are not normally regarded as alkaloids. [5]
- Alkanes** - Acyclic branched or unbranched hydrocarbons having the general formula  $C_nH_{2n+2}$ , and therefore consisting entirely of hydrogen atoms and saturated carbon atoms. [5]
- Alkenes** - Acyclic branched or unbranched hydrocarbons having one carbon-carbon double bond and the general formula  $C_nH_{2n}$ . Acyclic branched or unbranched hydrocarbons having more than one double bond are alkadienes, alkatrienes, etc. [5]
- Alkoxides** - Compounds,  $ROM$ , derivatives of alcohols,  $ROH$ , in which R is saturated at the site of its attachment to oxygen and M is a metal or other cationic species. [5]
- Alkyl groups** - Univalent groups derived from alkanes by removal of a hydrogen atom from any carbon atom:  $C_nH_{2n+1}$ -. The groups derived by removal of a hydrogen atom from a terminal carbon atom of unbranched alkanes form a subclass of normal alkyl ( $n$ -alkyl) groups. The groups  $RCH_2$ -,  $R_2CH$ -, and  $R_3C$ - (R not equal to H) are primary, secondary, and tertiary alkyl groups, respectively. [5]
- Alkynes** - Acyclic branched or unbranched hydrocarbons having a carbon-carbon triple bond and the general formula  $C_nH_{2n-2}$ ,  $RC\equiv CR'$ . Acyclic branched or unbranched hydrocarbons having more than one triple bond are known as alkadiynes, alkatriynes, etc. [5]
- Allotropy** - The occurrence of an element in two or more crystalline forms.
- Allylic groups** - The group  $CH_2=CHCH_2$ - (allyl) and derivatives formed by substitution. The term 'allylic position' or 'allylic site' refers to the saturated carbon atom. A group, such as  $-OH$ , attached at an allylic site is sometimes described as "allylic". [5]
- Amagat volume unit** - A non-SI unit previously used in high pressure science. It is defined as the molar volume of a real gas at one atmosphere pressure and 273.15 K. The approximate value is 22.4 L/mol.
- Amides** - Derivatives of oxoacids  $R(C=O)(OH)$  in which the hydroxy group has been replaced by an amino or substituted amino group. [5]
- Amine oxides** - Compounds derived from tertiary amines by the attachment of one oxygen atom to the nitrogen atom:  $R_3N^+O^-$ . By extension the term includes the analogous derivatives of primary and secondary amines. [5]
- Amines** - Compounds formally derived from ammonia by replacing one, two, or three hydrogen atoms by hydrocarbyl groups, and having the general structures  $RNH_2$  (primary amines),  $R_2NH$  (secondary amines),  $R_3N$  (tertiary amines). [5]
- Amino acids\*** - Compounds containing both a carboxylic acid group ( $-COOH$ ) and an amino group ( $-NH_2$ ). The most important are the  $\alpha$ -amino acids, in which the  $-NH_2$  group is attached to the C atom adjacent to the  $-COOH$  group. In the  $\beta$ -amino acids, there is an intervening carbon atom. [4]
- Ampere (A)\*** - The SI base unit of electric current. [1]
- Ampere's law** - The defining equation for the magnetic induction  $B$ , viz.,  $dF = Idl \times B$ , where  $dF$  is the force produced by a current  $I$  flowing in an element of the conductor  $dI$  pointing in the direction of the current.
- Ångström (Å)** - A unit of length used in spectroscopy, crystallography, and molecular structure, equal to  $10^{-10}$  m.
- Angular momentum ( $L$ )** - The angular momentum of a particle about a point is the vector product of the radius vector from this point to the particle and the momentum of the particle; i.e.,  $L = r \times p$ . [1]
- Angular velocity ( $\omega$ )** - The angle through which a body rotates per unit time.
- Anilides** - Compounds derived from oxoacids  $R(C=O)(OH)$  by replacing the  $-OH$  group by the  $-NHPh$  group or derivative formed by ring substitution. Also used for salts formed by replacement of a nitrogen-bound hydrogen of aniline by a metal. [5]
- Anion** - A negatively charged atomic or molecular particle.
- Antiferroelectricity\*** - An effect analogous to antiferromagnetism in which electric dipoles in a crystal are ordered in two sublattices that are polarized in opposite directions, leading to zero net polarization. The effect vanishes above a critical temperature.
- Antiferromagnetism\*** - A type of magnetism in which the magnetic moments of atoms in a solid are ordered into two antiparallel aligned sublattices. Antiferromagnets are characterized by a zero or small positive magnetic susceptibility. The

susceptibility increases with temperature up to a critical value, the Néel temperature, above which the material becomes paramagnetic.

**Antiparticle** - A particle having the same mass as a given elementary particle and a charge equal in magnitude but opposite in sign.

**Appearance potential\*** - The lowest energy which must be imparted to the parent molecule to cause it to produce a particular specified parent ion. This energy, usually stated in eV, may be imparted by electron impact, photon impact, or in other ways. More properly called appearance energy. [3]

**Appearance potential spectroscopy (APS)** - See Techniques for Materials Characterization, page 12-1.

**Are (a)** - A unit of area equal to 100 m<sup>2</sup>. [1]

**Arenes** - Monocyclic and polycyclic aromatic hydrocarbons. See aromatic compounds. [5]

**Aromatic compounds** - Compounds whose structure includes a cyclic delocalized  $\pi$ -electron system. Historical use of the term implies a ring containing only carbon (e.g., benzene, naphthalene), but it is often generalized to include heterocyclic structures such as pyridine and thiophene. [5]

**Arrhenius equation** - A key equation in chemical kinetics which expresses the rate constant  $k$  as  $k = A \exp(-E_a/RT)$ , where  $E_a$  is the activation energy,  $R$  the molar gas constant, and  $T$  the temperature.  $A$  is called the preexponential factor and, for simple gas phase reactions, may be identified with the collision frequency.

**Arsines** - AsH<sub>3</sub> and compounds derived from it by substituting one, two or three hydrogen atoms by hydrocarbyl groups. RAsH<sub>2</sub>, R<sub>2</sub>AsH, R<sub>3</sub>As (R not equal to H) are called primary, secondary and tertiary arsines, respectively. [5]

**Aryl groups** - Groups derived from arenes by removal of a hydrogen atom from a ring carbon atom. Groups similarly derived from heteroarenes are sometimes subsumed in this definition. [5]

**Astronomical unit (AU)\*** - The mean distance of the earth from the sun, equal to 1.49597870  $\times$  10<sup>11</sup> m.

**Atomic absorption spectroscopy (AAS)** - See Techniques for Materials Characterization, page 12-1.

**Atomic emission spectroscopy (AES)** - See Techniques for Materials Characterization, page 12-1.

**Atomic force microscopy (AFM)** - See Techniques for Materials Characterization, page 12-1.

**Atomic mass\*** - The mass of a nuclide, normally expressed in unified atomic mass units (u).

**Atomic mass unit (u)\*** - A unit of mass used in atomic, molecular, and nuclear science, defined as the mass of one atom of <sup>12</sup>C divided by 12. Its approximate value is 1.66054  $\times$  10<sup>-27</sup> kg. Also called the unified atomic mass unit. [1]

**Atomic number (Z)** - A characteristic property of an element, equal to the number of protons in the nucleus.

**Atomic weight (A<sub>p</sub>)\*** - The ratio of the average mass per atom of an element to 1/12 of the mass of nuclide <sup>12</sup>C. An atomic weight can be defined for a sample of any given isotopic composition. The standard atomic weight refers to a sample of normal terrestrial isotopic composition. The term relative atomic mass is synonymous with atomic weight. [2]

**Attenuated total reflection (ATR)** - See Techniques for Materials Characterization, page 12-1.

**Auger effect** - An atomic process in which an electron from a higher energy level fills a vacancy in an inner shell, transferring the released energy to another electron which is ejected.

**Aurora** - An atmospheric phenomenon in which streamers of light are produced when electrons from the sun are guided into the thermosphere by the earth's magnetic field. It occurs in the polar regions at altitudes of 95–300 km.

**Avogadro constant (N<sub>A</sub>)\*** - The number of elementary entities in one mole of a substance.

**Azeotrope** - A liquid mixture in a state where the variation of vapor pressure with composition at constant temperature (or, alternatively, the variation of normal boiling point with composition) shows either a maximum or a minimum. Thus when an azeotrope boils the vapor has the same composition as the liquid.

**Azides** - Compounds bearing the group -N<sub>3</sub>, viz. -N=N<sup>+</sup>=N<sup>-</sup>; usually attached to carbon, e.g. PhN<sub>3</sub>, phenyl azide or azidobenzene. Also used for salts of hydrazoic acid, HN<sub>3</sub>, e.g. NaN<sub>3</sub>, sodium azide. [5]

**Azines** - Condensation products, R<sub>2</sub>C=NN=CR<sub>2</sub>, of two moles of a carbonyl compound with one mole of hydrazine. [5]

**Azo compounds** - Derivatives of diazene (diimide), HN=NH, wherein both hydrogens are substituted by hydrocarbyl groups, e.g., PhN=NPh, azobenzene or diphenyldiazene. [5]

**Balmer series** - The series of lines in the spectrum of the hydrogen atom which corresponds to transitions between the state with principal quantum number  $n = 2$  and successive higher states. The wavelengths are given by  $1/\lambda = R_H(1/4 - 1/n^2)$ , where  $n = 3, 4, \dots$  and  $R_H$  is the Rydberg constant for hydrogen. The first member of the series ( $n = 2 \Rightarrow 3$ ), which is often called the H $_{\alpha}$  line, falls at a wavelength of 6563 Å.

**Bar (bar)** - A unit of pressure equal to 10<sup>5</sup> Pa.

**Bardeen-Cooper-Schrieffer (BCS) theory** - A theory of superconductivity which is based upon the formation of electron pairs as a result of an electron-lattice interaction. The theory relates the superconducting transition temperature to the density of states and the Debye temperature.

**Barn (b)** - A unit used for expressing cross sections of nuclear processes, equal to 10<sup>-28</sup> m<sup>2</sup>.

**Barrel** - A unit of volume equal to 158.9873 L.

**Baryon** - Any elementary particle built up from three quarks. Examples are the proton, neutron, and various short-lived hyperons. Baryons have odd half-integer spins.

**Base** - Historically, a substance that yields an OH<sup>-</sup> ion when it dissociates in solution, resulting in a pH > 7. In the Brønsted definition, a base is a substance capable of accepting a proton in any type of reaction. The more general definition, due to G.N. Lewis, classifies any chemical species capable of donating an electron pair as a base.

**Becquerel (Bq)\*** - The SI unit of radioactivity (disintegrations per unit time), equal to s<sup>-1</sup>. [1]

**Beer's law** - An approximate expression for the change in intensity of a light beam that passes through an absorbing medium, viz.,  $\log(I/I_0) = -\epsilon cl$ , where  $I_0$  is the incident intensity,  $I$  is the final intensity,  $\epsilon$  is the molar (decadic) absorption coefficient,  $c$  is the molar concentration of the absorbing substance, and  $l$  is the path length. Also called the Beer-Lambert law

**Binding energy\*** - A generic term for the energy required to decompose a system into two or more of its constituent parts. In nuclear physics, the binding energy is the energy differ-

ence between a nucleus and the separated nucleons of which it is composed (the energy equivalent of the mass defect). In atomic physics, it is the energy required to remove an electron from an atom.

**Biot (Bi)** - A name sometimes used for the unit of current in the emu system.

**Birefringence** - A property of certain crystals in which two refracted rays result from a single incident light ray. One, the ordinary ray, follows the normal laws of refraction, while the other, the extraordinary ray, exhibits a variable refractive index which depends on the direction in the crystal.

**Black body radiation\*** - The radiation emitted by a perfect black body, i.e., a body which absorbs all radiation incident on it and reflects none. The wavelength dependence of the radiated energy density  $\rho$  (energy per unit volume per unit wavelength range) is given by the Planck formula

$$\rho = \frac{8\pi hc}{\lambda^5 (e^{hc/\lambda kT} - 1)}$$

where  $\lambda$  is the wavelength,  $h$  is Planck's constant,  $c$  is the speed of light,  $k$  is the Boltzmann constant, and  $T$  is the temperature.

**Black hole** - A very dense object, formed in a supernova explosion, whose gravitational field is so large that no matter or radiation can escape from the object.

**Bloch wave function** - A solution of the Schrödinger equation for an electron moving in a spatially periodic potential; used in the band theory of solids.

**Bohr magneton ( $\mu_B$ )\*** - The atomic unit of magnetic moment, defined as  $eh/4\pi m_e$ , where  $h$  is Planck's constant,  $m_e$  the electron mass, and  $e$  the elementary charge. It is the moment associated with a single electron spin.

**Bohr, bohr radius ( $a_0$ )\*** - The radius of the lowest orbit in the Bohr model of the hydrogen atom, defined as  $\epsilon_0 h^2 / \pi m_e e^2$ , where  $\epsilon_0$  is the permittivity of a vacuum,  $h$  is Planck's constant,  $m_e$  the electron mass, and  $e$  the elementary charge. It is customarily taken as the unit of length when using atomic units.

**Boiling point** - The temperature at which the liquid and gas phases of a substance are in equilibrium at a specified pressure. The normal boiling point is the boiling point at normal atmospheric pressure (101.325 kPa).

**Boltzmann constant ( $k$ )\*** - The molar gas constant  $R$  divided by Avogadro's constant.

**Boltzmann distribution** - An expression for the equilibrium distribution of molecules as a function of their energy, in which the number of molecules in a state of energy  $E$  is proportional to  $\exp(-E/kT)$ , where  $k$  is the Boltzmann constant and  $T$  is the temperature.

**Bond strength** - See Dissociation energy.

**Born-Haber cycle\*** - A thermodynamic cycle in which a crystalline solid is converted to gaseous ions and then reconverted to the solid. The cycle permits calculation of the lattice energy of the crystal.

**Bose-Einstein distribution** - A modification of the Boltzmann distribution which applies to a system of particles that are bosons. The number of particles of energy  $E$  is proportional to  $[e^{(E-\mu)/kT} - 1]^{-1}$ , where  $\mu$  is a normalization constant,  $k$  is the Boltzmann constant, and  $T$  is the temperature.

**Boson** - A particle that obeys Bose-Einstein Statistics; specifically, any particle with spin equal to zero or an integer. This includes

the photon, pion, deuteron, and all nuclei of even mass number.

**Boyle's law** - The empirical law, exact only for an ideal gas, which states that the volume of a gas is inversely proportional to its pressure at constant temperature.

**Bragg angle ( $\theta$ )** - Defined by the equation  $n\lambda = 2d\sin\theta$ , which relates the angle  $\theta$  between a crystal plane and the diffracted x-ray beam, the wavelength  $\lambda$  of the x-rays, the crystal plane spacing  $d$ , and the diffraction order  $n$  (any integer).

**Bravais lattices\*** - The 14 distinct crystal lattices that can exist in three dimensions. They include three in the cubic crystal system, two in the tetragonal, four in the orthorhombic, two in the monoclinic, and one each in the triclinic, hexagonal, and trigonal systems.

**Breakdown voltage** - The potential difference at which an insulating substance undergoes a physical or chemical change that causes it to become a conductor, thus allowing current to flow through the sample.

**Bremsstrahlung** - Electromagnetic radiation generated when the velocity of a charged particle is reduced (literally, "braking radiation"). An example is the x-ray continuum resulting from collisions of electrons with the target in an x-ray tube.

**Brewster angle** - The angle of incidence for which the maximum degree of plane polarization occurs when a beam of unpolarized light is incident on the surface of a medium of refractive index  $n$ . At this angle, the angle between the reflected and refracted beams is  $90^\circ$ . The value of the Brewster angle is  $\tan^{-1}n$ .

**Brillouin scattering** - The scattering of light by acoustic phonons in a solid or liquid.

**Brillouin zone** - A region of allowed wave vectors and energy levels in a crystalline solid, which plays a part in the propagation of waves through the lattice.

**British thermal unit (Btu)** - A non-SI unit of energy, equal to approximately 1055 J. Several values of the Btu, defined in slightly different ways, have been used.

**Brownian motion** - The random movements of small particles suspended in a fluid, which arise from collisions with the fluid molecules.

**Brunauer-Emmett-Teller method (BET)** - See Techniques for Materials Characterization, page 12-1.

**Buffer\*** - A solution designed to maintain a constant pH when small amounts of a strong acid or base are added. Buffers usually consist of a fairly weak acid and its salt with a strong base. Suitable concentrations are chosen so that the pH of the solution remains close to the  $pK_a$  of the weak acid.

**Calorie (cal)** - A non-SI unit of energy, originally defined as the heat required to raise the temperature of 1 g of water by  $1^\circ\text{C}$ . Several calories of slightly different values have been used. The thermochemical calorie is now defined as 4.184 J.

