

GLOSSARY

This glossary has the definitions of the key terms that were marked in boldface throughout the chapters plus a few additional terms. The numbers in parentheses that follow the definitions are the numbers of the sections in which the glossary entries received their principal discussions.

A

Absolute Zero: 0 K, $-273.15\text{ }^{\circ}\text{C}$. Nature's lowest temperature. (1.5, 10.3)

Acceptor: A Lewis acid; the central metal ion in a complex ion. (17.4, 21.5)

Accuracy: Freedom from error. The closeness of a measurement to the true value. (1.6)

Acid: *Arrhenius theory:* A substance that produces hydronium ions (hydrogen ions) in water. (4.3)

Bronsted theory: A proton donor. (15.1)

Lewis theory: An electron-pair acceptor. (15.3)

Acid–Base Indicator: A dye with one color in acid and another color in base. (4.3, 4.8)

Acid–Base Neutralization: The reaction of an acid with a base. (4.3, 15.3)

Acid Ionization Constant (K_a):

$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$$

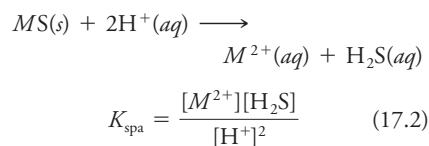
for the equilibrium,

$$\text{HA} \rightleftharpoons \text{H}^+ + \text{A}^-, \quad (16.1)$$

Acid Rain: Rain made acidic by dissolved sulfur and nitrogen oxides.

Acid Salt: A salt of a partially neutralized polyprotic acid, for example, NaHSO_4 or NaHCO_3 . (4.4)

Acid Solubility Product: The special solubility product expression for metal sulfides in dilute acid and related to the equation for their dissolving. For a divalent metal sulfide, MS ,



Acidic Anhydride: An oxide that reacts with water to make the solution acidic. (4.3)

Acidic Solution: An aqueous solution in which $[\text{H}^+] > [\text{OH}^-]$. (15.5)

Actinide Elements (Actinide Series): Elements 90–103. (2.3)

Activated Complex: The chemical species that exists with partly broken and partly formed bonds in the transition state. (13.5)

Activation Energy (E_a): The minimum kinetic energy that must be possessed by the reactants in order to give an effective collision (one that produces products). (13.5)

Activities: Effective concentrations which properly should be substituted into a mass action expression to satisfy the equilibrium law. The activity of a solid is defined as having a value of 1. (14.4)

Activity: For a radioactive material, the number of disintegrations per second. (20.6)

Activity Series: A list of metals in order of their reactivity as reducing agents. (5.4)

Actual Yield: See *Yield, Actual*.

Addition Compound: A molecule formed by the joining of two simpler molecules through formation of a covalent bond (usually a coordinate covalent bond). (8.6)

Addition Polymer: A polymer formed by the simple addition of one monomer unit to another, a process that continues over and over until a very long chain of monomer units is produced. (22.6)

Addition Reaction: The addition of a molecule to a double or triple bond. (22.2)

Adiabatic Change: A change within a system during which no energy enters or leaves the system. (6.3)

Alcohol: An organic compound whose molecules have the OH group attached to tetrahedral carbon. (2.6, 22.3)

Aldehyde: An organic compound whose molecules have the group $-\text{CH}=\text{O}$. (22.5)

Alkali Metals: The Group IA elements (except hydrogen)—lithium, sodium, potassium, rubidium, cesium, and francium. (2.3)

Alkaline Battery (Alkaline Dry Cell): A zinc–manganese dioxide galvanic cell of 1.54 V used commonly in flashlight batteries. (19.8)

Alkaline Earth Metals: The Group IIA elements—beryllium, magnesium, calcium, strontium, barium, and radium. (2.3)

Alkalis: (a) The alkali metals. (2.3)
(b) Hydroxides of the alkali metals; strong bases. (4.3)

Alkane: A hydrocarbon whose molecules have only single bonds. (2.6, 22.2)

Alkene: A hydrocarbon whose molecules have one or more double bonds. (22.2)

Alkyl Group: An organic group of carbon and hydrogen atoms related to an alkane but with one less hydrogen atom (e.g., CH_3- , methyl; CH_3CH_2- , ethyl). (22.2)

Alkyne: A hydrocarbon whose molecules have one or more triple bonds. (22.2)

Allotrope: One of two or more forms of an element. (21.2)

Allotropy: The existence of an element in two or more molecular or crystalline forms called allotropes. (21.2)

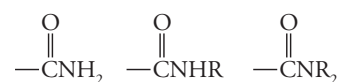
Alpha Particle (${}^4_2\text{He}$): The nucleus of a helium atom. (20.3)

Alpha Radiation: A high-velocity stream of alpha particles produced by radioactive decay. (20.3)

Alum: A double salt with the general formula $M^+M^{3+}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$, such as potassium alum: $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$.

Amalgam: A solution of a metal in mercury.

Amide: An organic compound whose molecules have any one of the following groups: (22.5)



α -Amino Acid: One of about 20 monomers of polypeptides. (22.7)

Amine: An organic compound whose molecules contain the group NH_2 , NHR , or NR_2 . (22.4)

Amorphous Solid: A noncrystalline solid. A glass. (11.9)

Ampere (A): The SI unit for electric current; one coulomb per second. (19.7)

Amphiprotic Compound: A compound that can act either as a proton donor or as a proton acceptor; an amphoteric compound. (15.1)

Amphoteric Compound: A compound that can react as either an acid or a base. (15.1)

Amplitude: The height of a wave, which is a measure of the wave's intensity. (7.1)

amu: See *Atomic Mass Unit*.

Angstrom (\AA): $1\text{ \AA} = 10^{-10}\text{ m} = 100\text{ pm} = 0.1\text{ nm}$. (7.8)

Anhydrous: Without water. (2.5)

Anion: A negatively charged ion. (2.8)

Anode: The positive electrode in a gas discharge tube. The electrode at which oxidation occurs during an electrochemical change. (19.1)

Antibonding Electrons: Electrons that occupy antibonding molecular orbitals. (9.7)

Antibonding Molecular Orbital: A molecular orbital that denies electron density to the space between nuclei and destabilizes a molecule when occupied by electrons. (9.7)

Anticodon: A triplet of bases on a tRNA molecule that pairs to a matching triplet—a codon—on an mRNA molecule during mRNA-directed polypeptide synthesis. (22.8)

Antimatter: Any particle annihilated by a particle of ordinary matter. (20.3)

Aqua Regia: One part concentrated nitric acid and three parts concentrated hydrochloric acid (by volume).

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Aqueous Solution: A solution that has water as the solvent.

Aromatic Compound: An organic compound whose molecules have the benzene ring system. (22.2)

Arrhenius Acid: See *Acid*.

Arrhenius Base: See *Base*.

Arrhenius Equation: An equation that relates the rate constant of a reaction to the reaction's activation energy. (13.6)

Association: The joining together of molecules by hydrogen bonds. (12.9)

Asymmetric Carbon Atom: A carbon atom that is bonded to four different groups and which is a chiral center. (22.1)

Atmosphere, Standard (atm): 101,325 Pa. The pressure that supports a column of mercury 760 mm high at 0 °C; 760 torr. (6.5, 10.2)

Atmospheric Pressure: The pressure exerted by the mixture of gases in our atmosphere. (6.5, 10.2)

Atom: A neutral particle having one nucleus; the smallest representative sample of an element. (1.2)

Atomic Mass: The average mass (in u) of the atoms of the isotopes of a given element as they occur naturally. (2.2)

Atomic Mass Unit (u): $1.6605402 \times 10^{-24}$ g; 1/12th the mass of one atom of carbon-12. Sometimes given the symbol amu. (2.2)

Atomic Number: The number of protons in a nucleus. (2.2)

Atomic Radiation: Radiation consisting of particles or electromagnetic radiation given off by radioactive elements. (20.3)

Atomic Spectrum: The line spectrum produced when energized or excited atoms emit electromagnetic radiation. (7.2)

Atomic Weight: See *Atomic Mass*.

Atomization Energy (ΔH_{atom}): The energy needed to rupture all of the bonds in one mole of a substance in the gas state and produce its atoms, also in the gas state. (18.10)

Aufbau Principle: A set of rules enabling the construction of an electron structure of an atom from its atomic number. (7.5)

Average: See *Mean*.