**Candela (cd)\*** - The SI base unit of luminous intensity. [1]

**Capacitance (C)** - Ratio of the charge acquired by a body to the change in potential. [1]

**Carbamates** - Salts or esters of carbamic acid,  $\text{H}_2\text{NC}(=\text{O})\text{OH}$ , or of N-substituted carbamic acids:  $\text{R}_2\text{NC}(=\text{O})\text{OR}'$ , ( $\text{R}' = \text{hydrocarbyl}$  or a cation). The esters are often called urethanes or urethans, a usage that is strictly correct only for the ethyl esters. [5]

**Carbenes** - The electrically neutral species  $\text{H}_2\text{C}$ : and its derivatives, in which the carbon is covalently bonded to two univa-

- lent groups of any kind or a divalent group and bears two non-bonding electrons, which may be spin-paired (singlet state) or spin-non-paired (triplet state). [5]
- Carbinols** - An obsolete term for substituted methanols, in which the name carbinol is synonymous with methanol. [5]
- Carbohydrates** - Originally, compounds such as aldoses and ketoses, having the stoichiometric formula  $C_n(H_2O)_n$  (hence "hydrates of carbon"). The generic term carbohydrate now includes mono-, oligo-, and polysaccharides, as well as their reaction products and derivatives. [5]
- Carboranes** - A contraction of carbaboranes. Compounds in which a boron atom in a polyboron hydride is replaced by a carbon atom with maintenance of the skeletal structure. [5]
- Carboxylic acids** - Oxoacids having the structure  $RC(=O)OH$ . The term is used as a suffix in systematic name formation to denote the  $-C(=O)OH$  group including its carbon atom. [5]
- Carnot cycle** - A sequence of reversible changes in a heat engine using a perfect gas as the working substance, which is used to demonstrate that entropy is a state function. The Carnot cycle also provides a means to calculate the efficiency of a heat engine.
- Catalyst** - A substance that participates in a particular chemical reaction and thereby increases its rate but without a net change in the amount of that substance in the system. [3]
- Catenanes, catena compounds** - Hydrocarbons having two or more rings connected in the manner of links of a chain, without a covalent bond. More generally, the class catena compounds embraces functional derivatives and hetero analogues. [5]
- Cation** - A positively charged atomic or molecular particle.
- Centipoise (cP)** - A common non-SI unit of viscosity, equal to mPa s.
- Centrifugal distortion** - An effect in molecular spectroscopy in which rotational levels are lowered in energy, relative to the values of a rigid rotor, as the rotational angular momentum increases. The effect may be understood classically as a stretching of the bonds in the molecule as it rotates faster, thus increasing the moment of inertia.
- Ceramic** - A nonmetallic material of very high melting point.
- Cerenkov radiation** - Light emitted when a beam of charged particles travels through a medium at a speed greater than the speed of light in the medium. It is typically blue in color.
- Cgs system of units** - A system of units based upon the centimeter, gram, and second. The cgs system has been supplanted by the International System (SI).
- Chalcogens** - The Group VIA elements (oxygen, sulfur, selenium, tellurium, and polonium). Compounds of these elements are called chalcogenides. [7]
- Chaotic system** - A complex system whose behavior is governed by deterministic laws but whose evolution can vary drastically when small changes are made in the initial conditions.
- Charge** - See Electric charge.
- Charles' law** - The empirical law, exact only for an ideal gas, which states that the volume of a gas is directly proportional to its temperature at constant pressure.
- Charm** - A quantum number introduced in particle physics to account for certain properties of elementary particles and their reactions.
- Chelate** - A compound characterized by the presence of bonds from two or more bonding sites within the same ligand to a central metal atom. [3]
- Chemical potential** - For a mixture of substances, the chemical potential of constituent B is defined as the partial derivative of the Gibbs energy  $G$  with respect to the amount (number of moles) of B, with temperature, pressure, and amounts of all other constituents held constant. Also called partial molar Gibbs energy. [2]
- Chemical shift\*** - A small change in the energy levels (and hence in the spectra associated with these levels) resulting from the effects of chemical binding in a molecule. The term is used in fields such as NMR, Mössbauer, and photoelectron spectroscopy, where the energy levels are determined primarily by nuclear or atomic effects.
- Chiral molecule** - A molecule which cannot be superimposed on its mirror image. A common example is an organic molecule containing a carbon atom to which four different atoms or groups are attached. Such molecules exhibit optical activity, i.e., they rotate the plane of a polarized light beam.
- Chlorocarbons** - Compounds consisting solely of chlorine and carbon. [5]
- Chromatography\*** - A method for separation of the components of a sample in which the components are distributed between two phases, one of which is stationary while the other moves. In gas chromatography the gas moves over a liquid or solid stationary phase. In liquid chromatography the liquid mixture moves through another liquid, a solid, or a gel. The mechanism of separation of components may be adsorption, differential solubility, ion-exchange, permeation, or other mechanisms. [6]
- Clapeyron equation** - A relation between pressure and temperature of two phases of a pure substance that are in equilibrium, viz.,  $dp/dT = \Delta_{trs} S / \Delta_{trs} V$ , where  $\Delta_{trs} S$  is the difference in entropy between the phases and  $\Delta_{trs} V$  the corresponding difference in volume.
- Clathrates** - Inclusion compounds in which the guest molecule is in a cage formed by the host molecule or by a lattice of host molecules. [5]
- Clausius (CI)** - A non-SI unit of entropy or heat capacity defined as cal/K = 4.184 J/K. [2]
- Clausius-Clapeyron equation** - An approximation to the Clapeyron equation applicable to liquid-gas and solid-gas equilibrium, in which one assumes an ideal gas with volume much greater than the condensed phase volume. For the liquid-gas case, it takes the form  $d(\ln p)/dT = \Delta_{vap} H / RT^2$  where  $R$  is the molar gas constant and  $\Delta_{vap} H$  is the molar enthalpy of vaporization. For the solid-gas case,  $\Delta_{vap} H$  is replaced by the molar enthalpy of sublimation,  $\Delta_{sub} H$ .
- Clausius-Mosotti equation** - A relation between the dielectric constant  $\epsilon_r$  at optical frequencies and the polarizability  $\alpha$ :
- $$\frac{\epsilon_r - 1}{\epsilon_r + 2} = \frac{\rho N_A \alpha}{3M\epsilon_0}$$
- where  $\rho$  is density,  $N_A$  is Avogadro's number,  $M$  is molar mass, and  $\epsilon_0$  is the permittivity of a vacuum.
- Clebsch-Gordon coefficients** - A set of coefficients used to describe the vector coupling of angular momenta in atomic and nuclear physics.
- Codon** - A set of three bases, chosen from the four primary bases found in the DNA molecule (uracil, cytosine, adenine, and guanine), which specifies the production of a particular amino

acid or carries some other genetic instruction. For example, the codon UCA specifies the amino acid serine, CAG specifies glutamine, etc. There are a total of 64 codons.

**Coercive force** - The magnetizing force at which the magnetic flux density is equal to zero. [10]

**Coercivity\*** - The maximum value of coercive force that can be attained when a magnetic material is symmetrically magnetized to saturation induction. [10]

**Coherent anti-Stokes Raman spectroscopy (CARS)** - See Techniques for Materials Characterization, page 12-1.

**Colloid** - Molecules or polymolecular particles dispersed in a medium that have, at least in one direction, a dimension roughly between 1 nm and 1  $\mu\text{m}$ . [3]

**Color center** - A defect in a crystal that gives rise to optical absorption, thus changing the color of the material. A common type is the F-center, which results when an electron occupies the site of a negative ion.

**Compressibility ( $\kappa$ )\*** - The fractional change of volume as pressure is increased, viz.,  $\kappa = -(1/V)(dV/dp)$ . [1]

**Compton wavelength ( $\lambda_c$ )\*** - In the scattering of electromagnetic radiation by a free particle (e.g., electron, proton),  $\lambda_c = h/mc$  is the increase in wavelength, at a  $90^\circ$  scattering angle, corresponding to the transfer of energy from radiation to particle. Here  $h$  is Planck's constant,  $c$  the speed of light, and  $m$  the mass of the particle.

**Conductance ( $G$ )\*** - For direct current, the reciprocal of resistance. More generally, the real part of admittance. [1]

**Conductivity, electrical ( $\sigma$ )\*** - The reciprocal of the resistivity. [1]

**Conductivity, thermal** - See Thermal conductivity.

**Congruent transformation** - A phase transition (melting, vaporization, etc.) in which the substance preserves its exact chemical composition.

**Constitutional repeating unit (CRU)** - In polymer science, the smallest constitutional unit, the repetition of which constitutes a regular macromolecule, i.e., a macromolecule with all units connected identically with respect to directional sense. [8]

**Copolymer** - A polymer derived from more than one species of monomer. [8]

**Coriolis effect** - The deviation from simple trajectories when a mechanical system is described in a rotating coordinate system. It affects the motion of projectiles on the earth and in molecular spectroscopy leads to an important interaction between the rotational and vibrational motions. The effect may be described by an additional term in the equations of motion, called the Coriolis force.

**Cosmic rays\*** - High energy nuclear particles, electrons, and photons, originating mostly outside the solar system, which continually bombard the earth's atmosphere.

**Coulomb (C)\*** - The SI unit of electric charge, equal to A s. [1]

**Coulomb's law** - The statement that the force  $F$  between two electrical charges  $q_1$  and  $q_2$  separated by a distance  $r$  is  $F = (4\pi\epsilon_0)^{-1} q_1 q_2 / r^2$ , where  $\epsilon_0$  is the permittivity of a vacuum.

**Covalent bond** - A chemical bond between two atoms whose stability results from the sharing of two electrons, one from each atom.

**Cowling number ( $Co$ )** - A dimensionless quantity used in plasma physics, defined by  $Co = B^2 / \mu \rho v^2$ , where  $\rho$  is density,  $v$  is velocity,  $\mu$  is permeability, and  $B$  is magnetic flux density. [2]

**CPT theorem** - A theorem in particle physics which states that any local Lagrangian theory that is invariant under proper

Lorentz transformations is also invariant under the combined operations of charge conjugation, C, space inversion, P, and time reversal, T, taken in any order.

**Critical point\*** - In general, the point on the phase diagram of a two-phase system at which the two coexisting phases have identical properties and therefore represent a single phase. At the liquid-gas critical point of a pure substance, the distinction between liquid and gas vanishes, and the vapor pressure curve ends. The coordinates of this point are called the critical temperature and critical pressure. Above the critical temperature, it is not possible to liquefy the substance.

**Cross section ( $\sigma$ )\*** - A measure of the probability of collision (or other interaction) between a beam of particles and a target which it encounters. In rough terms it is the effective area the target particles present to the incident ones; however, the precise definition depends on the nature of the interaction. A general definition of  $\sigma$  is the number of encounters per unit time divided by  $nv$ , where  $n$  is the concentration of incident particles and  $v$  their velocity.

**Crosslink** - In polymer science, a small region in a macromolecule from which at least four chains emanate, and formed by reactions involving sites or groups on existing macromolecules or by interactions between existing macromolecules. [8]

**Crown compounds** - Macrocyclic polydentate compounds, usually uncharged, in which three or more coordinating ring atoms (usually oxygen or nitrogen) are or may become suitably close for easy formation of chelate complexes with metal ions or other cationic species. [5]

**Crust\*** - The outer layer of the solid earth, above the Mohorovicic discontinuity. Its thickness averages about 35 km on the continents and about 7 km below the ocean floor.

**Cryoscopic constant ( $E_f$ )\*** - The constant that expresses the amount by which the freezing point  $T_f$  of a solvent is lowered by a non-dissociating solute, through the relation  $\Delta T_f = E_f m$ , where  $m$  is the molality of the solute.

**Curie (Ci)** - A non-SI unit of radioactivity (disintegrations per unit time), equal to  $3.7 \times 10^{10} \text{ s}^{-1}$ .

**Curie temperature ( $T_C$ )\*** - For a ferromagnetic material, the critical temperature above which the material becomes paramagnetic. Also applied to the temperature at which the spontaneous polarization disappears in a ferroelectric solid. [1]

**Cyanohydrins** - Alcohols substituted by a cyano group, most commonly, but not limited to, examples having a CN and an OH group attached to the same carbon atom. They are formally derived from aldehydes or ketones by the addition of hydrogen cyanide. [5]

**Cycloalkanes** - Saturated monocyclic hydrocarbons (with or without side chains). See alicyclic compounds. Unsaturated monocyclic hydrocarbons having one endocyclic double or one triple bond are called cycloalkenes and cycloalkynes, respectively. [5]

**Cyclotron resonance** - The resonant absorption of energy from a system in which electrons or ions that are orbiting in a uniform magnetic field are subjected to radiofrequency or microwave radiation. The resonance frequency is given by  $\nu = eH / 2\pi m^* c$ , where  $e$  is the elementary charge,  $H$  is the magnetic field strength,  $m^*$  is the effective mass of the charged particle, and  $c$  is the speed of light. The effect occurs in both solids (involving electrons or holes) and in low pressure gasses (involving ions)

**Dalton (Da)** - A name sometimes used in biochemistry for the unified atomic mass unit (u).

**De Broglie wavelength** - The wavelength associated with the wave representation of a moving particle, given by  $h/mv$ , where  $h$  is Planck's constant,  $m$  the particle mass, and  $v$  the velocity.

**De Haas-Van Alphen effect** - An effect observed in certain metals and semiconductors at low temperatures and high magnetic fields, characterized by a periodic variation of magnetic susceptibility with field strength.

**Debye equation\*** - The relation between the relative permittivity (dielectric constant)  $\epsilon_r$ , polarizability  $\alpha$ , and permanent dipole moment  $\mu$  in a dielectric material whose molecules are free to rotate. It takes the form

$$\frac{\epsilon_r - 1}{\epsilon_r + 2} = \frac{\rho N_A}{3M\epsilon_0} \left( \alpha + \frac{\mu^2}{3kT} \right)$$

where  $\rho$  is density,  $N_A$  is Avogadro's number,  $M$  is molar mass, and  $\epsilon_0$  is the permittivity of a vacuum.

**Debye length** - In the Debye-Hückel theory of ionic solutions, the effective thickness of the cloud of ions of opposite charge which surrounds each given ion and shields the Coulomb potential produced by that ion.

**Debye temperature ( $\theta_D$ )\*** - In the Debye model of the heat capacity of a crystalline solid,  $\theta_D = hv_D/k$ , where  $h$  is Planck's constant,  $k$  is the Boltzmann constant, and  $v_D$  is the maximum vibrational frequency the crystal can support. For  $T \ll \theta_D$ , the heat capacity is proportional to  $T^3$ .

**Debye unit (D)** - A non-SI unit of electric dipole moment used in molecular physics, equal to  $3.335641 \times 10^{-30}$  C m.

**Debye-Waller factor (D)** - The factor by which the intensity of a diffraction line is reduced because of lattice vibrations. [1]

**Defect** - Any departure from the regular structure of a crystal lattice. A Frenkel defect results when an atom or ion moves to an interstitial position and leaves behind a vacancy. A Schottky defect involves either a vacancy where the atom has moved to the surface or a structure where a surface atom has moved to an interstitial position.

**Degree of polymerization** - The number of monomeric units in a macromolecule or an oligomer molecule. [8]

**Dendrite** - A tree-like crystalline pattern often observed, for example, in ice crystals and alloys in which the crystal growth branches repeatedly.

**Density ( $\rho$ )\*** - In the most common usage, mass density or mass per unit volume. More generally, the amount of some quantity (mass, charge, energy, etc.) divided by a length, area, or volume.

**Density of states ( $N_E \rho$ )** - The number of one-electron states in an infinitesimal interval of energy, divided by the range of that interval and by volume. [1]

**Dew point\*** - The temperature at which liquid begins to condense as the temperature of a gas mixture is lowered. In meteorology, it is the temperature at which moisture begins to condense on a surface in contact with the air.

**Diamagnetism** - A type of magnetism characterized by a negative magnetic susceptibility, so that the material, when placed in an external magnetic field, becomes weakly magnetized in the direction opposite to the field. This magnetization is independent of temperature.

**Diazo compounds** - Compounds having the divalent diazo group,  $=N^+=N^-$ , attached to a carbon atom, e.g.,  $CH_2=N_2$  diazomethane. [5]

**Dielectric constant ( $\epsilon$ )\*** - Ratio of the electric displacement in a medium to the electric field strength. Also called permittivity. [1]

**Dienes** - Compounds that contain two fixed double bonds (usually assumed to be between carbon atoms). Dienes in which the two double-bond units are linked by one single bond are termed conjugated. [5]

**Differential scanning calorimetry (DSC)** - See Techniques for Materials Characterization, page 12-1.

**Differential thermal analysis (DTA)** - See Techniques for Materials Characterization, page 12-1.

**Diffusion\*** - The migration of atoms, molecules, ions, or other particles as a result of some type of gradient (concentration, temperature, etc.).

**Dioptr** - A unit used in optics, formally equal to  $m^{-1}$ . It is used in expressing dioptric power, which is the reciprocal of the focal length of a lens.

**Dipole moment, electric ( $p, \mu$ )\*** - For a distribution of equal positive and negative charge, the magnitude of the dipole moment vector is the positive charge multiplied by the distance between the centers of positive and negative charge distribution. The direction is given by the line from the center of negative charge to the center of positive charge.

**Dipole moment, magnetic ( $m, \mu$ )** - Formally defined in electromagnetic theory as a vector quantity whose vector product with the magnetic flux density equals the torque. The magnetic dipole generated by a current  $I$  flowing in a small loop of area  $A$  has a magnetic moment of magnitude  $IA$ . In atomic and nuclear physics, a magnetic moment is associated with the angular momentum of a particle; e.g., an electron with orbital angular momentum  $l$  exhibits a magnetic moment of  $-el/2m_e$  where  $e$  is the elementary charge and  $m_e$  the mass of the electron. [1]

**Disaccharides** - Compounds in which two monosaccharides are joined by a glycosidic bond. [5]

**Dislocation** - An extended displacement of a crystal from a regular lattice. An edge dislocation results when one portion of the crystal has partially slipped with respect to the other, resulting in an extra plane of atoms extending through part of the crystal. A screw dislocation transforms successive atomic planes into the surface of a helix.

**Dispersion** - Splitting of a beam of light (or other electromagnetic radiation) of mixed wavelengths into the constituent wavelengths as a result of the variation of refractive index of the medium with wavelength.

**Dissociation constant\*** - The equilibrium constant for a chemical reaction in which a compound dissociates into its constituent parts.

**Dissociation energy ( $D_0$ )\*** - For a diatomic molecule, the difference between the energies of the free atoms at rest and the minimum in the potential energy curve. The term bond dissociation energy ( $D_0$ ), which can be applied to polyatomic molecules as well, is used for the difference between the energies of the fragments resulting when a bond is broken and the energy of the original molecule in its lowest energy state. The term bond strength implies differences in enthalpy rather than energy.

- Domain** - A small region of a solid in which the magnetic or electric moments of the individual units (atoms, molecules, or ions) are aligned in the same direction.
- Domain wall** - The transition region between adjacent ferromagnetic domains, generally a layer with a thickness of a few hundred ångström units. Also called Bloch wall.
- Doppler effect** - The change in the apparent frequency of a wave (sound, light, or other) when the source of the wave is moving relative to the observer.
- Dose equivalent ( $H$ )** - The product of the absorbed dose of radiation at a point of interest in tissue and various modifying factors which depend on the type of tissue and radiation. [1]
- Drift velocity** - The velocity of charge carriers (electrons, ions, etc.) moving under the influence of an electric field in a medium which subjects the carriers to some frictional force.
- Dyne (dyn)** - A non-SI (cgs) unit of force, equal to  $10^{-5}$  N.
- Ebullioscopic constant ( $E_b$ )\*** - The constant that expresses the amount by which the boiling point  $T_b$  of a solvent is raised by a non-dissociating solute, through the relation  $\Delta T_b = E_b m$ , where  $m$  is the molality of the solute.
- Eddy currents** - Circulating currents set up in conducting bulk materials or sheets by varying magnetic fields.
- Effinghausen effect** - The appearance of a temperature gradient in a current carrying conductor that is placed in a transverse magnetic field. The direction of the gradient is perpendicular to the current and the field.
- Eigenvalue** - An allowed value of the constant  $a$  in the equation  $Au = au$ , where  $A$  is an operator acting on a function  $u$  (which is called an eigenfunction). In quantum mechanics, the outcome of any observation is an eigenvalue of the corresponding operator. Also called characteristic value.
- Einstein** - A non-SI unit used in photochemistry, equal to one mole of photons.
- Einstein temperature ( $\theta_v$ )** - In the Einstein theory of the heat capacity of a crystalline solid,  $\theta_v = hv/k$ , where  $h$  is Planck's constant,  $k$  is the Boltzmann constant, and  $v$  is the vibrational frequency of the crystal.
- Einstein transition probability** - A constant in the Einstein relation  $A_{ij} + B_{ij}\rho$  for the probability of a transition between two energy levels  $i$  and  $j$  in a radiation field of energy density  $\rho$ . The  $A_{ij}$  coefficient describes the probability of spontaneous emission, while  $B_{ij}$  and  $B_{ji}$  govern the probability of stimulated emission and absorption, respectively ( $B_{ij} = B_{ji}$ ).
- Elastic limit** - The greatest stress which a material is capable of sustaining without any permanent strain remaining after complete release of the stress. [10]
- Elastic modulus** - See Young's modulus.
- Electric charge ( $Q$ )** - The quantity of electricity; i.e., the property that controls interactions between bodies through electrical forces.
- Electric current ( $I$ )** - The charge passing through a circuit per unit time. [1]
- Electric displacement ( $D$ )** - A vector quantity whose magnitude equals the electric field strength multiplied by the permittivity of the medium and whose direction is the same as that of the field strength.
- Electric field strength ( $E$ )** - The force exerted by an electric field on a point charge divided by the electric charge. [1]
- Electric potential ( $V$ )** - A scalar quantity whose gradient is equal to the negative of the electric field strength.
- Electrical conductance** - See Conductance
- Electrical resistance** - See Resistance
- Electrical resistivity** - See Resistivity.
- Electrochemical series\*** - An arrangement of reactions which produce or consume electrons in an order based on standard electrode potentials. A common arrangement places metals in decreasing order of their tendency to give up electrons.
- Electrode potential\*** - The electromotive force of a cell in which the electrode on the left is the standard hydrogen electrode and that on the right is the electrode in question. [2]
- Electrolysis** - The decomposition of a substance as a result of passing an electric current between two electrodes immersed in the sample.
- Electromotive force (emf)** - The energy supplied by a source divided by the charge transported through the source. [1]
- Electron\*** - An elementary particle in the family of leptons, with negative charge and spin of 1/2.
- Electron affinity\*** - The energy difference between the ground state of a gas-phase atom or molecule and the lowest state of the corresponding negative ion.
- Electron cyclotron resonance (ECR)** - See Techniques for Materials Characterization, page 12-1.
- Electron energy loss spectroscopy (EELS)** - See Techniques for Materials Characterization, page 12-1.
- Electron nuclear double resonance (ENDOR)** - See Techniques for Materials Characterization, page 12-1.
- Electron paramagnetic resonance (EPR)** - See Techniques for Materials Characterization, page 12-1.
- Electron probe microanalysis (EPMA)** - See Techniques for Materials Characterization, page 12-1.
- Electron spectroscopy for chemical analysis (ESCA)** - See Techniques for Materials Characterization, page 12-1.
- Electron spin ( $s$ )** - The quantum number, equal to 1/2, that specifies the intrinsic angular momentum of the electron.
- Electron stimulated desorption (ESD)** - See Techniques for Materials Characterization, page 12-1.
- Electron volt (eV)\*** - A non-SI unit of energy used in atomic and nuclear physics, equal to approximately  $1.602177 \times 10^{-19}$  J. The electron volt is defined as the kinetic energy acquired by an electron upon acceleration through a potential difference of 1 V. [1]
- Electronegativity\*** - A parameter originally introduced by Pauling which describes, on a relative basis, the power of an atom or group of atoms to attract electrons from the same molecular entity. [3]
- Electrophoresis** - The motion of macromolecules or colloidal particles in an electric field. [3]
- Emissivity ( $\epsilon$ )\*** - Ratio of the radiant flux emitted per unit area to that of an ideal black body at the same temperature. Also called emittance. [1]
- Emu** - The electromagnetic system of units, based upon the cm, g, and s plus the emu of current (sometimes called the abampere).
- Enantiomers** - A chiral molecule and its non-superposable mirror image. The two forms rotate the plane of polarized light by equal amounts in opposite directions. Also called optical isomers.
- Energy ( $E, U$ )\*** - The characteristic of a system that enables it to do work.



**Energy gap\*** - In the theory of solids, the region between two energy bands, in which no bound states can occur.

**Enols, alkenols** - The term refers specifically to vinylic alcohols, which have the structure  $\text{HO-CR}'=\text{CR}_2$ . Enols are tautomeric with aldehydes ( $\text{R}' = \text{H}$ ) or ketones ( $\text{R}'$  not equal to  $\text{H}$ ). [5]

**Enthalpy ( $H$ )\*** - A thermodynamic function, especially useful when dealing with constant-pressure processes, defined by  $H = E + PV$ , where  $E$  is energy,  $P$  pressure, and  $V$  volume. [1]

**Enthalpy of combustion\*** - The enthalpy change in a combustion reaction. Its negative is the heat released in combustion.

**Enthalpy of formation, standard\*** - The enthalpy change for the reaction in which a substance is formed from its constituent elements, each in its standard reference state (normally refers to 1 mol, sometimes to 1 g, of the substance).

**Enthalpy of fusion\*** - The enthalpy change in the transition from solid to liquid state.

**Enthalpy of sublimation** - The enthalpy change in the transition from solid to gas state.

**Enthalpy of vaporization\*** - The enthalpy change in the transition from liquid to gas state.

**Entropy ( $S$ )\*** - A thermodynamic function defined such that when a small quantity of heat  $dQ$  is received by a system at temperature  $T$ , the entropy of the system is increased by  $dQ/T$ , provided that no irreversible change takes place in the system. [1]

**Entropy unit (e.u.)** - A non-SI unit of entropy, equal to 4.184 J/K mol.

**Ephemeris time** - Time measured in tropical years from January 1, 1900.

**Epoxy compounds** - Compounds in which an oxygen atom is directly attached to two adjacent or non-adjacent carbon atoms of a carbon chain or ring system; thus cyclic ethers. [5]

**Equation of continuity** - Any of a class of equations that express the fact that some quantity (mass, charge, energy, etc.) cannot be created or destroyed. Such equations typically specify that the rate of increase of the quantity in a given region of space equals the net current of the quantity flowing into the region.

**Equation of state\*** - An equation relating the pressure, volume, and temperature of a substance or system.

**Equilibrium constant ( $K$ )\*** - For a chemical reaction  $aA + bB \rightleftharpoons cC + dD$ , the equilibrium constant is defined by:

$$K = \frac{a_C^c \cdot a_D^d}{a_A^a \cdot a_B^b}$$

where  $a_i$  is the activity of component  $i$ . To a certain approximation, the activities can be replaced by concentrations. The equilibrium constant is related to  $\Delta_r G^\circ$ , the standard Gibbs energy change in the reaction, by  $RT \ln K = -\Delta_r G^\circ$ .

**Equivalent conductance** - See Conductivity, electrical

**Erg (erg)** - A non-SI (cgs) unit of energy, equal to  $10^{-7}$  J.

**Esters** - Compounds formally derived from an oxoacid  $\text{RC}(=\text{O})(\text{OH})$  and an alcohol, phenol, heteroarenol, or enol by linking, with formal loss of water from an acidic hydroxy group of the former and a hydroxy group of the latter. [5]

**Esu** - The electrostatic system of units, based upon the cm, g, and s plus the esu of charge (sometimes called the statcoulomb or franklin).

**Ethers** - Compounds with formula  $\text{ROR}$ , where  $\text{R}$  is not equal to  $\text{H}$ . [5]

**Euler number ( $Eu$ )** - A dimensionless quantity used in fluid mechanics, defined by  $Eu = \Delta p / \rho v^2$ , where  $p$  is pressure,  $\rho$  is density, and  $v$  is velocity. [2]

**Eutectic** - The point on a two-component solid-liquid phase diagram which represents the lowest melting point of any possible mixture. A liquid having the eutectic composition will freeze at a single temperature without change of composition.

**Excitance ( $M$ )** - Radiant energy flux leaving an element of a surface divided by the area of that element. [1]

**Exciton** - A localized excited state consisting of a bound electron-hole pair in a molecular or ionic crystal. The exciton can propagate through the crystal.

**Exosphere** - The outermost part of the earth's atmosphere, beginning at about 500 to 1000 km above the surface. It is characterized by densities so low that air molecules can escape into outer space.

**Expansion coefficient** - See thermal expansion coefficient.

**Extended electron energy loss fine structure (EXELFS)** - See Techniques for Materials Characterization, page 12-1.

**Extended x-ray absorption fine structure (EXAFS)** - See Techniques for Materials Characterization, page 12-1.

**Extinction coefficient** - See Absorption coefficient, molar

**F-Center** - See Color center

**Fahrenheit temperature ( $^\circ\text{F}$ )** - The temperature scale based on the assignment of  $32^\circ\text{F} = 0^\circ\text{C}$  and a temperature interval of  $^\circ\text{F} = (5/9)^\circ\text{C}$ ; i.e.,  $t/^\circ\text{F} = (9/5)t/^\circ\text{C} + 32$ .

**Farad ( $\text{F}$ )\*** - The SI unit of electric capacitance, equal to  $\text{C/V}$ . [1]

**Faraday constant ( $F$ )\*** - The electric charge of 1 mol of singly charged positive ions; i.e.,  $F = N_A e$ , where  $N_A$  is Avogadro's constant and  $e$  is the elementary charge. [1]

**Faraday effect\*** - The rotation of the plane of plane-polarized light by a medium placed in a magnetic field parallel to the direction of the light beam. The effect can be observed in solids, liquids, and gasses.

**Fatty acids** - Aliphatic monocarboxylic acids derived from or contained in esterified form in an animal or vegetable fat, oil, or wax. Natural fatty acids commonly have a chain of 4 to 28 carbons (usually unbranched and even-numbered), which may be saturated or unsaturated. By extension, the term is sometimes used to embrace all acyclic aliphatic carboxylic acids. [5]

**Fermat's principle** - The law that a ray of light traversing one or more media will follow a path which minimizes the time required to pass between two given points.

**Fermi ( $f$ )** - Name sometimes used in nuclear physics for the femtometer.

**Fermi level** - The highest energy of occupied states in a solid at zero temperature. Sometimes called Fermi energy. The Fermi surface is the surface in momentum space formed by electrons occupying the Fermi level.

**Fermi resonance** - An effect observed in vibrational spectroscopy when an overtone of one fundamental vibration closely coincides in energy with another fundamental of the same symmetry species. It leads to a splitting of vibrational bands.

**Fermi-Dirac distribution** - A modification of the Boltzmann distribution which takes into account the Pauli exclusion principle. The number of particles of energy  $E$  is proportional to  $[e^{(E-\mu)/kT} + 1]^{-1}$ , where  $\mu$  is a normalization constant,  $k$  the Boltzmann constant, and  $T$  the temperature. The distribution is applicable to a system of fermions.

**Fermion** - A particle that obeys Fermi-Dirac statistics. Specifically, any particle with spin equal to an odd multiple of  $1/2$ . Examples are the electron, proton, neutron, muon, etc.

**Ferrimagnetism\*** - A type of magnetism in which the magnetic moments of atoms in a solid are ordered into two nonequivalent sublattices with unequal magnetic moments, leading to a nonzero magnetic susceptibility.

**Ferrite** - A ferrimagnetic material of nominal formula  $MFe_2O_4$ , where  $M$  is a divalent metal; widely used in microwave switches and other solid state devices.

**Ferroelectricity\*** - The retention of electric polarization by certain materials after the external field that produced the polarization has been removed.

**Ferromagnetism\*** - A type of magnetism in which the magnetic moments of atoms in a solid are aligned within domains which can in turn be aligned with each other by a weak magnetic field. Some ferromagnetic materials can retain their magnetization when the external field is removed, as long as the temperature is below a critical value, the Curie temperature. They are characterized by a large positive magnetic susceptibility.

**Fick's law** - The statement that the flux  $J$  of a diffusing substance is proportional to the concentration gradient, i.e.,  $J = -D(dc/dx)$ , where  $D$  is called the diffusion coefficient.

**Field** - A mathematical construct which describes the interaction between particles resulting from gravity, electromagnetism, or other physical phenomena. In classical physics a field is described by equations. Quantum field theory introduces operators to represent the physical observables.

**Field emission microscopy (FEM)** - See Techniques for Materials Characterization, page 12-1.

**Field ion microscopy (FIM)** - See Techniques for Materials Characterization, page 12-1.

**Fine structure** - The splitting in spectral lines that results from interactions of the electron spin with the orbital angular momentum.

**Fine structure constant ( $\alpha$ )\*** - Defined as  $e^2/2hc\epsilon_0$ , where  $e$  is the elementary charge,  $h$  Planck's constant,  $c$  the speed of light, and  $\epsilon_0$  the permittivity of a vacuum. It is a measure of the strength of the electromagnetic interaction between particles.

**First radiation constant ( $c_1$ )\*** - Constant ( $= 2\pi hc^2$ ) in the equation for the radiant exitance  $M_\lambda$  of a black body:

$$M_\lambda = \frac{c_1 \lambda^{-5} \Delta\lambda}{e^{c_2/\lambda T} - 1}$$

where  $\lambda$  is the wavelength,  $T$  is the temperature, and  $c_2 = hc/k$  is the second radiation constant.

**Flash point** - The lowest temperature at which vapors above a volatile combustible substance will ignite in air when exposed to a flame. [10]

**Fluence ( $F$ )** - Term used in photochemistry to specify the energy per unit area delivered in a given time interval, for example by a laser pulse. [2]

**Fluorocarbons** - Compounds consisting solely of fluorine and carbon. [5]

**Fluxoid** - The quantum of magnetic flux in superconductivity theory, equal to  $hc/2e$ , where  $h$  is Planck's constant,  $c$  the velocity of light, and  $e$  the elementary charge.

**Force ( $F$ )** - The rate of change of momentum with time. [1]

**Force constants ( $f, k$ )\*** - In molecular vibrations, the coefficients in the expression of the potential energy in terms of atom displacements from their equilibrium positions. In a diatomic molecule,  $f = d^2V/dr^2$ , where  $V(r)$  is the potential energy and  $r$  is the interatomic distance. [2]

**Fourier number ( $Fo$ )** - A dimensionless quantity used in fluid mechanics, defined by  $Fo = at/l^2$ , where  $a$  is thermal diffusivity,  $t$  is time, and  $l$  is length. [2]

**Fourier transform infrared spectroscopy (FTIR)** - A technique for obtaining an infrared spectrum by use of an interferometer in which the path length of one of the beams is varied. A Fourier transformation of the resulting interferogram yields the actual spectrum. The technique is also used for NMR and other types of spectroscopy.

**Fractals** - Geometrical objects that are self-similar under a change of scale; i.e., they appear similar at all levels of magnification. They can be considered to have fractional dimensionality. Examples occur in diverse fields such as geography (rivers and shorelines), biology (trees), and solid state physics (amorphous materials).

**Franck-Condon principle** - An important principle in molecular spectroscopy which states that the nuclei in a molecule remain essentially stationary while an electronic transition is taking place. The physical interpretation rests on the fact that the electrons move much more rapidly than the nuclei because of their much smaller mass.

**Franklin (Fr)** - Name sometimes given to the unit of charge in the esu system.

**Fraunhofer diffraction** - Diffraction of light in situations where the source and observation point are so far removed that the wave surfaces may be considered planar.

**Fraunhofer lines** - Sharp absorption lines in the spectrum of sunlight, caused by absorption of the solar blackbody radiation by atoms near the sun's surface.

**Free radical** - See Radicals. The term "free radical" is often used more broadly for molecules that have a paramagnetic ground state (e.g.,  $O_2$ ) and sometimes for any transient or highly reactive molecular species.

**Freezing point** - See Melting point

**Frequency ( $\nu$ )\*** - Number of cycles of a periodic phenomenon divided by time. [1]

**Fresnel diffraction** - Diffraction of light in a situation where the source and observation point are sufficiently close together that the curvature of the wave surfaces must be taken into account.

**Froude number ( $Fr$ )** - A dimensionless quantity used in fluid mechanics, defined by  $Fr = v/(lg)^{1/2}$ , where  $v$  is velocity,  $l$  is length, and  $g$  is acceleration due to gravity. [2]

**Fugacity ( $f_B$ )** - For a gas mixture, the fugacity of component B is defined as the absolute activity  $\lambda_B$  times the limit, as the pressure  $p$  approaches zero at constant temperature, of  $p_B/\lambda_B$ . [2]

**Fullerenes** - Compounds composed solely of an even number of carbon atoms, which form a cage-like fused-ring polycyclic system with twelve five-membered rings and the rest six-membered rings. The archetypal example is [60]fullerene, where the atoms and bonds delineate a truncated icosahedron. The term has been broadened to include any closed cage structure consisting entirely of three-coordinate carbon atoms. [5]

**Fulvalenes** - The hydrocarbon fulvalene and its derivatives formed by substitution (and by extension, analogues formed

by replacement of one or more carbon atoms of the fulvalene skeleton by a heteroatom). [5]

**Fulvenes** - The hydrocarbon fulvene and its derivatives formed by substitution (and by extension, analogues formed by replacement of one or more carbon atoms of the fulvene skeleton by a heteroatom). [5]

**Fundamental vibrational frequencies\*** - In molecular spectroscopy, the characteristic vibrational frequencies obtained when the vibrational energy is expressed in normal coordinates. They determine the primary features of the infrared and Raman spectra of the molecule.

**γ** - Name sometimes used for microgram.

**γ-rays\*** - Electromagnetic radiation (photons) with energy greater than about 0.1 MeV (wavelength less than about 1 pm).

**g-Factor of the electron\*** - The proportionality factor in the equation relating the magnetic moment  $\mu$  of an electron to its total angular momentum quantum number  $J$ , i.e.,  $\mu = -g\mu_B J$ , where  $\mu_B$  is the Bohr magneton. Also called Landé factor.