Avogadro's Number (Avogadro's Constant): 6.022×10^{23} ; the number of particles or formula units in one mole. (3.1)

Avogadro's Principle: Equal volumes of gases contain equal numbers of molecules when they are at identical temperatures and pressures. (10.4)

Axial Bonds: Covalent bonds oriented parallel to the vertical axis in a trigonal bipyramidal molecule. (9.1)

Azimuthal Quantum Number (ℓ): The quantum number ℓ . (See also *Secondary Quantum Number*.) (7.3)

B

Backbone (Polymer): The long chain of atoms in a polymer to which other groups are attached. (22.6)

Background Radiation: The atomic radiation from the natural radionuclides in the environment and from cosmic radiation. (20.6)

Balance: An apparatus for measuring mass. (1.5)

Balanced Equation: A chemical equation that has on opposite sides of the arrow the same number of each atom and the same net charge. (2.5, 3.4)

Band of Stability: The envelope that encloses just the stable nuclides in a plot of all nuclides constructed according to their numbers of neutrons versus their numbers of protons. (20.4)

Bar: The standard pressure for thermodynamic quantities; 1 bar = 10^5 pascals, 1 atm = 101,325 Pa. (6.5, 10.2)

Barometer: An apparatus for measuring atmospheric pressure. (10.2)

Base: *Arrhenius theory:* A substance that releases OH^- ions in water. (4.3)

Bronsted theory: A proton-acceptor. (15.1)

Lewis theory: An electron-pair acceptor. (15.3)

Base Ionization Constant, K_b :

$$K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]}$$
 for the equilibrium,



Base Units: The units of the fundamental measurements of the SI. (1.5)

Basic Anhydride: An oxide that can neutralize acid or that reacts with water to give OH^- . (4.3)

Basic Oxygen Process: A method to convert pig iron into steel. (21.4)

Basic Solution: An aqueous solution in which $[\text{H}^+] < [\text{OH}^-]$. (15.5)

Battery: One or more galvanic cells arranged to serve as a practical source of electricity.

Becquerel (Bq): 1 disintegration s^{-1} . The SI unit for the activity of a radioactive source. (20.6)

Bent Molecule (V-Shaped Molecule): A molecule that is nonlinear. (9.2)

Beta Particle (${}_{-1}^0\text{e}$): An electron emitted by radioactive decay. (20.3)

Beta Radiation: A stream of electrons produced by radioactive decay. (20.3)

Bidentate Ligand: A ligand that has two atoms that can become simultaneously attached to the same metal ion. (21.5)

Bimolecular Collision: A collision of two molecules. (13.7)

Binary Acid: An acid with the general formula H_nX , where X is a nonmetal. (4.4, 15.2)

Binary Compound: A compound composed of two different elements. (2.8)

Binding Energy, Nuclear: The energy equivalent of the difference in mass between an atomic nucleus and the sum of the masses of its nucleons. (20.2)

Biochemistry: The study of the organic substances in organisms. (22.7)

Biological Catalyst: Biological molecule such as an enzyme that catalyzes a chemical reaction. (13.8)

Black Phosphorus: An allotrope of phosphorus that has a layered structure. (21.2)

Blast Furnace: A structure in which iron ore is reduced to iron. (21.4)

Body-Centered Cubic (bcc) Unit Cell: A unit cell having identical atoms, molecules, or ions at the corners of a cube plus one more particle in the center of the cube. (11.9)

Boiling Point: The temperature at which the vapor pressure of the liquid equals the atmospheric pressure. (11.6)

Boiling Point Elevation: A colligative property of a solution by which the solution's boiling point is higher than that of the pure solvent. (12.7)

Bond Angle: The angle formed by two bonds that extend from the same atom. (9.1)

Bond Dipole: A dipole within a molecule associated with a specific bond. (9.3)

Bond Dissociation Energy: See *Bond Energy*.

Bond Distance: See *Bond Length*.

Bond Energy: The energy needed to break one mole of a particular bond to give electrically neutral fragments. (8.3, 18.10)

Bond Length: The distance between two nuclei that are held together by a chemical bond. (8.3)

Bond Order: The number of electron pairs shared between two atoms. The *net* number of pairs of bonding electrons. (8.6, 9.7)

$$\text{Bond order} = \frac{1}{2} \times (\text{no. of bonding } e^- - \text{no. of antibonding } e^-)$$

Bonding Domain: A region between two atoms that contains one or more electron pairs in bonds and that influences molecular shape. (9.2)

Bonding Electrons: Electrons that occupy bonding molecular orbitals. (9.7)

Bonding Molecular Orbital: A molecular orbital that introduces a buildup of electron density between nuclei and stabilizes a molecule when occupied by electrons. (9.7)

Boundary: The interface between a system and its surroundings across which energy or matter might pass. (6.3)

Boyle's Law: See *Pressure–Volume Law*.

Bragg Equation: $n\lambda = 2d \sin \theta$. The equation used to convert X-ray diffraction data into a crystal structure. (11.10)

Branched-Chain Compound: An organic compound in whose molecules the carbon atoms do not all occur one after another in a continuous sequence. (22.1)

Branching (Polymer): The formation of side chains (branches) along the main backbone of a polymer. (22.6)

Branching Step: A step in a chain reaction that produces more chain-propagating species than it consumes. (Facets of Chemistry 13.1)

Brine: An aqueous solution of sodium chloride, often with other salts. (19.8)

Brønsted Acid: See *Acid*.

Brønsted Base: See *Base*.

Brownian Motion: The random, erratic motions of colloiddally dispersed particles in a fluid. (2.6)

Buckminsterfullerene: The C_{60} molecule. Also called buckyball. (21.2)

Buckyball: See *Buckminsterfullerene*.

Buffer: (a) A pair of solutes that can keep the pH of a solution almost constant if either acid or base is added. (b) A solution containing such a pair of solutes. (16.5)

Buffer Capacity: A measure of how much strong acid or strong base is needed to change the pH of a buffer by some specified amount.

Buret: A long tube of glass usually marked in mL and 0.1 mL units and equipped with a stopcock for the controlled addition of a liquid to a receiving flask. (4.8)

By-product: The substances formed by side reactions. (3.6)

C

Calorie (cal): 4.184 J. The energy that will raise the temperature of 1.00 g of water from 14.5 to 15.5 °C. (In popular books on foods, the term *Calorie*, with a capital C, means 1000 cal or 1 kcal.) (6.1)

Calorimeter: An apparatus used in the determination of the heat of a reaction. (6.5)

Calorimetry: The science of measuring the quantities of heat that are involved in a chemical or physical change. (6.5)

Carbohydrates: Polyhydroxyaldehydes or polyhydroxyketones or substances that yield these by hydrolysis and that are obtained from plants or animals. (22.7)

Carbon Nanotube: Tubular carbon molecules that can be visualized as rolled up sheets of graphite (with hexagonal rings of carbon atoms) capped at each end by half of a spherical fullerene molecule. (21.2)

Carbon Ring: A series of carbon atoms arranged in a ring. (22.1)

Carbonyl Group: An organic functional group consisting of a carbon atom joined to an oxygen atom by a double bond; $C=O$. (22.5)

Carboxyl Group: $-CO_2H$. (8.3, 22.5)

Carboxylic Acid: An organic compound whose molecules have the carboxyl group $-CO_2H$. (8.3, 22.5)

Catalysis: Rate enhancement caused by a catalyst. (13.8)

Catalyst: A substance that in relatively small proportion accelerates the rate of a reaction without being permanently chemically changed. (13.8)

Catenation: The linking together of atoms of the same element to form chains.

Cathode: The negative electrode in a gas discharge tube. The electrode at which reduction occurs during an electrochemical change. (19.1)

Cathode Ray: A stream of electrons ejected from a hot metal and accelerated toward a positively charged site in a vacuum tube.

Cation: A positively charged ion. (2.8)

Cell Potential, E_{cell} : The potential (voltage) of a galvanic cell when no current is drawn from the cell. (19.2)

Cell Reaction: The overall chemical change that takes place in an electrolytic cell or a galvanic cell. (19.1)

Celsius Scale: A temperature scale on which water freezes at 0 °C and boils at 100 °C (at 1 atm) and that has 100 divisions called Celsius degrees between those two points. (1.5)

Centimeter (cm): 0.01 m. (1.5)

Chain Reaction: A self-sustaining change in which the products of one event cause one or more new events. (Facets of Chemistry 13.1, 20.8)

Change of State: Transformation of matter from one physical state to another. In thermochemistry, any change in a variable used to define the state of a particular system—a change in composition, pressure, volume, or temperature. (11.4)

Charge: The mixture of raw materials added to a blast furnace. (21.4)

Charles' Law: See *Temperature–Volume Law*.

Chelate: A complex ion containing rings formed by polydentate ligands. (21.5)

Chelate Effect: The extra stability found in complexes that contain chelate rings. (21.5)

Chemical Bond: The force of electrical attraction that holds atoms together in compounds. (2.6, 8 Introduction)

Chemical Change: A change that converts substances into other substances; a chemical reaction. (1.3)

Chemical Energy: The potential energy of chemicals that is transferred during chemical reactions. (6.1)

Chemical Equation: A before-and-after description that uses formulas and coefficients to represent a chemical reaction. (2.5)

Chemical Equilibrium: Dynamic equilibrium in a chemical system. (4.3, 14.1)

Chemical Formula: A formula written using chemical symbols and subscripts that describes the composition of a chemical compound or element. (2.5)

Chemical Kinetics: The study of rates of reaction. (13 Introduction)

Chemical Property: The ability of a substance, either by itself or with other substances, to undergo a change into new substances. (1.4)

Chemical Reaction: A change in which new substances (products) form from starting materials (reactants). (1.3)

Chemical Symbol: A formula for an element. (1.3)

Chemical Thermodynamics: See *Thermodynamics*.