**Gal** - A non-SI unit of acceleration, equal to 0.01 m/s. Also called galileo.

**Gallon (US)** - A unit of volume equal to 3.785412 L.

**Gallon (UK, Imperial)** - A unit of volume equal to 4.546090 L.

**Gauss (G)** - A non-SI unit of magnetic flux density ( $B$ ) equal to  $10^{-4}$  T.

**Gaussian system of units** - A hybrid system used in electromagnetic theory, which combines features of both the esu and emu systems.

**Gel** - A colloidal system with a finite, but usually rather small, yield stress (the shear stress at which yielding starts abruptly). [3]

**Genetic code\*** - The set of relations between each of the 64 codons of DNA and a specific amino acid (or other genetic instruction).

**Gibbs energy (G)\*** - An important function in chemical thermodynamics, defined by  $G = H - TS$ , where  $H$  is the enthalpy,  $S$  the entropy, and  $T$  the thermodynamic temperature. Sometimes called Gibbs free energy and, in older literature, simply "free energy". [2]

**Gibbs phase rule** - The relation  $F = C - P + 2$ , where  $C$  is the number of components in a mixture,  $P$  is the number of phases, and  $F$  is the degrees of freedom, i.e., the number of intensive variables that can be changed independently without affecting the number of phases.

**Glass transition temperature\*** - The temperature at which an amorphous polymer is transformed, in a reversible way, from a viscous or rubbery condition to a hard and relatively brittle one. [10]

**Glow discharge mass spectroscopy (GDMS)** - See Techniques for Materials Characterization, page 12-1.

**Gloun** - A hypothetical particle postulated to take part in the binding of quarks, in analogy to the role of the photon in electromagnetic interactions.

**Glycerides** - Esters of glycerol (propane-1,2,3-triol) with fatty acids, widely distributed in nature. They are by long-established custom subdivided into triglycerides, 1,2- or 1,3-diglycerides, and 1- or 2-monoglycerides, according to the number and positions of acyl groups. [5]

**Glycols** - Dihydric alcohols in which two hydroxy groups are on different carbon atoms, usually but not necessarily adjacent. Also called diols. [5]

**Grain (gr)** - A non-SI unit of mass, equal to 64.79891 mg.

**Grain boundary** - The interface between two regions of different crystal orientation.

**Grashof number (Gr)** - A dimensionless quantity used in fluid mechanics, defined by  $Gr = \beta g \alpha \Delta T l^3 / \eta^2$ , where  $T$  is temperature,  $\rho$  is density,  $l$  is length,  $\eta$  is viscosity,  $\alpha$  is cubic expansion coefficient, and  $g$  is acceleration of gravity. [2]

**Gravitational constant (G)\*** - The universal constant in the equation for the gravitational force between two particles,  $F = Gm_1 m_2 / r^2$ , where  $r$  is the distance between the particles and  $m_1$  and  $m_2$  are their masses. [1]

**Gray (Gy)\*** - The SI unit of absorbed dose of radiation, equal to J/kg. [1]

**Gregorian calendar** - The modification of the Julian calendar introduced in 1582 by Pope Gregory XII which specified that a year divisible by 100 is a leap year only if divisible by 400.

**Grignard reagents** - Organomagnesium halides,  $\text{RMgX}$ , having a carbon-magnesium bond (or their equilibrium mixtures in solution with  $\text{R}_2\text{Mg} + \text{MgX}_2$ ). [5]

**Gruneisen parameter ( $\gamma$ )** - Defined by  $\gamma = \alpha_V / \kappa c_V \rho$ , where  $\alpha_V$  is the cubic thermal expansion coefficient,  $\kappa$  is the isothermal compressibility,  $c_V$  is the specific heat capacity at constant volume, and  $\rho$  is the mass density.  $\gamma$  is independent of temperature for most crystalline solids. [1]

**Gyromagnetic ratio ( $\gamma$ )** - Ratio of the magnetic moment of a particle to its angular momentum. Also called magnetogyric ratio.

**Hadron** - Any elementary particle that can take part in the strong interaction. Hadrons are subdivided into baryons, with odd half integer spins, and mesons, which have zero or integral spin.

**Hall effect\*** - The development of a transverse potential difference  $V$  in a conducting material when subjected to a magnetic field  $H$  perpendicular to the direction of the current. The potential difference is given by  $V = R_H B J t$ , where  $B$  is the magnetic induction,  $J$  the current density,  $t$  the thickness of the specimen in the direction of the potential difference, and  $R_H$  is called the Hall coefficient.

**Halocarbon** - A compound containing no elements other than carbon, hydrogen, and one or more halogens. In common practice, the term is used mainly for compounds of no more than four or five carbon atoms.

**Halogens** - The elements F, Cl, Br, I, and At. Compounds of these elements are called halogenides or halides. [7]

**Hamiltonian (H)** - An expression for the total energy of a mechanical system in terms of the momenta and positions of constituent particles. In quantum mechanics, the Hamiltonian operator appears in the eigenvalue equation  $H\psi = E\psi$ , where  $E$  is an energy eigenvalue and  $\psi$  the corresponding eigenfunction.

**Hardness\*** - The resistance of a material to deformation, indentation, or scratching. Hardness is measured on various scales, such as Mohs, Brinell, Knoop, Rockwell, and Vickers. [10]

**Hartmann number (Ha)** - A dimensionless quantity used in plasma physics, defined by  $Ha = Bl(\kappa/\eta)^{1/2}$ , where  $B$  is magnetic flux density,  $l$  is length,  $\kappa$  is electric conductivity, and  $\eta$  is viscosity. [2]

**Hartree ( $E_h$ )\*** - An energy unit used in atomic and molecular science, equal to approximately  $4.3597482 \times 10^{-18}$  J.

**Hartree-Fock method** - A iterative procedure for solving the Schrödinger equation for an atom or molecule in which the equation is solved for each electron in an initial assumed po-

tential from all the other electrons. The new potential that results is used to repeat the calculation and the procedure continued until convergence is reached. Also called self-consistent field (SCF) method.

**Heat capacity\*** - Defined in general as  $dQ/dT$ , where  $dQ$  is the amount of heat that must be added to a system to increase its temperature by a small amount  $dT$ . The heat capacity at constant pressure is  $C_p = (\partial H/\partial T)_p$ ; that at constant volume is  $C_v = (\partial E/\partial T)_v$ , where  $H$  is enthalpy,  $E$  is internal energy,  $p$  is pressure,  $V$  is volume, and  $T$  is temperature. An upper case  $C$  normally indicates the molar heat capacity, while a lower case  $c$  is used for the specific (per unit mass) heat capacity. [1]

**Heat of formation, vaporization, etc.** - See corresponding terms under Enthalpy.

**Hectare (ha)** - A unit of area equal to  $10^4$  m<sup>2</sup>. [1]

**Heisenberg uncertainty principle** - The statement that two observable properties of a system that are complementary, in the sense that their quantum-mechanical operators do not commute, cannot be specified simultaneously with absolute precision. An example is the position and momentum of a particle; according to this principle, the uncertainties in position  $\Delta q$  and momentum  $\Delta p$  must satisfy the relation  $\Delta p \Delta q \geq h/4\pi$ , where  $h$  is Planck's constant.

**Heitler-London model** - An early quantum-mechanical model of the hydrogen atom which introduced the concept of the exchange interaction between electrons as the primary reason for stability of the chemical bond.

**Helicon** - A low-frequency wave generated when a metal at low temperature is exposed to a uniform magnetic field and a circularly polarized electric field.

**Helmholz energy (A)** - A thermodynamic function defined by  $A = E - TS$ , where  $E$  is the energy,  $S$  the entropy, and  $T$  the thermodynamic temperature. [2]

**Hemiacetals** - Compounds having the general formula  $R_2C(OH)OR'$  ( $R'$  not equal to H). [5]

**Henry (H)\*** - The SI unit of inductance, equal to Wb/A. [1]

**Henry's law\*** - An expression which applies to an ideal dilute solution in which one or more gasses are dissolved, viz.,  $p_i = H_i x_i$ , where  $p_i$  is the partial pressure of component  $i$  above the solution,  $x_i$  is its mole fraction in the solution, and  $H_i$  is the Henry's law constant (a characteristic of the given gas and solvent, as well as the temperature).

**Hermitian operator** - An operator  $A$  that satisfies the relation  $\int u_m^* A u_n dx = (\int u_n^* A u_m dx)^*$ , where \* indicates the complex conjugate. The eigenvalues of Hermitian operators are real, and eigenfunctions belonging to different eigenvalues are orthogonal.

**Hertz (Hz)** - The SI unit of frequency, equal to s<sup>-1</sup>. [1]

**Heterocyclic compounds** - Cyclic compounds having as ring members atoms of at least two different elements, e.g., quino-line, 1,2-thiazole, bicyclo[3.3.1]tetrasiloxane. [5]

**Heusler alloys** - Alloys of manganese, copper, aluminum, nickel, and sometimes other metals which find important uses as permanent magnets.

**Holography** - A technique for creating a three-dimensional image of a object by recording the interference pattern between a light beam diffracted from the object and a reference beam. The image can be reconstructed from this pattern by a suitable optical system.

**Homopolymer** - A polymer derived from one species of (real, implicit, or hypothetical) monomer. [8]

**Hooke's law** - The statement that the ratio of stress to strain is a constant in a totally elastic medium.

**Horse power** - A non-SI unit of energy, equal to approximately 746 W.

**Hubble constant** - The ratio of the recessional velocity of an extragalactic object to the distance of that object. Its value is about  $2 \times 10^{-18}$  s<sup>-1</sup>.

**Huckel theory** - A simple approximation for calculating the energy of conjugated molecules in which only the resonance integrals between neighboring bonds are considered. Also called CNDO method (complete neglect of differential overlap).

**Hume-Rothery rules** - A set of empirical rules for predicting the occurrence of solid solutions in metallic systems. The rules involve size, crystal structure, and electronegativity.

**Hund's rules** - A series of rules for predicting the sequence of energy states in atoms and molecules. One of the important results is that when two electrons exist in different orbitals, the state with their spins parallel (triplet state) lies at lower energy than the state with antiparallel spins (singlet).

**Hydrazines** - Hydrazine (diazane),  $H_2NNH_2$ , and its hydrocarbyl derivatives. When one or more substituents are acyl groups, the compound is a hydrazide. [5]

**Hydrocarbon** - A compound containing only carbon and hydrogen. [5]

**Hydrolysis** - A reaction occurring in water in which a chemical bond is cleaved and a new bond formed with the oxygen atom of water.

**Hyperfine structure** - Splitting of energy levels and spectral lines into several closely spaced components as a result of interaction of nuclear spin angular momentum with other angular momenta in the atom or molecule.

**Hysteresis\*** - An irreversible response of a system (parameter  $A$ ) as a function of an external force (parameter  $F$ ), usually symmetric with respect to the origin of the  $A$  vs.  $F$  graph after the initial application of the force. A common example is magnetic induction vs. magnetic field strength in a ferromagnet.

**Ideal gas law** - The equation of state  $pV = RT$ , which defines an ideal gas, where  $p$  is pressure,  $V$  molar volume,  $T$  temperature, and  $R$  the molar gas constant.

**Ideal solution** - A solution in which solvent-solvent and solvent-solute interactions are identical, so that properties such as volume and enthalpy are exactly additive. Ideal solutions follow Raoult's law, which states that the vapor pressure  $p_i$  of component  $i$  is  $p_i = x_i p_i^*$ , where  $x_i$  is the mole fraction of component  $i$  and  $p_i^*$  the vapor pressure of the pure substance  $i$ .

**Ignition temperature\*** - The lowest temperature at which combustion of a material will occur spontaneously under specified conditions. Sometimes called autoignition temperature, kindling point. [10]

**Imides** - Diacyl derivatives of ammonia or primary amines, especially those cyclic compounds derived from diacids. Also used for salts having the anion  $RN_2^-$ . [5]

**Impedance (Z)** - The complex representation of potential difference divided by the complex representation of current. In terms of reactance  $X$  and resistance  $R$ , the impedance is given by  $Z = R + iX$ . [1]

**Index of refraction (n)\*** - For a non-absorbing medium, the ratio of the velocity of electromagnetic radiation *in vacuo* to the phase velocity of radiation of a specified frequency in the medium. [1]

- Inductance** - The ratio of the electromagnetic force induced in a coil by a current to the rate of change of the current.
- Inductive coupled plasma mass spectroscopy (ICPMS)** - See Techniques for Materials Characterization, page 12-1.
- Inertial defect** - In molecular spectroscopy, the quantity  $I_c - I_a - I_b$  for a molecule whose equilibrium configuration is planar, where  $I_a$ ,  $I_b$ , and  $I_c$  are the effective principal moments of inertia. The inertial defect for a rigid planar molecule would be zero, but vibration-rotation interactions in a real molecule lead to a positive inertial defect.
- Insulator** - A material in which the highest occupied energy band (valence band) is completely filled with electrons, while the next higher band (conduction band) is empty. Solids with an energy gap of 5 eV or more are generally considered as insulators at room temperature. Their conductivity is less than  $10^{-6}$  S/m and increases with temperature.
- Intercalation compounds** - Compounds resulting from reversible inclusion, without covalent bonding, of one kind of molecule in a solid matrix of another compound, which has a lamellar structure. The host compound, a solid, may be macromolecular, crystalline, or amorphous. [5]
- International System of Units (SI)\*** - The unit system adopted by the General Conference on Weights and Measures in 1960. It consists of seven base units (meter, kilogram, second, ampere, kelvin, mole, candela), plus derived units and prefixes. [1]
- International Temperature Scale (ITS-90)\*** - The official international temperature scale adopted in 1990. It consists of a set of fixed points and equations which enable the thermodynamic temperature to be determined from operational measurements. [9]
- Ion** - An atomic or molecular particle having a net electric charge. [3]
- Ion exchange** - A process involving the adsorption of one or several ionic species accompanied by the simultaneous desorption (displacement) of one or more other ionic species. [3]
- Ion neutralization spectroscopy (INS)** - See Techniques for Materials Characterization, page 12-1.
- Ionic strength ( $I$ )** - A measure of the total concentration of ions in a solution, defined by  $I = 1/2 \sum_i z_i^2 m_i$ , where  $z_i$  is the charge of ionic species  $i$  and  $m_i$  is its molality. For a 1-1 electrolyte at molality  $m$ ,  $I = m$ .
- Ionization constant\*** - The equilibrium constant for a reaction in which a substance in solution dissociates into ions.
- Ionization potential\*** - The minimum energy required to remove an electron from an isolated atom or molecule (in its vibrational ground state) in the gaseous phase. More properly called ionization energy. [3]
- Irradiance ( $E$ )** - The radiant energy flux incident on an element of a surface, divided by the area of that element. [1]
- Isentropic process** - A thermodynamic process in which the entropy of the system does not change.
- Ising model** - A model describing the coupling between two atoms in a ferromagnetic lattice, in which the interaction energy is proportional to the negative of the product of the spin components along a specified axis.
- Isobar** - A line connecting points of equal pressure on a graphical representation of a physical system.
- Isochore** - A line or surface of constant volume on a graphical representation of a physical system.
- Isoelectric point\*** - The pH of a solution or dispersion at which the net charge on the macromolecules or colloidal particles is zero. In electrophoresis there is no motion of the particles in an electric field at the isoelectric point.
- Isomers** - In chemistry, compounds that have identical molecular formulas but differ in the nature or sequence of bonding of their atoms or in the arrangement of their atoms in space. In physics, nuclei of the same atomic number  $Z$  and mass number  $A$  but in different energy states. [3]
- Isomorphs** - Substances of different chemical nature but having the same crystal structure.
- Isotactic macromolecule** - A tactic macromolecule, essentially comprising only one species of repeating unit which has chiral or prochiral atoms in the main chain in a unique arrangement with respect to its adjacent constitutional units. [8]
- Isotherm** - A line connecting points of equal temperature on a graphical representation of a physical system.
- Isothermal process** - A thermodynamic process in which the temperature of the system does not change.
- Isotones** - Nuclides having the same neutron number  $N$  but different atomic number  $Z$ . [3]
- Isotopes** - Two or more nuclides with the same atomic number  $Z$  but different mass number  $A$ . The term is sometimes used synonymously with nuclide, but it is preferable to reserve the word nuclide for a species of specific  $Z$  and  $A$ . [3]
- Jahn-Teller effect** - An interaction of vibrational and electronic motions in a nonlinear molecule which removes the degeneracy of certain electronic energy levels. It can influence the spectrum, crystal structure, and magnetic properties of the substance.
- Johnson noise** - Electrical noise generated by random thermal motion of electrons in a conductor or semiconductor. Also called thermal noise.
- Josephson effect** - The tunneling of electron pairs through a thin insulating layer which separates two superconductors. When a potential difference is applied to the superconductors, an alternating current is generated whose frequency is precisely proportional to the potential difference. This effect has important applications in metrology and determination of fundamental physical constants.
- Joule (J)\*** - The SI unit of energy, equal to N m. [1]
- Joule-Thomson coefficient ( $\mu$ )** - A parameter which describes the temperature change when a gas expands adiabatically through a nozzle from a high pressure to a low pressure region. It is defined by  $\mu = (\partial T / \partial p)_{H,P}$  where  $H$  is enthalpy.
- Julian calendar** - The calendar introduced by Julius Caesar in 46 B.C. which divided the year into 365 days with a leap year of 366 days every fourth year.
- Julian date (JD)** - The number of days elapsed since noon Greenwich Mean Time on January 1, 4713 B.C. Thus January 1, 2000, 0h (midnight) will be JD 2,451,543.5. This dating system was introduced by Joseph Scaliger in 1582.
- Kaon** - One of the elementary particles in the family of mesons. Kaons have a spin of zero and may be neutral or charged.
- Kelvin (K)\*** - The SI base unit of thermodynamic temperature. [1]
- Kepler's laws** - The three laws of planetary motion, which established the elliptical shape of planetary orbits and the relation between orbital dimensions and the period of rotation.