Chemistry: The study of the compositions of substances and the ways by which their properties are related to their compositions. (1.1)

Chirality: The “handedness” of an object; the property of an object (like a molecule) that makes it unable to be superimposed onto a model of its own mirror image. (21.8, 22.1)

Cis Isomer: A stereoisomer whose uniqueness is in having two groups on the same side of some reference plane. (21.8, 22.2)

Clausius–Clapeyron Equation: The relationship between the vapor pressure, the temperature, and the molar heat of vaporization of a substance (where C is a constant). (Facets of Chemistry 11.1)

$$\ln P = \frac{\Delta H_{\text{vap}}}{RT} + C$$

Closed-End Manometer: See *Manometer*.

Closed System: A system that can absorb or release energy but not mass across the boundary between the system and its surroundings. (6.3)

Closest-Packed Structure: A crystal structure in which atoms or molecules are packed as efficiently as possible. (11.9)

Codon: An individual unit of hereditary instruction that consists of three, side by side, side chains on a molecule of mRNA. (22.8)

Coefficients: Numbers in front of formulas in chemical equations. (2.5)

Coinage Metals: Copper, silver, and gold.

Coke: Coal that has been strongly heated to drive off its volatile components and that is mostly carbon. (21.4)

Collapsing Atom Paradox: The paradox faced by classical physics that predicts a moving electron in an atom should emit

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energy and spiral into the nucleus. (7 Introduction)

Colligative Property: A property such as vapor pressure lowering, boiling point elevation, freezing point depression, and osmotic pressure whose physical value depends only on the ratio of the numbers of moles of solute and solvent particles and not on their chemical identities. (12.6)

Collision Theory: The rate of a reaction is proportional to the number of effective collisions that occur each second between the reactants. (13.5)

Combined Gas Law: See *Gas Law, Combined*.

Combustion: A rapid reaction with oxygen accompanied by a flame and the evolution of heat and light. (5.5)

Common Ion: The ion in a mixture of ionic substances that is common to the formulas of at least two. (16.5)

Common Ion Effect: The solubility of one salt is reduced by the presence of another having a common ion. (16.5, 17.1)

Competing Reaction: A reaction that reduces the yield of the main product by forming by-products (3.6)

Complex Ion (Complex): The combination of one or more anions or neutral molecules (ligands) with a metal ion. (17.4, 21.5)

Compound: A substance consisting of chemically combined atoms from two or more elements and present in a definite ratio. (1.3)

Compound Nucleus: An atomic nucleus carrying excess energy following its capture of some bombarding particle. (20.5)

Compressibility: Capable of undergoing a reduction in volume under increasing pressure. (10.1, 11.3)

Concentrated Solution: A solution that has a large ratio of the amounts of solute to solvent. (4.1)

Concentration: The ratio of the quantity of solute to the quantity of solution (or the quantity of solvent). (See *Molal Concentration, Molar Concentration, Mole Fraction, Percentage Concentration*.) (4.1)

Concentration Table: A part of the strategy for organizing data needed to make certain calculations, particularly any involving equilibria. (14.7, 16.2)

Conclusion: A statement that is based on what we think about a series of observations. (1.2)

Condensation: The change of a vapor to its liquid or solid state. (11.4)

Condensation Polymer: A polymer formed from monomers by splitting out a small molecule such as H_2O or CH_3OH . (22.6)

Condensation Polymerization: The process of forming a condensation polymer. (22.6)

Conformation: A particular relative orientation or geometric form of a flexible molecule. (9.5)

Conjugate Acid: The species in a conjugate acid–base pair that has the greater number of H^+ units. (15.1)

Conjugate Acid–Base Pair: Two substances (ions or molecules) whose formulas differ by only one H^+ unit. (15.1)

Conjugate Base: The species in a conjugate acid–base pair that has the fewer number of H^+ units. (15.1)

Conservation of Energy, Law of: See *Law of Conservation of Energy*.

Conservation of Mass–Energy, Law of: See *Law of Conservation of Mass–Energy*.

Continuous Spectrum: The electromagnetic spectrum corresponding to the mixture of frequencies present in white light. (7.2)

Contributing Structure: One of a set of two or more Lewis structures used in applying the theory of resonance to the structure of a compound. A resonance structure. (8.7)

Conversion Factor: A ratio constructed from the relationship between two units such as $2.54\text{ cm}/1\text{ in.}$, from $1\text{ in.} = 2.54\text{ cm}$. (1.7)

Cooling Curve: A graph showing how the temperature of a substance changes as heat is removed from it at a constant rate as the substance undergoes changes in its physical state. (11.7)

Coordinate Covalent Bond: A covalent bond in which both electrons originated from one of the joined atoms, but otherwise like a covalent bond in all respects. (8.6)

Coordination Compound (Coordination Complex): A complex or its salt. (17.4, 21.5)

Coordination Number: The number of donor atoms that surround a metal ion. (21.7)

Copolymer: A polymer made from two or more different monomers. (22.6)

Core Electrons: The inner electrons of an atom that are not exposed to the electrons of other atoms when chemical bonds form. (7.6)

Corrosion: The slow oxidation of metals exposed to air or water. (5.5)

Coulomb (C): The SI unit of electrical charge; the charge on 6.25×10^{18} electrons; the amount of charge that passes a fixed point of a wire conductor when a current of 1 A flows for 1 s. (19.2, 19.7)

Covalent Bond: A chemical bond that results when atoms share electron pairs. (8.3)

Covalent Crystal (Network Solid): A crystal in which the lattice positions are occupied by atoms that are covalently bonded to the atoms at adjacent lattice sites. (11.11)

Critical Mass: The mass of a fissile isotope above which a self-sustaining chain reaction occurs. (20.8)

Critical Point: The point at the end of a vapor pressure versus temperature curve for a liquid and that corresponds to the critical pressure and the critical temperature. (11.12)

Critical Pressure (P_c): The vapor pressure of a substance at its critical temperature. (11.12)

Critical Temperature (T_c): The temperature above which a substance cannot exist as a liquid regardless of the pressure. (11.12)

Cross-Link: A bridge formed between polymer strands. (22.6)

Crystal Field Splitting (Δ): The difference in energy between sets of d orbitals in a complex ion. (21.9)

Crystal Field Theory: A theory that considers the effects of the polarities or the charges of the ligands in a complex ion on the energies of the d orbitals of the central metal ion. (21.9)

Crystal Lattice: The repeating symmetrical pattern of atoms, molecules, or ions that occurs in a crystal. (11.9)

Cubic Closest Packing (ccp): Efficient packing of spheres with an A-B-C-A-B-C... alternating stacking of layers of spheres. (11.9)

Cubic Meter (m^3): The SI derived unit of volume. (1.5)

Curie (Ci): A unit of activity for radioactive samples, equal to 3.7×10^{10} disintegrations per second. (20.6)

D

Dalton: One atomic mass unit, u.

Dalton's Atomic Theory: Matter consists of tiny, indestructible particles called atoms. All atoms of one element are identical. The atoms of different elements have different masses. Atoms combine in definite ratios by atoms when they form compounds. (2.1)

Dalton's Law of Partial Pressures: See *Partial Pressures, Law of*.

Data: The information (often in the form of physical quantities) obtained in an experiment or other experience or from references. (1.2)

Debye: Unit used to express dipole moments. $1\text{ D} = 3.34 \times 10^{-30}\text{ C m}$ (coulomb meter). (8.4)

Decay Constant: The first-order rate constant for radioactive decay. (20.6)

Decimal Multipliers: Factors—exponentials of 10 or decimals—that are used to define larger or smaller SI units. (1.5)

Decomposition: A chemical reaction that changes one substance into two or more simpler substances. (1.3)

Dehydration: Removal of water from a substance.

Dehydration Reaction: Formation of a carbon–carbon double bond by removal

of the components of water from an alcohol. (22.3)

Deliquescent Compound: A compound able to absorb enough water from humid air to form a concentrated solution.

Delocalization Energy: The difference between the energy a substance would have if its molecules had no delocalized molecular orbitals and the energy it has because of such orbitals. (9.8)

Delocalized Molecular Orbital: A molecular orbital that spreads over more than two nuclei. (9.8)

ΔH_{fusion} : See *Molar Heat of Fusion*

$\Delta H_{\text{sublimation}}$: See *Molar Heat of Sublimation*

$\Delta H_{\text{vaporization}}$: See *Molar Heat of Vaporization*

Density: The ratio of an object's mass to its volume. (1.8)

Dependent Variable: The experimental variable of a pair of variables whose value is determined by the other, the independent variable.