- Kerr effect\*** - An electrooptical effect in which birefringence is induced in a liquid or gas when a strong electric field is applied perpendicular to the direction of an incident light beam. The Kerr constant  $k$  is given by  $n_1 - n_2 = k\lambda E^2$ , where  $\lambda$  is the wavelength,  $E$  is the electric field strength, and  $n_1$  and  $n_2$  are the indices of refraction of the ordinary and extraordinary rays, respectively.
- Ketenes** - Compounds in which a carbonyl group is connected by a double bond to an alkylidene group:  $R_2C=C=O$ . [5]
- Ketones** - Compounds in which a carbonyl group is bonded to two carbon atoms:  $R_1R_2C=O$  (neither R may be H). [5]
- Kilogram (kg)\*** - The SI base unit of mass. [1]
- Kinetic energy ( $E_k$ ,  $T$ )** - The energy associated with the motion of a system of particles in a specified reference frame. For a single particle of mass  $m$  moving at velocity  $v$ ,  $E_k = 1/2mv^2$ .
- Kirchhoff's laws** - Basic rules for electric circuits, which state (a) the algebraic sum of the currents at a network node is zero and (b) the algebraic sum of the voltage drops around a closed path is zero.
- Klein-Gordon equation** - A relativistic extension of the Schrödinger equation.
- Klein-Nishima formula** - An expression for the scattering cross section of a photon by an unbound electron, based upon the Dirac electron theory.
- Knight shift** - The change in magnetic resonance frequency of a nucleus in a metal relative to the same nucleus in a diamagnetic solid. The effect is due to the polarization of the conduction electrons in the metal.
- Knudsen number ( $Kn$ )** - A dimensionless quantity used in fluid mechanics, defined by  $Kn = \lambda/l$ , where  $\lambda$  is mean free path and  $l$  is length. [2]
- Kondo effect** - A large increase in electrical resistance observed at low temperatures in certain dilute alloys of a magnetic metal in a nonmagnetic material.
- Kramers-Kronig relation** - A set of equations relating the real and imaginary parts of the index of refraction of a medium
- Lactams** - Cyclic amides of amino carboxylic acids, having a 1-azacycloalkan-2-one structure, or analogues having unsaturation or heteroatoms replacing one or more carbon atoms of the ring. [5]
- Lactones** - Cyclic esters of hydroxy carboxylic acids, containing a 1-oxacycloalkan-2-one structure, or analogues having unsaturation or heteroatoms replacing one or more carbon atoms of the ring. [5]
- Lagrangian function ( $L$ )** - A function used in classical mechanics, defined as the kinetic energy minus the potential energy for a system of particles.
- Lamb shift** - The small energy difference between the  $^2S_{1/2}$  and  $^2P_{1/2}$  levels in the hydrogen atom, which results from interactions between the electron and the radiation field.
- Laminar flow** - Smooth, uniform, non-turbulent flow of a gas or liquid in parallel layers, with little mixing between layers. It is characterized by small values of the Reynolds number.
- Landé g-factor** - See g-Factor of the electron
- Langevin function** - The mathematical function  $L(x) = (e^x + e^{-x}) / (e^x - e^{-x}) - 1/x$ , which occurs in the expression for the average dipole moment of a group of rotating polar molecules in an electric field:  $\mu_{av} = \mu L(\mu E/kT)$ , where  $\mu$  is the electric dipole moment of a single molecule,  $E$  is the electric field strength,  $k$  is the Boltzmann constant, and  $T$  is the temperature.
- Lanthanides** - The elements of atomic number 57 through 71, which share common chemical properties: La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu. [7]
- Larmor frequency ( $\nu_L$ )** - The precession frequency of a magnetic dipole in an applied magnetic field. In particular, a nucleus in a magnetic field of strength  $B$  has a Larmor frequency of  $\gamma B/2\pi$ , where  $\gamma$  is the magnetogyric ratio of the nucleus.
- Laser\*** - A device in which an optical cavity is filled with a medium where a population inversion can be produced by some means. When the resonant frequency of the cavity bears the proper relation to the separation of the inverted energy levels, stimulated emission occurs, producing a highly monochromatic, coherent beam of light.
- Laser ionization mass spectroscopy (LIMS)** - See Techniques for Materials Characterization, page 12-1.
- Lattice constants\*** - Parameters specifying the dimensions of a unit cell in a crystal lattice, specifically the lengths of the cell edges and the angles between them.
- Lattice energy\*** - The energy per ion pair required to separate completely the ions in a crystal lattice at a temperature of absolute zero.
- Laue diagram** - A diffraction pattern produced when an x-ray beam passes through a thin slice of a crystal and impinges on a detector behind the crystal.
- Lenz's law** - The statement that the current induced in a circuit by a change in magnetic flux is so directed as to oppose the change in flux
- Leonard-Jones potential** - A simple but useful function for approximating the interaction between two neutral atoms or molecules separated by a distance  $r$  by writing the potential energy as  $U(r) = 4\epsilon\{(r_0/r)^{12} - (r_0/r)^6\}$ , where  $\epsilon$  and  $r_0$  are adjustable parameters. In this form the depth of the potential well is  $\epsilon$  and the minimum occurs at  $2^{1/6}r_0$ . The  $(1/r)^{12}$  term is often replaced by other powers of  $1/r$ .
- Lepton** - One of the class of elementary particles that do not take part in the strong interaction. Included are the electron, muon, and neutrino. All leptons have a spin of  $1/2$ .
- Lewis number ( $Le$ )** - A dimensionless quantity used in fluid mechanics, defined by  $Le = a/D$ , where  $a$  is thermal diffusivity and  $D$  is diffusion coefficient. [2]
- Ligand field theory** - A description of the structure of crystals containing a transition metal ion surrounded by nonmetallic ions (ligands). It is based on construction of molecular orbitals involving the  $d$ -orbitals of the central metal ion and combinations of atomic orbitals of the ligands.
- Light year (l.y.)** - A unit of distance used in astronomy, defined as the distance light travels in one year in a vacuum. Its approximate value is  $9.46073 \times 10^{15}$  m.
- Lignins** - Macromolecular constituents of wood related to lignans, composed of phenolic propylbenzene skeletal units, linked at various sites and apparently randomly. [5]
- Ligroin** - The petroleum fraction consisting mostly of  $C_7$  and  $C_8$  hydrocarbons and boiling in the range 90-140°C; commonly used as a laboratory solvent.
- Lipids** - A loosely defined term for substances of biological origin that are soluble in nonpolar solvents. They consist of saponifiable lipids, such as glycerides (fats and oils) and phospholipids, as well as nonsaponifiable lipids, principally steroids. [5]
- Lipoproteins** - Clathrate complexes consisting of a lipid wrapped in a protein host without covalent binding, in such a way that

the complex has a hydrophilic outer surface consisting of all the protein and the polar ends of any phospholipids. [5]

**Liter (L)\*** - A synonym for cubic decimeter. [1]

**Lithosphere\*** - The outer layer of the solid earth, extending from the base of the mantle to the surface of the crust.

**Lorentz contraction** - The reduction in length of a moving body in the direction of motion, given by the factor  $(1-v^2/c^2)^{1/2}$ , where  $v$  is the velocity of the body and  $c$  the velocity of light. Also known as the FitzGerald-Lorentz contraction.

**Lorentz force** - The force exerted on a point charge  $Q$  moving at velocity  $v$  in the presence of external fields  $E$  and  $B$ . It is given (in SI units) by  $F = Q(E + v \times B)$ .

**Loss angle ( $\delta$ )** - For a dielectric material in an alternating electromagnetic field,  $\delta$  is the phase difference between the current and the potential difference. The function  $\tan \delta$  is a measure of the ratio of the power dissipated in the dielectric to the power stored.

**Low energy electron diffraction (LEED)** - See Techniques for Materials Characterization, page 12-1.

**Lumen (lm)\*** - The SI unit of luminous flux, equal to cd sr. [1]

**Luminous flux ( $\Phi$ )** - The intensity of light from a source multiplied by the solid angle. The SI unit is lumen. [1]

**Lux (lx)\*** - The SI unit of illuminance, equal to cd sr m<sup>-2</sup>. [1]

**Lyddane-Sachs-Teller relation** - A relation between the phonon frequencies and dielectric constants of an ionic crystal which states that  $(\omega_T/\omega_L)^2 = \epsilon(\infty)/\epsilon(0)$ , where  $\omega_T$  is the angular frequency of transverse optical phonons,  $\omega_L$  that of longitudinal optical phonons,  $\epsilon(0)$  is the static dielectric constant, and  $\epsilon(\infty)$  the dielectric constant at optical frequencies.

**Lyman series** - The series of lines in the spectrum of the hydrogen atom which corresponds to transitions between the ground state (principal quantum number  $n = 1$ ) and successive excited states. The wavelengths are given by  $1/\lambda = R_H(1-1/n^2)$ , where  $n = 2, 3, 4, \dots$  and  $R_H$  is the Rydberg constant for hydrogen. The first member of the series ( $n = 1 \leftrightarrow 2$ ), which is often called the Lyman- $\alpha$  line, falls at a wavelength of 1216 Å, and the series converges at 912 Å, the ionization limit of hydrogen.

**Mach number ( $Ma$ )** - A dimensionless quantity used in fluid mechanics, defined by  $Ma = v/c$ , where  $v$  is velocity and  $c$  is the speed of sound. [2]

**Macromolecule** - A molecule of high relative molecular mass (molecular weight), the structure of which essentially comprises the multiple repetition of units derived, actually or conceptually, from molecules of low relative molecular mass [8]

**Madelung constant\*** - A constant characteristic of a particular crystalline material which gives a measure of the electrostatic energy binding the ions in the crystal.

**Magnetic field strength ( $H$ )** - An axial vector quantity, the curl of which is equal to the current density, including the displacement current. [1]

**Magnetic induction ( $B$ )** - An axial vector quantity such that the force exerted on an element of current is equal to the vector product of this element and the magnetic induction. [1]

**Magnetic moment** - See Dipole moment, magnetic.

**Magnetic susceptibility ( $\chi_m, \kappa$ )\*** - Defined by  $\chi_m = (\mu - \mu_0)/\mu_0$ , where  $\mu$  is the permeability of the medium and  $\mu_0$  the permeability of a vacuum. [1]

**Magnetization ( $M$ )** - Defined by  $M = (B/\mu_0) - H$ , where  $B$  is magnetic induction,  $H$  magnetic field strength, and  $\mu_0$  the permeability of a vacuum. [1]

**Magnetogyric ratio ( $\gamma$ )** - Ratio of the magnetic moment of a particle to its angular momentum. Also called gyromagnetic ratio.

**Magneton** - See Bohr magneton, Nuclear magneton.

**Magnetostriction\*** - The change in dimensions of a solid sample when it is placed in a magnetic field.

**Magnon** - A quantum of magnetic energy associated with a spin wave in a ferromagnetic or antiferromagnetic crystal.

**Mantle** - The layer of the earth between the crust and the liquid outer core, which begins about 2900 km below the earth's surface.

**Maser** - A device in which a microwave cavity is filled with a medium where a population inversion can be produced by some means. When the resonant frequency of the cavity bears the proper relation to the separation of the inverted energy levels, the device can serve as an amplifier or oscillator at that frequency.

**Mass ( $m$ )\*** - Quantity of matter. Mass can also be defined as "resistance to acceleration".

**Mass defect ( $B$ )** - Defined by  $B = Zm(^1\text{H}) + Nm_n - m_a$ , where  $Z$  is the atomic number,  $m(^1\text{H})$  is the mass of the hydrogen atom,  $N$  is the neutron number,  $m_n$  is the rest mass of the neutron, and  $m_a$  is the mass of the atom in question. Thus  $Bc^2$  can be equated to the binding energy of the nucleus if the binding energy of atomic electrons is neglected. [1]

**Mass excess ( $\Delta$ )** - Defined by  $\Delta = m_a - Am_u$ , where  $m_a$  is the mass of the atom,  $A$  the number of nucleons, and  $m_u$  the unified atomic mass constant ( $m_u = 1$  u). [1]

**Mass fraction ( $w_B$ )** - The ratio of the mass of substance B to the total mass of a mixture. [1]

**Mass number ( $A$ )** - A characteristic property of a specific isotope of an element, equal to the sum of the number of protons and neutrons in the nucleus.

**Mass spectrometry** - An analytical technique in which ions are separated according to the mass/charge ratio and detected by a suitable detector. The ions may be produced by electron impact on a gas, a chemical reaction, energetic vaporization of a solid, etc. [6]

**Massieu function** - A thermodynamic function defined by  $J = -A/T$ , where  $A$  is the Helmholtz energy and  $T$  the thermodynamic temperature. [2]

**Matthiessen's rule** - The statement that the electrical resistivity  $\rho$  of a metal can be written as  $\rho = \rho_L + \rho_i$ , where  $\rho_L$  is due to scattering of conduction electrons by lattice vibrations and  $\rho_i$  to scattering by impurities and imperfections. If the impurity concentration is small,  $\rho_i$  is temperature independent.

**Maxwell (Mx)\*** - A non-SI unit of magnetic field strength ( $H$ ) equal to 10<sup>-8</sup> Wb. [1]

**Maxwell's equations** - The fundamental equations of electromagnetism. In a form appropriate to SI units, they are:

$$\begin{aligned}\text{curl } H &= \partial D / \partial t + j \\ \text{div } B &= 0 \\ \text{curl } E &= -\partial B / \partial t \\ \text{div } D &= \rho\end{aligned}$$

where  $H$  is the magnetic field strength,  $B$  the magnetic induction,  $E$  the electric field strength,  $D$  the electric displacement,  $j$  the current density,  $\rho$  the charge density, and  $t$  is time.

**Maxwell-Boltzmann distribution** - An expression for the fraction of molecules  $f(v)$  in a gas that have velocity  $v$  within a specified interval. It takes the form

$$f(v) = 4\pi(M/2\pi RT)^{3/2} v^2 e^{-Mv^2/2RT}$$

where  $M$  is the molar mass,  $R$  the molar gas constant, and  $T$  the temperature.

**Mean free path\*** - The average distance a gas molecule travels between collisions.

**Meissner effect** - The complete exclusion of magnetic induction from the interior of a superconductor.

**Melting point\*** - The temperature at which the solid and liquid phases of a substance are in equilibrium at a specified pressure (normally taken to be atmospheric unless stated otherwise).

**Mercaptans** - A traditional term abandoned by IUPAC, synonymous with thiols. This term is still widely used. [5]

**Meson** - Any elementary particle that has zero or integral spin. Mesons are responsible for the forces between protons and neutrons in the nucleus.

**Mesosphere** - The part of the earth's atmosphere extending from the top of the stratosphere (about 50 km above the surface) to 80-90 km. It is characterized by a decrease in temperature with increasing altitude.

**Metal** - A material in which the highest occupied energy band (conduction band) is only partially filled with electrons. The electrical conductivity of metals generally decreases with temperature.

**Metalloenes** - Organometallic coordination compounds in which one atom of a transition metal such as iron, ruthenium or osmium is bonded to and only to the face of two cyclopentadienyl ligands which lie in parallel planes. [5]

**Meter (m)\*** - The SI base unit of length. [1]

**Methine group** - In organic compounds, the  $-C=$  group. [5]

**Mho** - An archaic name for the SI unit siemens (reciprocal ohm).

**Micelle** - A particle formed by the aggregation of surfactant molecules (typically, 10 to 100 molecules) in solution. For aqueous solutions, the hydrophilic end of the molecule is on the surface of the micelle, while the hydrophobic end (often a hydrocarbon chain) points toward the center. At the critical micelle concentration (cmc) the previously dissolved molecules aggregate into a micelle.

**Micron ( $\mu$ )** - An obsolete name for micrometer.

**Mie scattering** - The scattering of light by spherical dielectric particles whose diameter is comparable to the wavelength of the light.

**Milky way** - The band of light in the night sky resulting from the stars in the galactic plane. The term is also used to denote the galaxy in which the sun is located.

**Miller indices ( $hkl$ )** - A set of indices used to label planes in a crystal lattice. [2]

**Millimeter of mercury (mmHg)** - A non-SI unit of pressure, equal to 133.322 Pa. The name is generally considered interchangeable with torr.

**Mobility ( $\mu$ )\*** - In solid state physics, the drift velocity of electrons or holes in a solid divided by the applied electric field strength. The term is used in a similar sense in other fields.

**Molality ( $m$ )** - A measure of concentration of a solution in which one states the amount of substance (i.e., number of moles) of solute per kilogram of solvent. Thus a 0.1 molal solution (often written as 0.1 m) has  $m = 0.1$  mol/kg.

**Molar mass** - The mass of one mole of a substance. It is normally expressed in units of g/mol, in which case its numerical value is identical with the molecular weight (relative molecular mass). [1]

**Molar quantity** - It is often convenient to express an extensive quantity (e.g., volume, enthalpy, heat capacity, etc.) as the actual value divided by amount of substance (number of moles). The resulting quantity is called molar volume, molar enthalpy, etc

**Molar refraction ( $R$ )** - A property of a dielectric defined by the equation  $R = V_m [(n^2-1)/(n^2+2)]$ , where  $n$  is the index of refraction of the medium (at optical wavelengths) and  $V_m$  the molar volume. It is related to the polarizability  $\alpha$  of the molecules that make up the medium by the Lorenz-Lorentz equation,  $R = N_A \alpha / 3\epsilon_0$ , where  $N_A$  is Avogadro's constant and  $\epsilon_0$  is the permittivity of a vacuum.

**Molarity ( $c$ )** - A measure of concentration of a solution in which one states the amount of substance (i.e., number of moles) of solute per liter of solution. Thus a 0.1 molar solution (often referred to as 0.1 M) has a concentration  $c = 0.1$  mol/L.

**Mole (mol)\*** - The SI base unit of amount of substance. [1]

**Mole fraction ( $x_B$ )** - The ratio of the amount of substance (number of moles) of substance B to the total amount of substance in a mixture. [1]

**Molecular orbital** - See Orbital.

**Molecular weight ( $M_r$ )\*** - The ratio of the average mass per molecule or specified entity of a substance to 1/12 of the mass of nuclide  $^{12}\text{C}$ . Also called relative molar (or molecular) mass. [1]

**Moment of inertia ( $I$ )** - The moment of inertia of a body about an axis is the sum (or integral) of the products of its elements of mass and the squares of their distances from the axis. [1]

**Momentum ( $p$ )** - The product of mass and velocity. [1]

**Monomer** - A substance consisting of molecules which can undergo polymerization, thereby contributing constitutional units to the essential structure of a macromolecule. [8]

**Monosaccharides** - A term which includes aldoses, ketoses, and a wide variety of derivatives. [5]

**Mössbauer effect** - The recoilless emission of  $\gamma$ -rays from nuclei bound in a crystal under conditions where the recoil energy associated with the  $\gamma$  emission is taken up by the crystal as a whole. This results in a very narrow line width, which can be exploited in various types of precise measurements.

**Muon\*** - An unstable elementary particle of spin 1/2 and mass about 200 times that of the electron.

**Naphtha** - The petroleum fraction consisting mostly of  $\text{C}_6$  to  $\text{C}_8$  hydrocarbons and boiling in the range 80-120°C. Solvents derived from this fraction include ligroin and petroleum ether.

**Nautical mile** - A non-SI unit of length, equal to exactly 1852 m.

**Navier-Stokes equations** - A set of complex equations for the motion of a viscous fluid subject to external forces.

**Néel temperature ( $T_N$ )\*** - The critical temperature above which an antiferromagnetic substance becomes paramagnetic. [1]

**Nernst effect** - The production of an electric field in a conductor subject to an applied magnetic field and containing a transverse temperature gradient. The electric field is perpendicular to the magnetic field and the temperature gradient.

**Network** - In polymer science, a highly ramified macromolecule in which essentially each constitutional unit is connected to each other constitutional unit and to the macroscopic phase boundary by many permanent paths through the macromolecule, the number of such paths increasing with the number of intervening bonds. The paths must on the average be coextensive with the macromolecule. [8]



**Neutrino** - A stable elementary particle in the lepton family. Neutrinos have zero (or at least near-zero) rest mass and spin 1/2.

**Neutron\*** - An elementary particle on spin 1/2 and zero charge. The free neutron has a mean lifetime of 887 seconds. Neutrons and protons, which are collectively called nucleons, are the constituents of the nucleus.

**Neutron activation analysis (NAA)** - See Techniques for Materials Characterization, page 12-1.

**Neutron number (N)** - A characteristic property of a specific isotope of an element, equal to the number of neutrons in the nucleus.

**Newton (N)\*** - The SI unit of force, equal to  $\text{m kg s}^{-2}$ . [1]

**Nitriles** - Compounds having the structure  $\text{RC}\equiv\text{N}$ ; thus C-substituted derivatives of hydrocyanic acid,  $\text{HC}\equiv\text{N}$ . [5]

**Nitrosamines** - N-Nitroso amines: compounds of the structure  $\text{R}_2\text{NNO}$ . Compounds  $\text{RNHNO}$  are not ordinarily isolatable, but they, too, are nitrosamines. The name is a contraction of N-nitrosoamine and, as such, does not require the N locant. [5]

**Nuclear magnetic resonance (NMR)\*** - A widely used technique in which the resonant absorption of radiofrequency radiation by magnetic nuclei in a magnetic field is measured. The results give important information on the local environment of each nucleus.

**Nuclear magneton ( $\mu_N$ )\*** - The unit of nuclear magnetic moment, defined as  $eh/4\pi m_p$ , where  $h$  is Planck's constant,  $m_p$  the proton mass, and  $e$  the elementary charge.

**Nuclear quadrupole resonance (NQR)** - See Techniques for Materials Characterization, page 12-1.

**Nuclear reaction analysis (NRA)** - See Techniques for Materials Characterization, page 12-1.

**Nuclear spin (I)** - The quantum number that specifies the intrinsic angular momentum of a particular nucleus. The magnitude of the angular momentum is given by  $[I(I+1)]^{1/2} h/2\pi$ , where  $h$  is Planck's constant.

**Nucleic acids\*** - Macromolecules, the major organic matter of the nuclei of biological cells, made up of nucleotide units, and hydrolyzable into certain pyrimidine or purine bases (usually adenine, cytosine, guanine, thymine, uracil), D-ribose or 2-deoxy-D-ribose. [5]

**Nucleon** - A collective term for the proton and neutron.

**Nucleosides** - Ribosyl or deoxyribosyl derivatives (rarely, other glycosyl derivatives) of certain pyrimidine or purine bases. They are thus glycosylamines or N-glycosides related to nucleotides by the lack of phosphorylation. [5]

**Nucleotides** - Compounds formally obtained by esterification of the 3' or 5' hydroxy group of nucleosides with phosphoric acid. They are the monomers of nucleic acids and are formed from them by hydrolytic cleavage. [5]

**Nuclide** - A species of atoms in which each atom has identical atomic number  $Z$  and identical mass number  $A$ . [3]

**Nusselt number (Nu)** - A dimensionless quantity used in fluid mechanics, defined by  $Nu = hl/k$ , where  $h$  is coefficient of heat transfer,  $l$  is length, and  $k$  is thermal conductivity. [2]

**Nyquist theorem** - An expression for the mean square thermal noise voltage across a resistor, given by  $4RkT\Delta f$  where  $R$  is the resistance,  $k$  the Boltzmann constant,  $T$  the temperature, and  $\Delta f$  the frequency band within which the voltage is measured.

**Octanol-water partition coefficient (P)\*** - A measure of the way in which a compound will partition itself between the octanol and water phases in the two-phase octanol-water system, and thus an indicator of certain types of biological activity. Specifically,  $P$  is the ratio of the concentration (in moles per liter) of the compound in the octanol phase to that in the water phase at infinite dilution. The quantity normally reported is  $\log P$ .

**Oersted (Oe)** - A non-SI unit of magnetic field ( $H$ ), equal to 79.57747 A/m.

**Ohm ( $\Omega$ )\*** - The SI unit of electric resistance, equal to V/A. [1]

**Ohm's law** - A relation among electric current  $I$ , potential difference  $V$ , and resistance  $R$ , viz.,  $I = V/R$ . The resistance is constant at constant temperature to high precision for many materials.

**Olefins** - Acyclic and cyclic hydrocarbons having one or more carbon-carbon double bonds, apart from the formal ones in aromatic compounds. The class olefins subsumes alkenes and cycloalkenes and the corresponding polyenes. [5]

**Oligomer** - A substance consisting of molecules of intermediate relative molecular mass (molecular weight), the structure of which essentially comprises the multiple repetition of units derived, actually or conceptually, from molecules of low relative molecular mass. In contrast to a polymer, the properties of an oligomer can vary significantly with the removal of one or a few of its units. [8]

**Oligopeptides** - Peptides containing from three to nine amino groups. [5]

**Onsager relations** - An important set of equations in the thermodynamics of irreversible processes. They express the symmetry between the transport coefficients describing reciprocal processes in systems with a linear dependence of flux on driving forces.

**Optical rotary power** - Angle by which the plane of polarization of a light beam is rotated by an optically active medium, divided by path length and by concentration of the active constituent. Depending on whether mass or molar concentration is used, the modifier "specific" or "molar" is attached. [2]

**Orbital** - A one-electron wavefunction. Atomic orbitals are classified as  $s$ -,  $p$ -,  $d$ -, or  $f$ -orbitals according to whether the angular momentum quantum number  $l = 0, 1, 2, \text{ or } 3$ . Molecular orbitals, which are usually constructed as linear combinations of atomic orbitals, describe the distribution of electrons over the entire molecule.

**Oscillator strength (f)** - A measure of the intensity of a spectroscopic transition, defined by

$$f = \frac{8\pi^2 M e v}{3 h e^2} |\mu_{ij}|^2$$

where  $v$  is the frequency,  $\mu_{ij}$  the transition dipole moment,  $m_e$  the mass of the electron,  $e$  the elementary charge, and  $h$  Planck's constant.

**Osmosis** - The flow of a solvent in a system in which two solutions of different concentration are separated by a semipermeable membrane which cannot pass solute molecules. The solvent will flow from the side of lower concentration to that of higher concentration, thus tending to equalize the concentrations. The pressure that must be applied to the more concentrated side to stop the flow is called the osmotic pressure.

**Osmotic coefficient ( $\phi$ )** - Defined by  $\phi = \ln a_A / (M_A \sum m_B)$ , where  $M_A$  is the molar mass of substance A (normally the solvent),  $a_A$  is its activity, and the  $m_B$  are molalities of the solutes. [1]

**Osmotic pressure ( $\Pi$ )** - The excess pressure necessary to maintain osmotic equilibrium between a solution and the pure solvent separated by a membrane permeable only to the solvent. In an ideal dilute solution  $\Pi = c_B RT$ , where  $c_B$  is the amount-of-substance concentration of the solute,  $R$  is the molar gas constant, and  $T$  the temperature. [1,2]

**Ostwald dilution law** - A relation for the concentration dependence of the molar conductivity  $\Lambda$  of an electrolyte solution, viz.,

$$\frac{1}{\Lambda} = \frac{1}{\Lambda^\circ} + \frac{\Lambda c}{K(\Lambda^\circ)^2}$$

where  $c$  is the solute concentration,  $K$  is the equilibrium constant for dissociation of the solute, and  $\Lambda^\circ$  is the conductivity at  $c\Lambda = 0$ .

**Ounce (oz)** - A non-SI unit of mass. The avoirdupois ounce equals 28.34952 g, while the troy ounce equals 31.10348 g.

**Overpotential ( $\eta$ )** - In an electrochemical cell, the difference between the potential of an electrode and its zero-current value.

**Oximes** - Compounds of structure  $R_2C=NOH$  derived from condensation of aldehydes or ketones with hydroxylamine. Oximes from aldehydes may be called aldoximes; those from ketones may be called ketoximes. [5]

**Oxo compounds** - Compounds containing an oxygen atom, =O, doubly bonded to carbon or another element. The term thus embraces aldehydes, carboxylic acids, ketones, sulfonic acids, amides and esters. [5]

**Ozonides** - The 1,2,4-trioxolanes formed by the reaction of ozone at a carbon-carbon double bond, or the analogous compounds derived from acetylenic compounds. [5]

**Pair production** - A process in which a photon is converted into a particle and its antiparticle (e.g., an electron and positron) in the electromagnetic field of a nucleus.

**Paraffins** - Obsolescent term for saturated hydrocarbons, commonly but not necessarily acyclic. Still widely used in the petrochemical industry, where the term designates acyclic saturated hydrocarbons, and stands in contradistinction to naphthenes. [5]

**Paramagnetism\*** - A type of magnetism characterized by a positive magnetic susceptibility, so that the material becomes weakly magnetized in the direction of an external field. The magnetization disappears when the field is removed. In the simplest approximation (Curie's law) the susceptibility is inversely proportional to temperature.

**Parity** - The property of a quantum-mechanical wave function that describes its behavior under the symmetry operation of coordinate inversion. A parity of +1 (or even) is assigned if the wave function does not change sign when the signs of all the coordinates are changed; the parity is -1 (or odd) if the wave function changes sign under this operation.

**Parsec (pc)** - A unit of distance defined as the distance at which 1 astronomical unit (AU) subtends an angle of 1 second of arc. It is equal to 206264.806 AU or  $3.085678 \times 10^{16}$  m.

**Particle induced x-ray emission (PIXE)** - See Techniques for Materials Characterization, page 12-1.

**Partition function ( $q, z$ )** - For a single molecule,  $q = \sum_i g_i \exp(\epsilon_i/kT)$ , where  $\epsilon_i$  is an energy level of degeneracy  $g_i$ ,  $k$  the Boltzmann constant, and  $T$  the absolute temperature; the summation extends over all energy states. For a system of  $N$  non-interacting molecules which are indistinguishable, as in an ideal gas, the canonical partition function  $Q = qN/N!$ .

**Pascal (Pa)\*** - The SI unit of pressure, equal to  $N/m^2$ . [1]

**Paschen series** - The series of lines in the spectrum of the hydrogen atom which corresponds to transitions between the state with principal quantum number  $n = 3$  and successive higher states. The wavelengths are given by  $1/\lambda = R_H(1/9 - 1/n^2)$ , where  $n = 4, 5, 6, \dots$  and  $R_H$  is the Rydberg constant. The first member of the series ( $n = 3 \leftrightarrow 4$ ), which is often called the  $P_\alpha$  line, falls in the infrared at a wavelength of 1.875  $\mu\text{m}$ .

**Paschen-Back effect** - In atomic spectroscopy, the decoupling of electron spin from orbital angular momentum as the strength of an external magnetic field is increased.

**Pauli exclusion principle** - The statement that two electrons in an atom cannot have identical quantum numbers; thus if there are two electrons in the same orbital, their spin quantum numbers must be of opposite sign.

**Pearson symbol** - A code for designating crystallographic information, including the crystal system, the lattice type, and the number of atoms per unit cell.

**Péclet number ( $Pe$ )** - A dimensionless quantity used in fluid mechanics, defined by  $Pe = vl/a$ , where  $v$  is velocity,  $l$  is length, and  $a$  is thermal diffusivity. [2]

**Peltier effect** - The absorption or generation of heat (depending on the current direction) which occurs when an electric current is passed through a junction between two materials.

**Peptides** - Amides derived from two or more amino carboxylic acid molecules (the same or different) by formation of a covalent bond from the carbonyl carbon of one to the nitrogen atom of another with formal loss of water. [5]

**Permeability ( $\mu$ )** - Magnetic induction divided by magnetic field strength; i.e.  $\mu = B/H$ . The relative permeability  $\mu_r = \mu/\mu_0$ , where  $\mu_0$  is the permeability of a vacuum. [1]

**Permittivity ( $\epsilon$ )** - Ratio of the electric displacement in a medium to the electric field strength. Also called dielectric constant. [1]

**Peroxides** - Compounds of structure ROOR in which R may be any organic group. In inorganic chemistry, salts of the anion  $O_2^{-2}$  [5]

**Peroxy acids** - Acids in which an acidic -OH group has been replaced by an -OOH group; e.g.  $CH_3C(=O)OOH$  peroxyacetic acid,  $PhS(=O)_2OOH$  benzeneperoxy sulfonic acid. [5]

**Petroleum ether** - The petroleum fraction consisting of  $C_5$  and  $C_6$  hydrocarbons and boiling in the range 35-60°C; commonly used as a laboratory solvent.

**pH\*** - A convenient measure of the acid-base character of a solution, usually defined by  $pH = -\log [c(H^+)/\text{mol L}^{-1}]$ , where  $c(H^+)$  is the concentration of hydrogen ions. The more precise definition is in terms of activity rather than concentration. [2]

**Phenols** - Compounds having one or more hydroxy groups attached to a benzene or other arene ring. [5]

**Phonon** - A quantum of energy associated with a vibrational mode of a crystal lattice.

**Phosphines** -  $PH_3$  and compounds derived from it by substituting one, two or three hydrogen atoms by hydrocarbyl groups.

RPH<sub>2</sub>, R<sub>2</sub>PH and R<sub>3</sub>P (R not equal to H) are called primary, secondary and tertiary phosphines, respectively. [5]

**Phosphonium compounds** - Salts (and hydroxides) [R<sub>4</sub>P]<sup>+</sup>X<sup>-</sup> containing tetracoordinate phosphonium ion and the associated anion. [5]

**Phosphonium ylides** - Compounds having the structure R<sub>3</sub>P<sup>+</sup>-C<sup>-</sup>R<sub>2</sub> ⇌ R<sub>3</sub>P=CR<sub>2</sub>. Also known as Wittig reagents. [5]

**Phosphorescence** - The process by which a molecule is excited by light to a higher electronic state and then undergoes a radiationless transition to a state of different multiplicity from which it decays, after some delay, to the ground state. The emitted light is normally of longer wavelength than the exciting light because vibrational energy has been dissipated.

**Photoelectric effect** - The complete absorption of a photon by a solid with the emission of an electron.

**Photon** - An elementary particle of zero mass and spin 1/2. The photon is involved in electromagnetic interactions and is the quantum of electromagnetic radiation.

**Photon stimulated desorption (PSD)** - See Techniques for Materials Characterization, page 12-1.

**Pinacols** - Tetra(hydrocarbyl)ethane-1,2-diols, R<sub>2</sub>C(OH)C(OH)R<sub>2</sub>, of which the tetramethyl example is the simplest one and is itself commonly known as pinacol. [5]

**Pion** - An elementary particle in the family of mesons. Pions have zero spin and may be neutral or charged. They participate in the strong interaction which holds the nucleus together.

**pK<sup>\*</sup>** - The negative logarithm (base 10) of an equilibrium constant *K*. For pK<sub>a</sub>, see Acid dissociation constant.

**Planck constant (*h*)<sup>\*</sup>** - The elementary quantum of action, which relates energy to frequency through the equation  $E = h\nu$ .

**Planck distribution** - See Black body radiation

**Planck function** - A thermodynamic function defined by  $Y = -G/T$ , where *G* is Gibbs energy and *T* thermodynamic temperature. [2]

**Plasma** - A highly ionized gas in which the charge of the electrons is balanced by the charge of the positive ions, so that the system as a whole is electrically neutral.

**Plasmon** - A quantum associated with a plasma oscillation in the electron gas of a solid.

**Point group<sup>\*</sup>** - A group of symmetry operations (rotations, reflections, etc.) that leave a molecule invariant. Every molecular conformation can be assigned to a specific point group, which plays a major role in determining the spectrum of the molecule.

**Poise (P)** - A non-SI unit of viscosity, equal to 0.1 Pa s.

**Poiseuille's equation** - A formula for the rate of flow of a viscous fluid through a tube:

$$\frac{dV}{dt} = \frac{(p_1^2 - p_2^2)\pi r^4}{16l\eta p_0}$$

where *V* is the volume as measured at pressure *p*<sub>0</sub>; *p*<sub>1</sub> and *p*<sub>2</sub> are the pressures at each end of the tube; *r* is the radius and *l* the length of the tube; and  $\eta$  is the viscosity.

**Poisson ratio ( $\mu$ )** - The absolute value of the ratio of the transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit (i.e., where Hooke's law is valid). [10]

**Polariton** - A quantum associated with the coupled modes of photons and optical phonons in an ionic crystal.

**Polarizability ( $\alpha$ )<sup>\*</sup>** - The change in dipole moment of a molecule produced by an external electric field; specifically,  $\alpha_{ab} = \partial p_a / \partial E_b$ , where *p*<sub>*a*</sub> is the dipole moment component on the *a* axis and *E*<sub>*b*</sub> is the component of the electric field strength along the *b* axis. [2]

**Polymer** - A substance composed of molecules of high relative molecular mass (molecular weight), the structure of which essentially comprises the multiple repetition of units derived, actually or conceptually, from molecules of low relative molecular mass. A single molecule of a polymer is called a macromolecule. [8]

**Polypeptides** - Peptides containing 10 or more amino acid residues. See also Peptides. [5]

**Polysaccharides** - Compounds consisting of a large number of monosaccharides linked glycosidically. This term is commonly used only for those containing more than ten monosaccharide residues. Also called glycans. [5]

**Porphyryns** - Natural pigments containing a fundamental skeleton of four pyrrole nuclei united through the  $\alpha$ -positions by four methine groups to form a macrocyclic structure (porphyrin is designated porphine in Chemical Abstracts indexes). [5]

**Positron** - The antiparticle of the electron. It has the same mass and spin as an electron, and an equal but opposite charge.