Derived Unit: Any unit defined solely in terms of base units. (1.5)

Deuterium, ${}^2_1\text{H}$: The isotope of hydrogen with a mass number of 2. (20.8)

Diagonal Relationship: Physical or chemical properties that generally vary diagonally from one corner to the other in the periodic table (e.g., ionization energy, electron affinity, and electronegativity). (7.8)

Dialysis: The passage of small molecules and ions, but not species of a colloidal size, through a semipermeable membrane. (12.8)

Diamagnetism: The property experienced by a substance that contains no unpaired electrons whereby the substance is repelled weakly by a magnet. (7.4)

Diamond: A crystalline form of carbon in which each carbon atom is bonded tetrahedrally to four other carbon atoms. (21.2)

Diaphragm Cell: An electrolytic cell used to manufacture sodium hydroxide by the electrolysis of aqueous sodium chloride. (19.8)

Diatom Substance (Diatomic Molecule): A molecular substance made from two atoms. (2.5)

Diffraction: Constructive and destructive interference by waves. (7.3)

Diffraction Pattern: The image formed on a screen or a photographic film caused by the diffraction of electromagnetic radiation such as visible light or X rays. (11.10)

Diffusion: The spontaneous intermingling of one substance with another. (10.7)

Dilute Solution: A solution in which the ratio of the quantities of solute to solvent is small. (4.1)

Dilution: The process whereby a concentrated solution is made more dilute. (4.6)

Dimensional Analysis: See *Factor-Label Method*.

Dimer: Two monomer units joined by chemical bonds or intramolecular forces. (12.9)

Dipole (Electric): Partial positive and partial negative charges separated by a distance. (8.4)

Dipole–Dipole Attraction: Attraction between molecules that are dipoles. (11.2)

Dipole Moment (μ): The product of the sizes of the partial charges in a dipole multiplied by the distance between them; a measure of the polarity of a molecule. (8.4)

Diprotic Acid: An acid that can furnish two H^+ per molecule. (4.3)

Disaccharide: A carbohydrate whose molecules can be hydrolyzed to two monosaccharides. (22.7)

Dispersion Forces: Another term for London forces. (11.2)

Disproportionation: A redox reaction in which a portion of a substance is oxidized at the expense of the rest, which is reduced.

Dissociation: The separation of preexisting ions when an ionic compound dissolves or melts. (4.2)

Distorted Tetrahedron: A description of a molecule in which the central atom is surrounded by five electron pairs, one of which is a lone pair of electrons. The central atom is bonded to four other atoms. The structure is also said to have a seesaw shape. (9.2)

Dissymmetric: Lacking or deficient in symmetry. In a dissymmetric molecule the effects of the individual bond dipoles do not cancel, causing the molecule as a whole to be polar. (9.3)

DNA: Deoxyribonucleic acid; a nucleic acid that hydrolyzes to deoxyribose, phosphate ion, adenine, thymine, guanine, and cytosine, and that is the carrier of genes. (22.8)

DNA Double Helix: Two oppositely running strands of DNA held in a helical configuration by interstrand hydrogen bonds. (22.8)

Donor Atom: The atom on a ligand that makes an electron pair available in the formation of a complex. (17.4, 21.5)

Double Bond: (a) A covalent bond formed by sharing two pairs of electrons. (8.3) (b) A covalent bond consisting of one sigma bond and one pi bond. (9.6)

Double Replacement Reaction (Metathesis Reaction): A reaction of two salts in which cations and anions exchange partners (e.g., $\text{AgNO}_3 + \text{NaCl} \longrightarrow \text{AgCl} + \text{NaNO}_3$). (4.5)

Downs Cell: An electrolytic cell for the industrial production of sodium. (19.8)

Ductility: A metal's ability to be drawn (or stretched) into wire. (2.4)

Dynamic Equilibrium: A condition in which two opposing processes are occurring at equal rates. (4.3, 14.1)

E

ΔE : See *Internal Energy Change*.

Effective Collision: A collision between molecules that is capable of leading to a net chemical change. (13.5)

Effective Nuclear Charge: The net positive charge an outer electron experiences as a result of the partial screening of the full nuclear charge by core electrons. (7.8)

Effusion: The movement of a gas through a very tiny opening into a region of lower pressure. (10.7)

Effusion, Law of (Graham's Law): The rates of effusion of gases are inversely proportional to the square roots of their densities when compared at identical pressures and temperatures.

$$\text{Effusion rate} \propto \frac{1}{\sqrt{d}} \quad (\text{constant } P \text{ and } T)$$

where d is the gas density. (10.7)

Einstein Equation: $\Delta E = \Delta m_0 c^2$ where ΔE is the energy obtained when a quantity of rest mass, Δm_0 , is destroyed, or the energy lost when this quantity of mass is created. (20.1)

Electric Dipole: Two poles of electric charge separated by a distance. (8.4)

Electrochemical Change: A chemical change that is caused by or that produces electricity. (19 Introduction)

Electrochemistry: The study of electrochemical changes. (19 Introduction)

Electrolysis: The production of a chemical change by the passage of electricity through a solution that contains ions or through a molten ionic compound. (19.6)

Electrolysis Cell: An apparatus for electrolysis. (19.6)

Electrolyte: A compound that conducts electricity either in solution or in the molten state. (4.2)

Electrolytic Cell: See *Electrolysis Cell*.

Electrolytic Conduction: The transport of electrical charge by ions. (19.1)

Electromagnetic Spectrum: The distribution of frequencies of electromagnetic radiation among various types of such radiation—microwave, infrared, visible, ultraviolet, X, and gamma rays. (7.1)

Electromagnetic Wave (Electromagnetic Radiation): The successive series of oscillations in the strengths of electrical and magnetic fields associated with light, microwaves, gamma rays, ultraviolet rays, infrared rays, and the like. (7.1)

Electron (e^- or 0_1e): (a) A subatomic particle with a charge of $1-$ and mass of 0.0005486 u ($9.109383 \times 10^{-28} \text{ g}$) that occurs outside an atomic nucleus.

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The particle that moves when an electric current flows. (2.2) (b) A beta particle. (20.3)

Electron Affinity (EA): The energy change (usually expressed in kJ mol^{-1}) that occurs when an electron adds to an isolated gaseous atom or ion. (7.8)

Electron Capture: The capture by a nucleus of an orbital electron and that changes a proton into a neutron in the nucleus. (20.3)

Electron Cloud: Because of its wave properties, an electron's influence spreads out like a cloud around the nucleus. (7.7)

Electron Configuration: The distribution of electrons in an atom's orbitals. (7.5)

Electron Density: The concentration of the electron's charge within a given volume. (7.7)

Electron Domain: A region around an atom where one or more electron pairs are concentrated and which influences the shape of a molecule. (9.2)

Electron Domain Model: See *Valence Shell Electron Pair Repulsion Theory*.

Electron Pair Bond: A covalent bond. (8.3)

Electron Spin: The spinning of an electron about its axis that is believed to occur because the electron behaves as a tiny magnet. (7.4)

Electron Volt (eV): The energy an electron receives when it is accelerated under the influence of 1 V and equal to 1.6×10^{-19} J. (20.3)

Electronegativity: The relative ability of an atom to attract electron density toward itself when joined to another atom by a covalent bond. (8.4)

Electronic Structure: The distribution of electrons in an atom's orbitals. (7.5)

Electroplating: Depositing a thin metallic coating on an object by electrolysis. (19.8)

Element: A substance in which all of the atoms have the same atomic number. A substance that cannot be broken down by chemical reactions into anything that is both stable and simpler. (1.3, 2.2)

Elementary Process: One of the individual steps in the mechanism of a reaction. (13.7)

Elimination Reaction: The loss of a small molecule from a larger molecule as in the elimination of water from an alcohol. (22.3)

Emission Spectrum: See *Atomic Spectrum*.

Empirical Formula: A chemical formula that uses the smallest whole-number subscripts to give the proportions by atoms of the different elements present. (3.3)

Enantiomers: Stereoisomers whose molecular structures are related as an object to its mirror image but that cannot be superimposed. (21.8)

End Point: The moment in a titration when the indicator changes color and the titration is ended. (4.8, 16.7)

Endergonic: Descriptive of a change accompanied by an increase in free energy. (18.4)

Endothermic: Descriptive of a change in which a system's internal energy increases. (6.4)

Energy: Something that matter possesses by virtue of an ability to do work. (6.1)

Energy Density: For a galvanic cell, the ratio of the energy available to the volume of the cell. (19.8)

Energy Level: A particular energy an electron can have in an atom or a molecule. (7.2)

Enthalpy (H): The heat content of a system. (6.5, 18.1)

Enthalpy Change (ΔH): The difference in enthalpy between the initial state and the final state for some change. (6.5, 18.1)

Enthalpy Diagram: A graphical depiction of enthalpy changes following different paths from reactants to products. (6.7)

Enthalpy of Solution: See *Heat of Solution*.

Entropy (S): A thermodynamic quantity related to the number of equivalent ways the energy of a system can be distributed. The greater this number, the more probable is the state and the higher is the entropy. (18.3)

Entropy Change (ΔS): The difference in entropy between the initial state and the final state for some change. (18.3)

Enzyme: A catalyst in a living system and that consists of a protein. (13.8, 22.7)

Equation of State of an Ideal Gas: See *Gas Law, Ideal*.

Equatorial Bond: A covalent bond located in the plane perpendicular to the long axis of a trigonal bipyramidal molecule. (9.1)

Equilibrium: See *Dynamic Equilibrium*.