**Positronium** - The hydrogen-like "atom" formed from a positron nucleus and an electron. Its lifetime is very short because of annihilation of the positron and electron.

**Potential** - See Electric potential

**Potential energy (*E*<sub>*p*</sub>, *V*, *U*)** - The portion of the energy of a system that is associated with its position in a force field.

**Pound (lb)** - A non-SI unit of mass, equal to 0.4535924 kg.

**Power (*P*)** - Rate of energy transfer. For electrical circuits, this is equal to the product of current and potential difference,  $P = IV$ . [1]

**Poynting vector (*S*)** - For electromagnetic radiation, the vector product of the electric field strength and the magnetic field strength. [1]

**Prandtl number (*Pr*)** - A dimensionless quantity used in fluid mechanics, defined by  $Pr = \eta/\rho a$ , where  $\eta$  is viscosity,  $\rho$  is density, and *a* is thermal diffusivity. [2]

**Pressure<sup>\*</sup>** - Force divided by area. [1]

**Proteins** - Naturally occurring and synthetic polypeptides having molecular weights greater than about 10,000 (the limit is not precise). See also Peptides. [5]

**Proton<sup>\*</sup>** - A stable elementary particle of unit positive charge and spin 1/2. Protons and neutrons, which are collectively called nucleons, are the constituents of the nucleus.

**Pulsar** - A neutron star which rotates rapidly and emits electromagnetic radiation in regular pulses at a frequency related to the rotation period.

**Purine bases<sup>\*</sup>** - Purine and its substitution derivatives, especially naturally occurring examples. [5]

**Pyrimidine bases<sup>\*</sup>** - Pyrimidine and its substitution derivatives, especially naturally occurring examples. [5]

**Q-switching** - A technique for obtaining very high power from a laser by keeping the *Q* factor of the laser cavity low while the population inversion builds up, then suddenly increasing the *Q* to initiate the stimulated emission.

**Quad** - A unit of energy defined as 10<sup>15</sup> Btu, equal to approximately 1.055056 × 10<sup>18</sup> J.

- Quadrupole moment** - A coefficient of the third term (after monopole and dipole) in the power series expansion of the electric potential of an array of charges. A nucleus of spin greater than 1/2 has a non-vanishing nuclear quadrupole moment which can interact with the electric field gradient of the surrounding electrons. Molecular quadrupole moments have an influence on intermolecular forces.
- Quality factor (Q)** - The ratio of the absolute value of the reactance of an electrical system to the resistance; thus a measure of the energy stored per cycle relative to the energy dissipated.
- Quantum yield** - In photochemistry, the number of moles transformed in a specific process, either physically (e.g., by emission of photons) or chemically, per mole of photons absorbed by the system. [3]
- Quark** - An elementary entity which has not been directly observed but is considered a constituent of protons, neutrons, and other hadrons.
- Quasar** - An extragalactic object emitting electromagnetic radiation at a very high power level and showing a very large red shift, thus indicating that the object is receding at a speed approaching the speed of light.
- Quasicrystal** - A solid having conventional crystalline properties but whose lattice does not display translational periodicity.
- Quaternary ammonium compounds** - Derivatives of ammonium compounds,  $\text{NH}_4^+ \text{Y}^-$ , in which all four of the hydrogens bonded to nitrogen have been replaced with hydrocarbyl groups. Compounds having a carbon-nitrogen double bond (i.e.  $\text{R}_2\text{C}=\text{N}^+\text{R}_2\text{Y}^-$ ) are more accurately called iminium compounds. [5]
- Quinones** - Compounds having a fully conjugated cyclic dione structure, such as that of benzoquinones, derived from aromatic compounds by conversion of an even number of  $-\text{CH}=\text{O}$  groups into  $-\text{C}(=\text{O})-$  groups with any necessary rearrangement of double bonds. [5]
- Racemic mixture** - A mixture of equal amounts of a pair of enantiomers (optical isomers); such a mixture is not optically active.
- Rad** - A non-SI unit of absorbed dose of radiation, equal to 0.01 Gy.
- Radiance (L)** - The radiant intensity in a given direction from an element of a surface, divided by the area of the orthogonal projection of this element on a plane perpendicular to the given direction. [1]
- Radiant intensity (I)** - The radiant energy flux leaving an element of a source within an element of solid angle, divided by that element of solid angle. [1]
- Radicals** - Molecular entities possessing an unpaired electron, such as  $\cdot\text{CH}_3$ ,  $\cdot\text{SnH}_3$ ,  $\cdot\text{Cl}$ . (In these formulas the dot, symbolizing the unpaired electron, should be placed so as to indicate the atom of highest spin density, if this is possible). [5]
- Raman effect** - The inelastic scattering of light by a molecule, in which the incident photon either gives up to, or receives energy from, one of the internal vibrational modes of the molecule. The scattered light thus has either a lower frequency (Stokes radiation) or higher frequency (anti-Stokes radiation) than the incident light. These shifts provide a measure of the normal vibrational frequencies of the molecule.
- Rankine cycle** - A thermodynamic cycle which can be used to calculate the ideal performance of a heat engine that uses a condensable vapor as the working fluid (e.g., a steam engine or a heat pump).
- Rankine temperature** - A thermodynamic temperature scale based on a temperature interval  $^\circ\text{R} = (5/9) \text{K}$ ; i.e.,  $T/^\circ\text{R} = (9/5)T/\text{K} = t/^\circ\text{F} + 459.67$ .
- Raoult's law** - The expression for the vapor pressure  $p_i$  of component  $i$  in an ideal solution, viz.,  $p_i = x_i p_{i0}$ , where  $x_i$  is the mole fraction of component  $i$  and  $p_{i0}$  the vapor pressure of the pure substance  $i$ .
- Rare earth elements** - The elements Sc, Y, and the lanthanides (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu). [7]
- Rayleigh number (Ra)** - A dimensionless quantity used in fluid mechanics, defined by  $Ra = \beta g \alpha \Delta T \rho / \eta a$ , where  $l$  is length,  $g$  is acceleration of gravity,  $\alpha$  is cubic expansion coefficient,  $T$  is temperature,  $\rho$  is density,  $\eta$  is viscosity, and  $a$  is thermal diffusivity. [2]
- Rayleigh scattering** - The scattering of light by particles which are much smaller than the wavelength of the light. It is characterized by a scattered intensity which varies as the inverse fourth power of the wavelength.
- Rayleigh wave** - A guided elastic wave along the surface of a solid; also called surface acoustic wave.
- Reactance (X)** - The imaginary part of impedance. For an inductive reactance  $L$  and a capacitive reactance  $C$  in series, the reactance is  $X = L\omega - 1/(C\omega)$ , where  $\omega$  is  $2\pi$  times the frequency of the current. [1]
- Red shift** - A displacement of a spectral line toward longer wavelengths. This can occur through the Doppler effect (e.g., in the light from receding galaxies) or, in the general theory of relativity, from the effects of a star's gravitational field.
- Reflectance (p)** - Ratio of the radiant or luminous flux at a given wavelength that is reflected to that of the incident radiation. Also called reflection factor. [1]
- Reflection high energy electron diffraction (RHEED)** - See Techniques for Materials Characterization, page 12-1.
- Relative humidity\*** - The ratio of the partial pressure of water vapor in air to the saturation vapor pressure of water at the same temperature, expressed as a percentage. [10]
- Relative molar mass** - See Molecular weight.
- Rem** - A non-SI unit of dose equivalent, equal to 0.01 Sv.
- Resistance (R)** - Electric potential difference divided by current when there is no electromotive force in the conductor. This definition applies to direct current. More generally, resistance is defined as the real part of impedance. [1]
- Resistivity (p)** - Electric field strength divided by current density when there is no electromotive force in the conductor. Resistivity is an intrinsic property of a material. For a conductor of uniform cross section with area  $A$  and length  $L$ , and whose resistance is  $R$ , the resistivity is given by  $\rho = RA/L$ . [1]
- Reynolds number (Re)** - A dimensionless quantity used in fluid mechanics, defined by  $Re = \rho v l / \eta$ , where  $\rho$  is density,  $v$  is velocity,  $l$  is length, and  $\eta$  is viscosity. [2]
- Rheology** - The study of the flow of liquids and deformation of solids. Rheology addresses such phenomena as creep, stress relaxation, anelasticity, nonlinear stress deformation, and viscosity.
- Ribonucleic acids (RNA)** - Naturally occurring polyribonucleotides. See also nucleic acids, nucleosides, nucleotides, ribonucleotides. [5]
- Ribonucleotides** - Nucleotides in which the glycosyl group is a ribosyl group. See also nucleotides. [5]

**Roentgen (R)** - A unit used for expressing the charge (positive or negative) liberated by x-ray or  $\gamma$  radiation in air, divided by the mass of air. A roentgen is defined as  $2.58 \times 10^{-4}$  C/kg.

**Rotational constants** - In molecular spectroscopy, the constants appearing in the expression for the rotational energy levels as a function of the angular momentum quantum numbers. These constants are proportional to the reciprocals of the principal moments of inertia, averaged over the vibrational motion.

**Rutherford back scattering (RBS)** - See Techniques for Materials Characterization, page 12-1.

**Rydberg constant ( $R_\infty$ )\*** - The fundamental constant which appears in the equation for the energy levels of hydrogen-like atoms; i.e.,  $E_n = hcR_\infty Z^2\mu/n^2$ , where  $h$  is Planck's constant,  $c$  the speed of light,  $Z$  the atomic number,  $\mu$  the reduced mass of nucleus and electron, and  $n$  the principal quantum number ( $n = 1, 2, \dots$ ).

**Rydberg series** - A regular series of lines in the spectrum of an atom or molecule, with the spacing between successive lines becoming smaller as the frequency increases (wavelength decreases). The series eventually converges to a limit which usually corresponds to the complete removal of an electron from the atom or molecule.

**Sackur-Tetrode equation\*** - An equation for the molar entropy  $S_m$  of an ideal monatomic gas:  $S_m = R \ln(e^{5/2} V/N_A \Lambda^3)$ , where  $R$  is the molar gas constant,  $V$  is the volume, and  $N_A$  is Avogadro's number. The constant  $\Lambda$  is given by  $\Lambda = h/(2\pi mkT)^{1/2}$ , where  $h$  is Planck's constant,  $m$  the atomic mass,  $k$  the Boltzmann constant, and  $T$  the temperature.

**Salinity (S)\*** - A parameter used in oceanography to describe the concentration of dissolved salts in seawater. It is defined in terms of electrical conductivity relative to a standard solution of KCl. When expressed in units of parts per thousand,  $S$  may be roughly equated to the concentration of dissolved material in grams per kilogram of seawater.

**Salt** - An ionic compound formed by the reaction of an acid and a base.

**Scanned probe microscopy (SPM)** - See Techniques for Materials Characterization, page 12-1.

**Scanning electron microscopy (SEM)** - See Techniques for Materials Characterization, page 12-1.

**Scanning laser acoustic microscopy (SLAM)** - See Techniques for Materials Characterization, page 12-1.

**Scanning transmission electron microscopy (STEM)** - See Techniques for Materials Characterization, page 12-1.

**Scanning tunneling microscopy (STM)** - See Techniques for Materials Characterization, page 12-1.

**Schiff bases** - Imines bearing a hydrocarbyl group on the nitrogen atom:  $R_2C=NR'$  ( $R'$  not equal to H). Considered by many to be synonymous with azomethines. [5]

**Schmidt number (Sc)** - A dimensionless quantity used in fluid mechanics, defined by  $Sc = \eta/\rho D$ , where  $\eta$  is viscosity,  $\rho$  is density, and  $D$  is diffusion coefficient. [2]

**Schottky barrier** - A potential barrier associated with a metal-semiconductor contact. It forms the basis for the rectifying device known as the Schottky diode.

**Schrödinger equation** - The basic equation of wave mechanics which, for systems not dependent on time, takes the form:

$$-(\hbar/2m)\nabla^2\psi + V\psi = E\psi$$

where  $\psi$  is the wavefunction,  $V$  is the potential energy expressed as a function of the spatial coordinates,  $E$  is an energy eigenvalue,  $\nabla^2$  is the Laplacian operator,  $\hbar$  is Planck's constant divided by  $2\pi$ , and  $m$  is the mass.

**Second (s)\*** - The SI base unit of time. [1]

**Second radiation constant ( $c_2$ )\*** - See First radiation constant.

**Secondary ion mass spectroscopy (SIMS)** - See Techniques for Materials Characterization, page 12-1.

**Seebeck effect** - The development of a potential difference in a circuit where two different metals or semiconductors are joined and their junctions maintained at different temperatures. It is the basis of the thermocouple.

**Selenides** - Compounds having the structure RSeR ( $R$  not equal to H). They are thus selenium analogues of ethers. Also used for metal salts of  $H_2Se$ . [5]

**Semicarbazones** - Compounds having the structure  $R_2C=NNHC(=O)NH_2$ , formally derived by condensation of aldehydes or ketones with semicarbazide [ $NH_2NHC(=O)NH_2$ ]. [5]

**Semiconductor** - A material in which the highest occupied energy band (valence band) is completely filled with electrons at  $T = 0$  K, and the energy gap to the next highest band (conduction band) ranges from 0 to 4 or 5 eV. With increasing temperature electrons are excited into the conduction band, leading to an increase in the electrical conductivity.

**Semiquinones** - Radical anions having the structure  $-O-Z-O\cdot$  where  $Z$  is an ortho- or para-arylene group or analogous heteroarylene group; they are formally generated by the addition of an electron to a quinone. [5]

**SI units\*** - The International System of Units adopted in 1960 and recommended for use in all scientific and technical fields. [1]

**Siemens (S)\*** - The SI unit of electric conductance, equal to  $\Omega^{-1}$ . [1]

**Sievert (Sv)\*** - The SI unit of dose equivalent (of radiation), equal to J/kg. [1]

**Silanes** - Saturated silicon hydrides, analogues of the alkanes; i.e. compounds of the general formula  $Si_n H_{2n+2}$ . Silanes may be subdivided into silane, oligosilanes, and polysilanes. Hydrocarbyl derivatives are often referred to loosely as silanes. [5]

**Silicones** - Polymeric or oligomeric siloxanes, usually considered unbranched, of general formula  $[-OSiR_2-]_n$  ( $R$  not equal to H). [5]

**Siloxanes** - Saturated silicon-oxygen hydrides with unbranched or branched chains of alternating silicon and oxygen atoms (each silicon atom is separated from its nearest silicon neighbors by single oxygen atoms). [5]

**Skin effect** - The concentration of high frequency alternating currents near the surface of a conductor.

**Slater orbital** - A particular mathematical expression for the radial part of the wave function of a single electron, which is used in quantum-mechanical calculations of the energy and other properties of atoms and molecules.

**Small angle neutron scattering (SANS)** - See Techniques for Materials Characterization, page 12-1.

**Snell's law** - The relation between the angle of incidence  $i$  and the angle of refraction  $r$  of a light beam which passes from a medium of refractive index  $n_0$  to a medium of index  $n_1$ , viz.,  $\sin i/\sin r = n_1/n_0$ .

**Solar constant\*** - The mean radiant energy flux from the sun on a unit surface normal to the direction of the rays at the mean

distance of the earth from the sun. The value is approximately  $1373 \text{ W/m}^2$ .

**Solar wind** - The stream of high velocity hydrogen and helium ions emitted by the sun which flows through the solar system and beyond.

**Soliton** - A spatially localized wave in a solid or liquid that can interact strongly with other solitons but will afterwards regain its original form.

**Solubility\*** - A quantity expressing the maximum concentration of some material (the solute) that can exist in another liquid or solid material (the solvent) at thermodynamic equilibrium at specified temperature and pressure. Common measures of solubility include the mass of solute per unit mass of solution (mass fraction), mole fraction of solute, molality, molarity, and others.

**Solubility product constant ( $K_{sp}$ )\*** - The equilibrium constant for the dissolution of a sparsely soluble salt into its constituent ions.

**Space group\*** - A group of symmetry operations (reflections, rotations, etc.) that leave a crystal invariant. A total of 230 space groups have been identified.

**Spark source mass spectroscopy (SSMS)** - See Techniques for Materials Characterization, page 12-1.

**Specific gravity** - Ratio of the mass density of a material to that of water. Since one must specify the temperature of both the sample and the water to have a precisely defined quantity, the use of this term is now discouraged.

**Specific heat** - Heat capacity divided by mass. See Heat capacity.

**Specific quantity** - It is often convenient to express an extensive quantity (e.g., volume, enthalpy, heat capacity, etc.) as the actual value divided by mass. The resulting quantity is called specific volume, specific enthalpy, etc.

**Specific rotation  $[\alpha]_{\lambda}^{\theta}$**  - For an optically active substance, defined by  $[\alpha]_{\lambda}^{\theta} = \alpha/\gamma l$ , where  $\alpha$  is the angle through which plane polarized light is rotated by a solution of mass concentration  $\gamma$  and path length  $l$ . Here  $\theta$  is the Celsius temperature and  $\lambda$  the wavelength of the light at which the measurement is carried out. Also called specific optical rotatory power. [2]

**Spin ( $s, I$ )\*** - A measure of the intrinsic angular momentum of a particle, which it possesses independent of its orbital motion. The symbol  $s$  is used for the spin quantum number of an electron, while  $I$  is generally used for nuclear spin.

**Spiro compounds** - Compounds having one atom (usually a quaternary carbon) as the only common member of two rings. [5]

**Stacking fault** - An error in the normal sequence of layer growth in a crystal.

**Standard mean ocean water (SMOW)** - A standard sample of pure water of accurately known isotopic composition which is maintained by the International Atomic Energy Agency. It is used for precise calibration of density and isotopic composition measurements.

**Standard reduction potential ( $E^{\circ}$ )** - The zero-current potential of a cell in which the specified reduction reaction occurs at the right-hand electrode and the left-hand electrode is the standard hydrogen electrode. Also called Standard electrode potential.

**Standard state** - A defined state (specified temperature, pressure, concentration, etc.) for tabulating thermodynamic functions and carrying out thermodynamic calculations. The standard

state pressure is usually taken as 100,000 Pa (1 bar), but various standard state temperatures are used. [2]

**Stanton number ( $St$ )** - A dimensionless quantity used in fluid mechanics, defined by  $St = h/\rho v c_p$ , where  $h$  is coefficient of heat transfer,  $\rho$  is density,  $v$  is velocity, and  $c_p$  is specific heat capacity at constant pressure. [2]

**Stark effect** - The splitting of an energy level of an atom or molecule, and hence a splitting of spectral lines arising from that level, as a result of the application of an external electric field.

**Statistical weight ( $g$ )** - The number of distinct states corresponding to the same energy level. Also called degeneracy.

**Stefan-Boltzmann constant ( $\sigma$ )\*** - Constant in the equation for the radiant exitance  $M$  (radiant energy flux per unit area) from a black body at thermodynamic temperature  $T$ , viz.  $M = \sigma T^4$ . [1]

**Stibines** -  $\text{SbH}_3$  and compounds derived from it by substituting one, two or three hydrogen atoms by hydrocarbyl groups:  $\text{R}_3\text{Sb}$ ,  $\text{RSbH}_2$ ,  $\text{R}_2\text{SbH}$ , and  $\text{R}_3\text{Sb}$  (R not equal to H) are called primary, secondary and tertiary stibines, respectively. [5]

**Stochastic process** - A process which involves random variables and whose outcome can thus be described only in terms of probabilities.

**Stoichiometric number ( $\nu$ )** - The number appearing before the symbol for each compound in the equation for a chemical reaction. By convention, it is negative for reactants and positive for products. [2]

**Stokes (St)** - A non-SI unit of kinematic viscosity, equal to  $10^{-4} \text{ m}^2/\text{s}$ .

**Stokes' law** - The statement, valid under certain conditions, that the viscous force  $F$  experienced by a sphere of radius  $a$  moving at velocity  $v$  in a medium of viscosity  $\eta$  is given by  $F = -6\pi\eta av$ .

**Strain** - The deformation of a body that results from an applied stress.

**Stratosphere** - The part of the earth's atmosphere extending from the top of the troposphere (typically 10 to 15 km above the surface) to about 50 km. It is characterized by an increase in temperature with increasing altitude.

**Stress** - Force per unit area (pressure) applied to a body. Tensile stress tends to stretch or compress the body in the direction of the applied force. Shear stress results from a tangential force which tends to twist the body.

**Strong interaction** - The short range (order of 1 fm) attractive forces between protons, neutrons, and other hadrons which are responsible for the stability of the nucleus.

**Strouhal number ( $Sr$ )** - A dimensionless quantity used in fluid mechanics, defined by  $Sr = lf/v$ , where  $l$  is length,  $f$  is frequency, and  $v$  is velocity. [2]

**Structure factor** - In x-ray crystallography, the sum of the scattering factors of all the atoms in a unit cell, weighted by an appropriate phase factor. The intensity of a given reflection is proportional to the square of the structure factor.

**Sublimation pressure** - The pressure of a gas in equilibrium with a solid at a specified temperature.

**Sulfides** - Compounds having the structure  $\text{RSR}$  (R not equal to H). Such compounds were once called thioethers. In an inorganic sense, salts or other derivatives of hydrogen sulfide. [5]

**Sulfones** - Compounds having the structure,  $\text{RS(=O)}_2\text{R}$  (R not equal to H), e.g.  $\text{C}_2\text{H}_5\text{S(=O)}_2\text{CH}_3$ , ethyl methyl sulfone. [5]

**Sulfonic acids** -  $\text{HS(=O)}_2\text{OH}$ , sulfonic acid, and its S-hydrocarbyl derivatives. [5]

**Sulfoxides** - Compounds having the structure  $\text{R}_2\text{S=O}$  (R not equal to H), e.g.  $\text{Ph}_2\text{S=O}$ , diphenyl sulfoxide. [5]

**Superconductor** - A material that experiences a nearly total loss of electrical resistivity below a critical temperature  $T_c$ . The effect can occur in pure metals, alloys, semiconductors, organic compounds, and certain inorganic solids.

**Superfluid** - A fluid with near-zero viscosity and extremely high thermal conductivity. Liquid helium exhibits these properties below 2.186 K (the  $\lambda$  point).

**Supernova** - A star in the process of exploding because of instabilities which follow the exhaustion of its nuclear fuel.

**Surface analysis by laser ionization (SALI)** - See Techniques for Materials Characterization, page 12-1.

**Surface tension ( $\gamma, \sigma$ )**\* - The force per unit length in the plane of the interface between a liquid and a gas, which resists an increase in the area of that surface. It can also be equated to the surface Gibbs energy per unit area.

**Surfactant** - A substance which lowers the surface tension of the medium in which it is dissolved, and/or the interfacial tension with other phases, and accordingly is positively adsorbed at the liquid-vapor or other interfaces. [3]

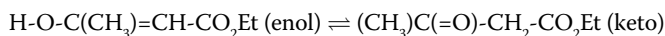
**Susceptance ( $B$ )** - Imaginary part of admittance. [1]

**Svedberg** - A non-SI unit of time, used to express sedimentation coefficients, equal to  $10^{-13}$  s.

**Syndiotactic macromolecule** - A tactic macromolecule, essentially comprising alternating enantiomeric configurational base units which have chiral or prochiral atoms in the main chain in a unique arrangement with respect to their adjacent constitutional units. In this case the repeating unit consists of two configurational base units that are enantiomeric. [8]

**Tacticity** - The orderliness of the succession of configurational repeating units of a macromolecule or oligomer molecule. In a tactic macromolecule essentially all the configurational repeating units are identical with respect to directional sense. See Configurational repeating unit, Isotactic, Syndiotactic. [8]

**Tautomerism** - Isomerism of the general form  $\text{G-X-Y=Z} \rightleftharpoons \text{X=Y-Z-G}$ , where the isomers (called tautomers) are readily interconvertible; the atoms connecting the groups X, Y, Z are typically any of C, H, O, or S, and G is a group which becomes an electrofuge (i.e., a group that does not carry away the bonding electron pair when it leaves its position in the molecule) or nucleofuge (a group that does carry away the bonding electrons when leaving) during isomerization. The commonest case, when the electrofuge is  $\text{H}^+$ , is also known as prototropy. A common example, written so as to illustrate the general pattern given above, is keto-enol tautomerism, such as



In some cases the interconversion rate between tautomers is slow enough to permit isolation of the separate keto and enol forms. [5]

**Tensile strength**\* - In tensile testing, the ratio of maximum load a body can bear before breaking to original cross-sectional area. Also called ultimate strength. [11]

**Terpenes** - Hydrocarbons of biological origin having carbon skeletons formally derived from isoprene [ $\text{CH}_2=\text{C}(\text{CH}_3)\text{CH}=\text{CH}_2$ ]. [5]

**Terpenoids** - Natural products and related compounds formally derived from isoprene units. They contain oxygen in various functional groups. The skeleton of terpenoids may differ from strict additivity of isoprene units by the loss or shift of a methyl (or other) group. [5]

**Tesla ( $T$ )**\* - The SI unit of magnetic flux density ( $B$ ), equal to  $\text{Vs/m}^2$ . [1]

**Thermal conductivity**\* - Rate of heat flow divided by area and by temperature gradient. [1]

**Thermal diffusivity** - Thermal conductivity divided by density and by specific heat capacity at constant pressure. [1]

**Thermal expansion coefficient ( $\alpha$ )**\* - The linear expansion coefficient is defined by  $\alpha_l = (1/l)(dl/dT)$ ; the volume expansion coefficient by  $\alpha_v = (1/V)(dV/dT)$ . [1]

**Thermionic emission** - The emission of electrons from a solid as a result of heat. The effect requires a high enough temperature to impart sufficient kinetic energy to the electrons to exceed the work function of the solid.

**Thermodynamic laws** - The foundation of the science of thermodynamics:

**First law:** The internal energy of an isolated system is constant; if energy is supplied to the system in the form of heat  $dq$  and work  $dw$ , then the change in energy  $dU = dq + dw$ .

**Second law:** No process is possible in which the only result is the transfer of heat from a reservoir and its complete conversion to work.

**Third law:** The entropy of a perfect crystal approaches zero as the thermodynamic temperature approaches zero.

**Thermoelectric power** - For a bar of a pure material whose ends are at different temperatures, the potential difference divided by the difference in temperature of the ends. See also Seebeck effect.

**Thermogravimetric analysis (TGA)** - See Techniques for Materials Characterization, page 12-1.

**Thermosphere** - The layer of the earth's atmosphere extending from the top of the mesosphere (typically 80–90 km above the surface) to about 500 km. It is characterized by a rapid increase in temperature with increasing altitude up to about 200 km, followed by a leveling off in the 300–500 km region.

**Thiols** - Compounds having the structure  $\text{RSH}$  (R not equal to H). Also known by the term mercaptans (abandoned by IUPAC); e.g.  $\text{CH}_3\text{CH}_2\text{SH}$ , ethanethiol. [5]

**Thomson coefficient ( $\mu, \tau$ )** - The heat power developed in the Thomson effect (whereby heat is evolved in a conductor when a current is flowing in the presence of a temperature gradient), divided by the current and the temperature difference. [1]

**Tonne (t)** - An alternative name for megagram (1000 kg). [1]

**Torque ( $T$ )** - For a force  $F$  that produces a torsional motion,  $T = r \times F$ , where  $r$  is a vector from some reference point to the point of application of the force.

**Torr** - A non-SI unit of pressure, equal to 133.322 Pa. The name is generally considered interchangeable with millimeter of mercury.

**Townsend coefficient** - In a radiation counter, the number of ionizing collisions by an electron per unit path length in the direction of an applied electric field.

**Transducer** - Any device that converts a signal from acoustical, optical, or some other form of energy into an electrical signal (or vice versa) while preserving the information content of the original signal.

**Transistor** - A voltage amplifier using controlled electron currents inside a semiconductor.

**Transition metals** - Elements characterized by a partially filled  $d$  subshell. The First Transition Series comprises Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu. The Second and Third Transition Series include the lanthanides and actinides, respectively. [7]

**Transition probability\*** - See Einstein transition probability.

**Transmittance ( $\tau$ )** - Ratio of the radiant or luminous flux at a given wavelength that is transmitted to that of the incident radiation. Also called transmission factor. [1]

**Tribology** - The study of frictional forces between solid surfaces.

**Triple point\*** - The point in  $p, T$  space where the solid, liquid, and gas phases of a substance are in thermodynamic equilibrium. The corresponding temperature and pressure are called the triple point temperature and triple point pressure.

**Troposphere** - The lowest part of the earth's atmosphere, extending to 10-15 km above the surface. It is characterized by a decrease in temperature with increasing altitude. The exact height varies with latitude and season.

**Tunnel diode** - A device involving a p-n junction in which both sides are so heavily doped that the Fermi level on the p-side lies in the valence band and on the n-side in the conduction band. This leads to a current-voltage curve with a maximum, so that the device exhibits a negative resistance in some regions.

**Ultraviolet photoelectron spectroscopy (UPS)** - See Techniques for Materials Characterization, page 12-1.

**Umklapp process** - A process involving the interaction of three or more waves (lattice or electron) in a solid in which the sum of the wave vectors does not equal zero.

**Unified atomic mass unit ( $u$ )\*** - A unit of mass used in atomic, molecular, and nuclear science, defined as the mass of one atom of  $^{12}\text{C}$  divided by 12. Its approximate value is  $1.66054 \times 10^{-27}$  kg. [1]

**Universal time ( $t_u$ , UT)** - Mean solar time counted from midnight at the Greenwich meridian. Also called Greenwich mean time (GMT). The interval of mean solar time is based on the average, over one year, of the time between successive transits of the sun across the observer's meridian.

**Vacancy** - A missing atom or ion in a crystal lattice.

**Van Allen belts** - Two toroidal regions above the earth's atmosphere containing protons and electrons. The outer belt at about 25,000 km above the surface is probably of solar origin. The inner belt at about 3000 km contains more energetic particles from outside the solar system.

**Van der Waals' equation\*** - An equation of state for fluids which takes the form:

$$pV_m = RT \left( \frac{1}{V_m - b} - \frac{a}{V_m^2} \right)$$

where  $p$  is pressure,  $V_m$  is molar volume,  $T$  is temperature,  $R$  is the molar gas constant, and  $a$  and  $b$  are characteristic parameters of the substance which describe the effect of attractive and repulsive intermolecular forces, respectively.

**Van der Waals' force** - The weak attractive force between two molecules which arises from electric dipole interactions. It can lead to the formation of stable but weakly bound dimer molecules or clusters.

**Van't Hoff equation** - The equation expressing the temperature dependence of the equilibrium constant  $K$  of a chemical reaction:

$$\frac{d \ln K}{dT} = \frac{\Delta_r H^\circ}{RT^2}$$

where  $\Delta_r H^\circ$  is the standard enthalpy of reaction,  $R$  the molar gas constant, and  $T$  the temperature. Also called van't Hoff isochore.

**Vapor pressure\*** - The pressure of a gas in equilibrium with a liquid (or, in some usage, a solid) at a specified temperature.

**Varistor** - A device that utilizes the properties of certain metal oxides with small amounts of impurities, which show abrupt nonlinearities at specific voltages where the material changes from a semiconductor to an insulator.

**Velocity ( $v$ )** - Rate of change of distance with time.

**Verdet constants ( $V$ )\*** - Angle of rotation of a plane polarized light beam passing through a medium in a magnetic field, divided by the field strength and by the path length.

**Virial equation of state\*** - An equation relating the pressure  $p$ , molar volume  $V_m$ , and temperature  $T$  of a real gas in the form of an expansion in powers of the molar volume, viz.,  $pV_m = RT(1 + BV_m^{-1} + CV_m^{-2} + \dots)$ , where  $R$  is the molar gas constant.  $B$  is called the second virial coefficient,  $C$  the third virial coefficient, etc. The virial coefficients are functions of temperature.

**Viscosity ( $\eta$ )\*** - The proportionality factor between shear rate and shear stress, defined through the equation  $F = \eta A(dv/dx)$ , where  $F$  is the tangential force required to move a planar surface of area  $A$  at velocity  $v$  relative to a parallel surface separated from the first by a distance  $x$ . Sometimes called dynamic or absolute viscosity. The term kinematic viscosity (symbol  $\nu$ ) is defined as  $\eta$  divided by the mass density.

**Volt ( $V$ )\*** - The SI unit of electric potential, equal to  $W/A$ . [1]

**Volume fraction ( $\phi$ )** - Defined as  $V_j/\sum_i V_i$ , where  $V_j$  is the volume of the specified component and the  $V_i$  are the volumes of all the components of a mixture prior to mixing. [2]

**Watt ( $W$ )\*** - The SI unit of power, equal to  $J/s$ . [1]

**Wave function** - A function of the coordinates of all the particles in a quantum mechanical system (and, in general, of time) which fully describes the state of the system. The product of the wave function and its complex conjugate is proportional to the probability of finding a particle at a particular point in space.

**Weak interaction** - The weak forces (order of  $10^{-12}$  of the strong interaction) between elementary particles which are responsible for beta decay and other nuclear effects.

**Weber ( $Wb$ )\*** - The SI unit of magnetic flux, equal to  $V \cdot s$ . [1]

**Weber number ( $We$ )** - A dimensionless quantity used in fluid mechanics, defined by  $We = \rho v^2 l / \gamma$ , where  $\rho$  is density,  $v$  is velocity,  $l$  is length, and  $\gamma$  is surface tension. [2]

**Weight** - That force which, when applied to a body, would give it an acceleration equal to the local acceleration of gravity. [1]

**Wiedeman-Franz law** - The law stating that the thermal conductivity  $k$  and electrical conductivity  $\sigma$  of a pure metal are related by  $k = L\sigma T$ , where  $T$  is the temperature and  $L$  (called the Lorenz ratio) has the approximate value  $2.45 \times 10^{-8} \text{ V}^2/\text{K}^2$ .

**Wien displacement law** - The relation, which can be derived from the Planck formula for black body radiation, that



$\lambda_{\max} T = 0.0028978 \text{ m K}$ , where  $\lambda_{\max}$  is the wavelength of maximum radiance at temperature  $T$ .

**Wigner-Seitz method** - A method of calculating electron energy levels in a solid using a model in which each electron is subject to a spherically symmetric potential.

**Wittig reagents** - See phosphonium ylides.

**Work ( $W$ )** - Force multiplied by the displacement in the direction of the force. [1]

**Work function ( $\Phi$ )\*** - The energy difference between an electron at rest at infinity and an electron at the Fermi level in the interior of a substance. It is thus the minimum energy required to remove an electron from the interior of a solid to a point just outside the surface. [1]

**X unit ( $X$ )** - A unit of length used in x-ray crystallography, equal to approximately  $1.002 \times 10^{-13} \text{ m}$ .

**X-ray photoelectron spectroscopy (XPS)** - See Techniques for Materials Characterization, page 12-1.

**Yield strength** - The stress at which a material exhibits a specified deviation (often chosen as 0.2% for metals) from proportionality of stress and strain. [11]

**Young's modulus ( $E$ )** - In tension or compression of a body below its elastic limit, the ratio of stress to corresponding strain. Since strain is normally expressed on a fractional basis, Young's modulus has dimensions of pressure. Also called elastic modulus. [11]

**Zeeman effect** - The splitting of an energy level of an atom or molecule, and hence a splitting of spectral lines arising from that level, as a result of the application of an external magnetic field.

**Zener diode** - A control device utilizing a p-n junction with a well defined reverse-bias avalanche breakdown voltage.

**Zeotrope** - A liquid mixture that shows no maximum or minimum when vapor pressure is plotted against composition at constant temperature. See Azeotrope.

**Zero-point energy** - The energy possessed by a quantum mechanical system as a result of the uncertainty principle even when it is in its lowest energy state; e.g., the difference between the lowest energy level of a harmonic oscillator and the minimum in the potential well.

**Zeta potential ( $\zeta$ )** - The electric potential at the surface of a colloidal particle relative to the potential in the bulk medium at a long distance. Also called electrokinetic potential.

**Zwitterions** - Neutral compounds having formal unit electrical charges of opposite sign. Some chemists restrict the term to compounds with the charges on non-adjacent atoms. Sometimes referred to as inner salts, dipolar ions (a misnomer). [5]