Equilibrium Constant, K: The value that the mass action expression has when the system is at equilibrium. (14.2)

Equilibrium Law: The mathematical equation for a particular equilibrium system that sets the mass action expression equal to the equilibrium constant. (14.2)

Equilibrium Vapor Pressure of a Liquid: The pressure exerted by a vapor in equilibrium with its liquid state. (11.5)

Equilibrium Vapor Pressure of a Solid: The pressure exerted by a vapor in equilibrium with its solid state. (11.5)

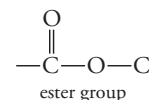
Equivalence: A relationship between two quantities expressed in different units. (1.8)

Equivalence Point: The moment in a titration when the number of equivalents of the

reactant added from a buret equals the number of equivalents of another reactant in the receiving flask. (16.7)

Error in a Measurement: The difference between a measurement and the "true" value we are trying to measure. (1.6)

Ester: An organic compound whose molecules have the ester group. (22.5)



Ether: An organic compound in whose molecules two hydrocarbon groups are joined to an oxygen. (22.3)

Ethyl Group: $\text{CH}_3\text{CH}_2\text{---}$. (22.2)

Evaporate: To change from a liquid to a vapor. (11.3)

Exact Number: A number obtained by a direct count or that results by a definition; and that is considered to have an infinite number of significant figures. (1.6)

Excess Reactant: The reactant left over once the limiting reactant is used up. (3.5)

Excited State: A term describing an atom or molecule where all of the electrons are not in their lowest possible energy levels. (7.2)

Exergonic: Descriptive of a change accompanied by a decrease in free energy. (18.4)

Exon: One of a set of sections of a DNA molecule (separated by introns) that, taken together, constitute a gene. (22.8)

Exothermic: Descriptive of a change in which energy leaves a system and enters the surroundings. (6.4)

Expansion Work: See *Pressure-Volume Work*.

Exponential Notation: See *Scientific Notation*.

Extensive Property: A property of an object that is described by a physical quantity whose magnitude is proportional to the size or amount of the object (e.g., mass or volume). (1.4)

F

Face-Centered Cubic (fcc) Unit Cell:

A unit cell having identical atoms, molecules, or ions at the corners of a cube and also in the center of each face of the cube. (11.9)

Factor-Label Method: A problem-solving technique that uses the correct cancellation of the units of physical quantities as a guide for the correct setting up of the solution to the problem. (1.7)

Fahrenheit Scale: A temperature scale on which water freezes at 32°F and boils at 212°F (at 1 atm) and between which points there are 180 degree divisions called Fahrenheit degrees. (1.5)

Family of Elements: See *Group*.

Faraday (F): One mole of electrons; 9.65×10^4 coulombs. (19.4)

Faraday Constant (F): 9.65×10^4 coulombs/mol e^- . (19.4)

Fatty Acid: One of several long-chain carboxylic acids produced by the hydrolysis (digestion) of a lipid. (22.7)

Film Dosimeter: A device used by people working with radioactive isotopes that records doses of atomic radiation by the darkening of photographic film. (20.6)

First Law of Thermodynamics: A formal statement of the law of conservation of energy. $\Delta E = q + w$. (6.5, 18.1)

First-Order Reaction: A reaction with a rate law in which rate = $k[A]^1$, where A is a reactant. (13.3)

Fissile Isotope: An isotope capable of undergoing fission following neutron capture. (20.8)

Fission: The breaking apart of atomic nuclei into smaller nuclei accompanied by the release of energy, and the source of energy in nuclear reactors. (20.2, 20.8)

Flotation: A method for concentrating sulfide ores of copper and lead by bubbling air through a slurry of oil-coated ore particles. The sulfides, but not soil or other rock particles, stick to the rising air bubbles and collect in the foam at the surface. (21.4)

Force: Anything that can cause an object to change its motion or direction. (1.5)

Formal Charge: The apparent charge on an atom in a molecule or polyatomic ion as calculated by a set of rules. (8.6)

Formation Constant (K_{form}): The equilibrium constant for an equilibrium involving the formation of a complex ion. Also called the stability constant. (17.4)

Formula: See *Chemical Formula*.

Formula Mass: The sum of the atomic masses (in u) of all of the atoms represented in a chemical formula. Often used with units of g mol^{-1} to represent masses of ionic substances. See also *Molar Mass*. (3.1)

Formula Unit: A particle that has the composition given by the chemical formula. (2.7)

Forward Reaction: In a chemical equation, the reaction as read from left to right. (4.3)

Fossil Fuels: Coal, oil, and natural gas.

Free Element: An element that is not combined with another element in a compound. (2.5)

Free Energy: See *Gibbs Free Energy* or *Standard Free Energy Change*

Free Energy Diagram: A plot of the changes in free energy for a multicomponent system versus the composition. (18.8)

Free Radical: An atom, molecule, or ion that has one or more unpaired electrons. (13.7, 22.6)

Freezing Point Depression: A colligative property of a liquid solution by which the freezing point of the solution is lower than that of the pure solvent. (12.7)

Frequency (ν): The number of cycles per second of electromagnetic radiation. (7.1)

Frequency Factor: The proportionality constant, A , in the Arrhenius equation. (13.6)

Fuel Cell: An electrochemical cell in which electricity is generated from the redox reactions of common fuels. (19.8)

Fullerene: An allotrope of carbon made of an extended joining together of five- and six-membered rings of carbon atoms. (21.2)

Functional Group: The group of atoms of an organic molecule that enters into a characteristic set of reactions that are independent of the rest of the molecule. (22.1)

Fusion: (a) Melting. (11.7) (b) The formation of atomic nuclei by the joining together of the nuclei of lighter atoms. (20.2, 20.8)

G

G: See *Gibbs Free Energy*.

ΔG : See *Gibbs Free Energy Change*.

ΔG° : See *Standard Free Energy Change*.

ΔG_f° : See *Standard Free Energy of Formation*.

Galvanic Cell: An electrochemical cell in which a spontaneous redox reaction produces electricity. (19.1)

Gamma Radiation: Electromagnetic radiation with wavelengths in the range of 1 \AA or less (the shortest wavelengths of the spectrum). (20.3)

Gangue: The unwanted rock and sand that is separated from an ore. (21.4)

Gas: One of the states of matter. A gas consists of rapidly moving widely spaced atomic or molecular sized particles. (1.4)

Gas Constant, Universal (R):
 $R = 0.0821 \text{ liter atm mol}^{-1} \text{ K}^{-1}$ or
 $R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$ (10.5)

Gas Law, Combined: For a given mass of gas, the product of its pressure and volume divided by its Kelvin temperature is a constant. (10.3)

$$PV/T = \text{a constant}$$

Gas Law, Ideal: $PV = nRT$. (10.5)

Gay-Lussac's Law: See *Pressure-Temperature Law*.

Geiger Counter: A device that detects beta and gamma radiation (20.6)

Genetic Code: The correlation of codons with amino acids. (22.8)

Geometric Isomer: One of a set of isomers that differ only in geometry. (22.2)

Geometric Isomerism: The existence of isomers whose molecules have identical atomic organizations but different geometries; cis-trans isomers. (21.8, 22.2)

Gibbs Free Energy (G): A thermodynamic quantity that relates enthalpy (H), entropy (S), and temperature (T) by the equation: (18.4)

$$G = H - TS$$

Gibbs Free Energy Change (ΔG): The difference given by: (18.4)

$$\Delta G = \Delta H - T\Delta S$$

Glass: Any amorphous solid. (11.9)

Glycogen: A polysaccharide that animals use to store glucose units for energy. (22.7)

Graham's Law: See *Effusion, Law of*.

Gram (g): 0.001 kg. (1.5)

Graphite: The most stable allotrope of carbon, consisting of layers of joined six-membered rings of carbon atoms. (21.2)

Gray (Gy): The SI unit of radiation absorbed dose. (20.6)

$$1 \text{ Gy} = 1 \text{ J kg}^{-1}$$

Greenhouse Effect: The retention of solar energy made possible by the ability of the greenhouse gases (e.g., CO_2 , CH_4 , H_2O , and the chlorofluorocarbons) to absorb outgoing radiation and reradiate some of it back to earth.

Ground State: The lowest energy state of an atom or molecule. (7.2)

Group: A vertical column of elements in the periodic table. (2.3)

H

ΔH : See *Enthalpy Change*.

ΔH_{atom} : See *Atomization Energy*.

ΔH_c : See *Heat of Combustion*.

ΔH° : See *Standard Heat of Reaction*.

ΔH_f° : See *Standard Heat of Formation*.

ΔH_{fusion} : See *Molar Heat of Fusion*.

ΔH_{soln} : See *Heat of Solution*.

$\Delta H_{\text{sublimation}}$: See *Molar Heat of Sublimation*.

$\Delta H_{\text{vaporization}}$: See *Molar Heat of Vaporization*.

Half-Cell: That part of a galvanic cell in which either oxidation or reduction takes place. (19.1)

Half-Life ($t_{1/2}$): The time required for a reactant concentration or the mass of a radionuclide to be reduced by half. (13.4)

Half-Reaction: A hypothetical reaction that constitutes exclusively either the oxidation or the reduction half of a redox reaction and

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in whose equation the correct formulas for all species taking part in the change are given together with enough electrons to give the correct electrical balance. (5.2)

Hall–Héroult Process: A method for manufacturing aluminum by the electrolysis of aluminum oxide in molten cryolite. (19.8)

Halogen Family: Group VIIA in the periodic table—fluorine, chlorine, bromine, iodine, and astatine. (2.3)

Hard Water: Water with dissolved Mg^{2+} , Ca^{2+} , Fe^{2+} , or Fe^{3+} ions at a concentration high enough (above 25 mg L^{-1}) to interfere with the use of soap. (Facets of Chemistry 4.1)

Heat: Energy that flows from a hot object to a cold object as a result of their difference in temperature. (6.1)

Heat Capacity: The quantity of heat needed to raise the temperature of an object by 1°C . (6.3)

Heat of Combustion: The heat evolved in the combustion of a substance. (6.5)

Heat of Formation, Standard: See *Standard Heat of Formation*.

Heat of Reaction: The heat exchanged between a system and its surroundings when a chemical change occurs in the system. (6.5)

Heat of Reaction at Constant

Pressure (q_p): The heat of a reaction in an open system, ΔH . (6.5, 18.1)

Heat of Reaction at Constant Volume (q_v): The heat of a reaction in a sealed vessel, like a bomb calorimeter, ΔE . (6.5)

Heat of Reaction, Standard: See *Standard Heat of Reaction*.

Heat of Solution (ΔH_{soln}): The energy exchanged between the system and its surroundings when one mole of a solute dissolves in a solvent to make a dilute solution. (12.2)

Heating Curve: A graph showing how the temperature of a substance changes as heat is added to it at a constant rate as the substance undergoes changes in its physical state. (11.7)

Henderson–Hasselbalch Equation:

$$\text{pH} = \text{p}K_a + \log \frac{[\text{A}^-]_{\text{initial}}}{[\text{HA}]_{\text{initial}}} \quad \text{or}$$

$$\text{pH} = \text{p}K_a + \log \frac{[\text{salt}]}{[\text{acid}]} \quad (16.5)$$

Henry's Law: See *Pressure–Solubility Law*.

Hertz (Hz): 1 cycle s^{-1} ; the SI unit of frequency. (7.1)

Hess's Law: For any reaction that can be written in steps, the standard heat of reaction is the same as the sum of the standard heats of reaction for the steps. (6.7)

Hess's Law Equation: For the change,
 $aA + bB + \dots \longrightarrow nN + mM + \dots$: (6.8)

$$\Delta H^\circ = \left(\begin{array}{l} \text{sum of } \Delta H_f^\circ \text{ of all} \\ \text{of the products} \end{array} \right) - \left(\begin{array}{l} \text{sum of } \Delta H_f^\circ \text{ of all} \\ \text{of the reactants} \end{array} \right)$$

Heterocyclic Compound: A compound whose molecules have rings that include one or more multivalent atoms other than carbon. (22.1)

Heterogeneous Catalyst: A catalyst that is in a different phase than the reactants and onto whose surface the reactant molecules are adsorbed and where they react. (13.8)

Heterogeneous Equilibrium: An equilibrium involving more than one phase. (14.4)

Heterogeneous Mixture: A mixture that has two or more phases with different properties. (1.3)

Heterogeneous Reaction: A reaction in which not all of the chemical species are in the same phase. (13.1, 14.4)

Heteronuclear Molecule: A molecule in which not all atoms are of the same element. (9.7)

Hexagonal Closest Packing (hcp): Efficient packing of spheres with an A-B-A-B-... alternating stacking of layers of spheres. (11.9)

High-Spin Complex: A complex ion or coordination compound in which there is the maximum number of unpaired electrons. (21.9)

Homogeneous Catalyst: A catalyst that is in the same phase as the reactants. (13.8)

Homogeneous Equilibrium: An equilibrium system in which all components are in the same phase. (14.4)

Homogeneous Mixture: A mixture that has only one phase and that has uniform properties throughout; a solution. (1.3)

Homogeneous Reaction: A reaction in which all of the chemical species are in the same phase. (13.1, 14.4)

Homonuclear Diatomic Molecule:

A diatomic molecule in which both atoms are of the same element. (9.7)

Hund's Rule: Electrons that occupy orbitals of equal energy are distributed with unpaired spins as much as possible among all such orbitals. (7.5)

Hybrid Atomic Orbitals: Orbitals formed by mixing two or more of the basic atomic orbitals of an atom and that make possible more effective overlaps with the orbitals of adjacent atoms than do ordinary atomic orbitals. (9.5)

Hydrate: A compound that contains molecules of water in a definite ratio to other components. (2.5)

Hydrated Ion: An ion surrounded by a cage of water molecules that are attracted by the charge on the ion. (4.2)

Hydration: The development in an aqueous solution of a cage of water molecules about ions or polar molecules of the solute. (12.1)

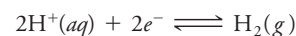
Hydration Energy: The enthalpy change associated with the hydration of gaseous ions or molecules as they dissolve in water. (12.2)

Hydride: (a) A binary compound of hydrogen. (2.6) (b) A compound containing the hydride ion (H^-).

Hydrocarbon: An organic compound whose molecules consist entirely of carbon and hydrogen atoms. (2.6, 22.2)

Hydrogen Bond: An extra strong dipole–dipole attraction between a hydrogen bound covalently to nitrogen, oxygen, or fluorine and another nitrogen, oxygen, or fluorine atom. (11.2)

Hydrogen Electrode: The standard of comparison for reduction potentials and for which $E_{\text{H}^+}^\circ$ has a value of 0.00 V at 25°C , when $P_{\text{H}_2} = 1 \text{ atm}$ and $[\text{H}^+] = 1 \text{ M}$ in the reversible half-cell reaction: (19.2)



Hydrolysis: A reaction with water

Hydrometer: A device for measuring specific gravity. (19.8)

Hydronium Ion: H_3O^+ . (4.3)

Hydrophilic Group: A polar molecular unit capable of having dipole–dipole attractions or hydrogen bonds with water molecules. (22.7)

Hydrophobic Group: A nonpolar molecular unit with no affinity for water. (22.7)

Hypertonic Solution: A solution that has a higher osmotic pressure than cellular fluids. (12.8)

Hypothesis: A tentative explanation of the results of experiments. (1.2)

Hypotonic Solution: A solution that has a lower osmotic pressure than cellular fluids. (12.8)

Ideal Gas: A hypothetical gas that obeys the gas laws exactly. (10.3)

Ideal Gas Law: $PV = nRT$. (10.5)

Ideal Solution: A hypothetical solution that would obey the vapor pressure–concentration law (Raoult's law) exactly. (12.2)

Immiscible: Mutually insoluble. Usually used to describe liquids that are insoluble in each other. (12.1)

Incompressible: Incapable of losing volume under increasing pressure. (11.3)

Independent Variable: The experimental variable of a pair of variables whose value is first selected and from which the value of the dependent variable then results.

Indicator: A chemical put in a solution being titrated and whose change in color signals the end point. (4.3, 15.5)

Induced Dipole: A dipole created when the electron cloud of an atom or a molecule is distorted by a neighboring dipole or by an ion. (11.2)

Inert Gas: Any of the noble gases—Group VIIIA of the periodic table. Any gas that has virtually no tendency to react. (2.3)

Initiation Step: The step in a chain reaction that produces reactive species that can start chain propagation steps. (Facets of Chemistry 13.1)

Inner Transition Elements: Members of the two long rows of elements below the main body of the periodic table—elements 58–71 and elements 90–103. (2.3)

Inorganic Compound: A compound made from any elements except those compounds of carbon classified as organic compounds. (2.9)

Instability Constant (K_{inst}): The reciprocal of the formation constant for an equilibrium in which a complex ion forms. (17.4)

Instantaneous Dipole: A momentary dipole in an atom, ion, or molecule caused by the erratic movement of electrons. (11.2)

Instantaneous Rate: The rate of reaction at any particular moment during a reaction. (13.2)

Integrated Rate Law: A rate law that relates concentration versus time. (13.4)

Intensive Property: A property whose physical magnitude is independent of the size of the sample, such as density or temperature. (1.4)

Intercalation: The insertion of small atoms or ions between layers in a crystal such as graphite. (19.8)

Interference Fringes: Pattern of light produced by waves that undergo diffraction. (7.3)

Intermolecular Forces (Intermolecular Attractions): Attractions *between* neighboring molecules. (11.2)

Internal Energy (E): The sum of all of the kinetic energies and potential energies of the particles within a system. (6.2, 18.1)

Internal Energy Change (ΔE): The difference in internal energy between the initial state and the final state for some change. (6.2, 6.5)

International System of Units (SI): The successor to the metric system of measurements that retains most of the units of the metric system and their decimal relationships but employs new reference standards. (1.5)

Intramolecular Forces: Forces of attraction within molecules; chemical bonds. (11.2)

Intron: One of a set of sections of a DNA molecule that separate the exon sections of a gene from each other. (22.8)

Inverse Square Law: The intensity of a radiation is inversely proportional to the square of the distance from its source. (20.6)

Ion: An electrically charged particle on the atomic or molecular scale of size. (2.7)

Ion–Dipole Attraction: The attraction between an ion and the charged end of a polar molecule. (11.2)

Ion–Electron Method: A method for balancing redox reactions that uses half-reactions. (5.2)

Ion–Induced Dipole Attraction: Attraction between an ion and a dipole induced in a neighboring molecule. (11.2)

Ion Pair: A more or less loosely associated pair of ions in a solution. (12.9)

Ion Product: The mass action expression for the solubility equilibrium involving the ions of a salt and equal to the product of the molar concentrations of the ions, each concentration raised to a power that equals the number of ions obtained from one formula unit of the salt. (17.1)

Ion Product Constant of Water (K_w):
 $K_w = [\text{H}^+][\text{OH}^-]$ (15.5)

Ionic Bond: The attractions between ions that hold them together in ionic compounds. (8.1)

Ionic Character: The extent to which a covalent bond has a dipole moment and is polarized. (8.4)

Ionic Compound: A compound consisting of positive and negative ions. (2.7)

Ionic Crystal: A crystal that has ions located at the lattice points. (11.11)

Ionic Equation: A chemical equation in which soluble strong electrolytes are written in dissociated or ionized form. (4.2)

Ionic Reaction: A chemical reaction in which ions are involved. (4.2)

Ionization Energy (IE): The energy needed to remove an electron from an isolated, gaseous atom, ion, or molecule (usually given in units of kJ mol^{-1}). (7.8)

Ionization Reaction: A reaction of chemical particles that produces ions. (4.3)

Ionizing Radiation: Any high-energy radiation—X rays, gamma rays, or radiations from radionuclides—that generates ions as it passes through matter. (20.6)

Isolated System: A system that cannot exchange matter or energy with its surroundings. (6.3)

Isomer: One of a set of compounds that have identical molecular formulas but different structures. (21.8)

Isomerism: The existence of sets of isomers. (21.8)

Isopropyl Group: $(\text{CH}_3)_2\text{CH}-$. (22.2)

Isotonic Solution: A solution that has the same osmotic pressure as cellular fluids. (12.8)

Isotopes: Atoms of the same element with different atomic masses. Atoms of the same element with different numbers of neutrons in their nuclei. (2.2)

IUPAC Rules: The formal rules for naming substances as developed by the International Union of Pure and Applied Chemistry. (2.3, 2.9)

J

Joule (J): The SI unit of energy. (6.1)

$$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$$

$$4.184 \text{ J} = 1 \text{ cal (exactly)}$$

K

K: See *Kelvin*.

K_a : See *Acid Ionization Constant*.

K_b : See *Base Ionization Constant*.

K_{form} : See *Formation Constant*.

K_{inst} : See *Instability Constant*.

K_{sp} : See *Solubility Product Constant*.

K_{spa} : See *Acid Solubility Product*.

K_w : See *Ion Product Constant of Water*.

K-Capture: See *Electron Capture*.

Kelvin (K): One degree on the Kelvin scale of temperature and identical in size to the Celsius degree. (1.5)

Kelvin Scale: The temperature scale on which water freezes at 273.15 K and boils at 373.15 K and that has 100 degree divisions called kelvins between these points.
 $\text{K} = ^\circ\text{C} + 273.15$. (1.5)

Ketone: An organic compound whose molecules have the carbonyl group ($\text{C}=\text{O}$) flanked by hydrocarbon groups. (22.5)

Kilocalorie (kcal): 1000 cal. (6.1)

Kilogram (kg): The base unit for mass in the SI and equal to the mass of a cylinder of platinum–iridium alloy kept by the International Bureau of Weights and Measures at Sevres, France. $1 \text{ kg} = 1000 \text{ g}$. (1.5)

Kilojoule (kJ): 1000 J. (6.1)

Kinetic Energy (KE): Energy of motion.
 $\text{KE} = (1/2)mv^2$. (6.1)

Kinetic Molecular Theory: Molecules of a substance are in constant motion with a distribution of kinetic energies at a given temperature. The average kinetic energy of the molecules is proportional to the Kelvin temperature. (6.2)

Kinetic Molecular Theory of Gases: A set of postulates used to explain the gas laws. A gas consists of an extremely large number of very tiny, very hard particles in constant, random motion. They have negligible volume and, between collisions, experience no forces between themselves. (10.8)

G-10 Glossary

L

Lanthanide Elements: Elements 58–71. (2.3)

Lattice: A symmetrical pattern of points arranged with constant repeat distances along lines oriented at constant angles. (11.9)

Lattice Energy: Energy released by the imaginary process in which isolated ions come together to form a crystal of an ionic compound. (8.1)

Law: A description of behavior (and not an *explanation* of behavior) based on the results of many experiments. (1.2)

Law of Combining Volumes: When gases react at the same temperature and pressure, their combining volumes are in ratios of simple whole numbers. (10.4)

Law of Conservation of Energy: The energy of the universe is constant; it can be neither created nor destroyed but only transferred and transformed. (6.1)

Law of Conservation of Mass: No detectable gain or loss in mass occurs in chemical reactions. Mass is conserved. (2.1)

Law of Conservation of Mass–Energy: The sum of all the mass in the universe and of all of the energy, expressed as an equivalent in mass (calculated by the Einstein equation), is a constant. (20.1)

Law of Definite Proportions: In a given chemical compound, the elements are always combined in the same proportion by mass. (2.1)

Law of Gas Effusion: See *Effusion, Law of*.

Law of Multiple Proportions: Whenever two elements form more than one compound, the different masses of one element that combine with the same mass of the other are in a ratio of small whole numbers. (2.1)

Law of Partial Pressures: See *Partial Pressures, Dalton's Law of*.

Law of Radioactive Decay:

$$\text{Activity} = -\frac{\Delta N}{\Delta t} = kN,$$

where ΔN is the change in the number of radioactive nuclei during the time span Δt , and k is the decay constant. (20.6)

Le Châtelier's Principle: When a system that is in dynamic equilibrium is subjected to a disturbance that upsets the equilibrium, the system undergoes a change that counteracts the disturbance and, if possible, restores the equilibrium. (11.8, 14.6)

Lead Storage Battery: A galvanic cell of about 2 V involving lead and lead(IV) oxide in sulfuric acid. (19.8)

Leclanché Cell: See *Zinc–Manganese Dioxide Cell*.

Lewis Acid: An electron-pair acceptor. (15.3)

Lewis Base: An electron-pair donor. (15.3)

Lewis Structure (Lewis Formula): A structural formula drawn with Lewis symbols and that uses dots and dashes to show the valence electrons and shared pairs of electrons. (8.3)

Lewis Symbol: The symbol of an element that includes dots to represent the valence electrons of an atom of the element. (8.2)

Ligand: A molecule or an anion that can bind to a metal ion to form a complex. (17.4, 21.5)

Like Dissolves Like Rule: Strongly polar and ionic solutes tend to dissolve in polar solvents and nonpolar solutes tend to dissolve in nonpolar solvents. (12.1)

Limiting Reactant: The reactant that determines how much product can form when nonstoichiometric amounts of reactants are used. (3.5)

Line Spectrum: An atomic spectrum. So named because the light emitted by an atom and focused through a narrow slit yields a series of lines when projected on a screen. (7.1)

Linear Molecule: A molecule all of whose atoms lie on a straight line. (9.1, 9.2)

Lipid: Any substance found in plants or animals that can be dissolved in nonpolar solvents. (22.7)

Liquid: One of the states of matter. A liquid consists of tightly packed atomic or molecular sized particles that can move past each other. (1.4)

Liter (L): 1 dm³. 1 L = 1000 mL = 1000 cm³. (1.5)

Lithium Ion Cell: A cell in which lithium ions are transferred between the electrodes through an electrolyte, while electrons travel through the external circuit. (19.8)

Lithium–Manganese Dioxide Battery: A battery that uses metallic lithium as the anode and manganese dioxide as the cathode. (19.8)

Localized Bond: A covalent bond in which the bonding pair of electrons is localized between two nuclei. (9.8)

London Forces (Dispersion Forces): Weak attractive forces caused by instantaneous dipole–induced dipole attractions. (11.2)

Lone Pair: A pair of electrons in the valence shell of an atom that is not shared with another atom. An unshared pair of electrons. (9.2)

Low-Spin Complex: A coordination compound or a complex ion with electrons paired as much as possible in the lower energy set of d orbitals. (21.9)

M

Macromolecule: A molecule whose molecular mass is very large. (22.6)

Magic Numbers: The numbers 2, 8, 20, 28, 50, 82, and 126, numbers whose significance

in nuclear science is that a nuclide in which the number of protons or neutrons equals a magic number has nuclei that are relatively more stable than those of other nuclides nearby in the band of stability. (20.4)

Magnetic Quantum Number (m_ℓ): A quantum number that can have values from $-\ell$ to $+\ell$. (7.3)

Main Group Elements: Elements in any of the A groups in the periodic table. (2.3)

Main Reaction: The desired reaction between the reactants as opposed to competing reactions that give by-products. (3.6)

Malleability: A metal's ability to be hammered or rolled into thin sheets. (2.4)

Manometer: A device for measuring the pressure within a closed system. The two types—*closed end* and *open end*—differ according to whether the operating fluid (e.g., mercury) is exposed at one end to the atmosphere. (10.2)

Mass: A measure of the amount of matter that there is in a given sample. (1.3)

Mass Action Expression: A fraction in which the numerator is the product of the molar concentrations of the products, each raised to a power equal to its coefficient in the equilibrium equation, and the denominator is the product of the molar concentrations of the reactants, each also raised to the power that equals its coefficient in the equation. (For gaseous reactions, partial pressures can be used in place of molar concentrations.) (14.2)

Mass Defect: For a given isotope, it is the mass that changed into energy as the nucleons gathered to form the nucleus, this energy being released from the system. (20.2)

Mass Number: The numerical sum of the protons and neutrons in an atom of a given isotope. (2.2)

Matter: Anything that has mass and occupies space. (1.3)

Mean: The sum of N numerical values divided by N ; the average. (1.6)

Measurement: A numerical observation. (1.5)

Mechanism of a Reaction: The series of individual steps (called elementary processes) in a chemical reaction that gives the net, overall change. (13.7)

Melting Point: The temperature at which a substance melts; the temperature at which a solid is in equilibrium with its liquid state. (11.4)

Meniscus: The interface between a liquid and a gas.

Metal: An element or an alloy that is a good conductor of electricity, that has a shiny surface, and that is malleable and ductile; an element that normally forms positive ions and has an oxide that is basic. (2.4, 4.3)

Metallic Conduction: Conduction of electrical charge by the movement of electrons. (19.1)

Metallic Crystal: A solid having positive ions at the lattice positions that are attracted to a "sea of electrons" that extends throughout the entire crystal. (11.11)

Metalloids: Elements with properties that lie between those of metals and nonmetals, and that are found in the periodic table around the diagonal line running from boron (B) to astatine (At). (2.4)

Metallurgy: The science and technology of metals, the procedures and reactions that separate metals from their ores, and the operations that create practical uses for metals. (21.4)

Metathesis Reaction: See *Double Replacement Reaction*.

Meter (m): The SI base unit for length. (1.5)

Methyl Group: CH₃—. (22.2)

Metric Units: A decimal system of units for physical quantities taken over by the SI. (1.5) See also *International System of Units*.

Millibar: 1 mb = 10⁻³ bar. (10.2)

Milliliter (mL): 0.001 L. 1000 mL = 1 L. (1.5)

Millimeter (mm): 0.001 m. 1000 mm = 1 m. (1.5)

Millimeter of Mercury (mm Hg): A unit of measurement that is proportional to pressure; equal to 1/760 atm. 760 mm Hg = 1 atm. 1 mm Hg = 1 torr. (10.2)

Miscible: Mutually soluble. (12.1)

Mixture: Any matter consisting of two or more substances physically combined in no particular proportion by mass. (1.3)

MO Theory: See *Molecular Orbital Theory*.

Model, Theoretical: A picture or a mental construction derived from a set of ideas and assumptions that are imagined to be true because they can be used to explain certain observations and measurements (e.g., the model of an ideal gas). (1.2)

Molal Boiling Point Elevation Constant (K_b): The number of degrees (°C) per unit of molal concentration that a boiling point of a solution is higher than that of the pure solvent. (12.7)

Molal Concentration (m): The number of moles of solute in 1000 g of solvent. (12.5)

Molal Freezing Point Depression Constant (K_f): The number of degrees (°C) per unit of molal concentration that a freezing point of a solution is lower than that of the pure solvent. (12.7)

Molality: The molal concentration. (12.5)

Molar Concentration (M): The number of moles of solute per liter of solution. The molarity of a solution. (4.6)

Molar Enthalpy of Solution: See *Heat of Solution*.

Molar Heat Capacity: The heat that can raise the temperature of 1 mol of a substance by 1 °C; the heat capacity per mole. (6.3)

Molar Heat of Fusion, ΔH_{fusion}: The heat absorbed when 1 mol of a solid melts to give 1 mol of the liquid at constant temperature and pressure. (11.7)

Molar Heat of Sublimation, ΔH_{sublimation}: The heat absorbed when 1 mol of a solid sublimates to give 1 mol of its vapor at constant temperature and pressure. (11.7)

Molar Heat of Vaporization, ΔH_{vaporization}: The heat absorbed when 1 mol of a liquid changes to 1 mol of its vapor at constant temperature and pressure. (11.7)

Molar Mass: The mass of one mole of a substance; the mass in grams equal to the sum of the atomic masses of the atoms in a substance, with units of g mol⁻¹. (3.1)

Molar Solubility: The number of moles of solute required to give 1 L of a saturated solution of the solute. (17.1)

Molar Volume, Standard: The volume of 1 mol of a gas at STP; 22.4 L mol⁻¹. (10.4)

Molarity: See *Molar Concentration*.

Mole (mol): The SI unit for amount of substance; the formula mass in grams of an element or compound; an amount of a chemical substance that contains 6.022 × 10²³ formula units. (3.1)

Mole Fraction: The ratio of the number of moles of one component of a mixture to the total number of moles of all components. (10.6)

Mole Percent (mol%): The mole fraction of a component expressed as a percent; mole fraction × 100%. (10.6)

Molecular Compound: A compound consisting of electrically neutral molecules. (2.6)

Molecular Crystal: A crystal that has molecules or individual atoms at the lattice points. (11.11)

Molecular Equation: A chemical equation that gives the full formulas of all of the reactants and products and that is used to plan an actual experiment. (4.2)

Molecular Formula: A chemical formula that gives the actual composition of one molecule. (2.6, 3.3)

Molecular Kinetic Energy: The energy associated with the motions of and within molecules as they fly about, spinning and vibrating. (6.2)

Molecular Mass: The sum of the atomic masses (in u) of all of the atoms represented in a molecular chemical substance; also called the *molecular weight*. May be used with units of g mol⁻¹. See also *Molar Mass*. (3.1)

Molecular Orbital (MO): An orbital that extends over two or more atomic nuclei. (9.7)

Molecular Orbital Theory (MO Theory): A theory about covalent bonds that views a molecule as a collection of positive nuclei surrounded by electrons distributed among a set of bonding, antibonding, and nonbonding orbitals of different energies. (9.4, 9.7)

Molecular Weight: See *Molecular Mass*.

Molecule: A neutral particle composed of two or more atoms combined in a definite ratio of whole numbers. (1.2, 2.6)

Monatomic: A particle consisting of just one atom. (2.9)

Monoclinic Sulfur: An allotrope of sulfur. (21.2)

Monodentate Ligand: A ligand that can attach itself to a metal ion by only one atom. (21.5)

Monomer: A substance of relatively low formula mass that is used to make a polymer. (22.6)

Monoprotic Acid: An acid that can furnish one H⁺ per molecule. (4.3)

Monosaccharide: A carbohydrate that cannot be hydrolyzed. (22.7)

N

Negative Charge: A type of electrical charge possessed by certain particles such as the electron. A negative charge is attracted by a positive charge and is repelled by another negative charge. (2.2)

Nernst Equation: An equation relating cell potential and concentration. (19.5)

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{RT}{n\mathcal{F}} \ln Q$$

Net Ionic Equation: An ionic equation from which spectator ions have been omitted. It is balanced when both atoms and electrical charge balance. (4.2)

Network Solid: See *Covalent Crystal*.

Neutralization, Acid–Base: See *Acid–Base Neutralization*.

Neutral Solution: A solution in which [H⁺] = [OH⁻]. (15.5)

Neutron (n, ¹0n): A subatomic particle with a charge of zero, a mass of 1.0086649 u (1.674927 × 10⁻²⁴ g) and that exists in all atomic nuclei except those of the hydrogen-1 isotope. (2.2)

Neutron Activation Analysis: A technique to analyze for trace impurities in a sample by studying the frequencies and intensities of the gamma radiations they emit after they have been rendered radioactive by neutron bombardment of the sample. (20.7)

Neutron Emission: A nuclear reaction in which a neutron is ejected. (20.3)

G-12 Glossary

Nicad Battery: A nickel–cadmium cell. (19.8)

Nickel–Cadmium Storage Cell: A galvanic cell of about 1.4 V involving the reaction of cadmium with nickel(IV) oxide. (19.8)

Nitrogen Family: Group VA in the periodic table—nitrogen, phosphorus, arsenic, antimony, and bismuth. (2.3)

Noble Gases: Group VIIIA in the periodic table—helium, neon, argon, krypton, xenon, and radon. (2.3)

Nodal Plane: A plane that can be drawn to separate opposing lobes of p , d , and f orbitals. (7.7)

Node: A place where the amplitude or intensity of a wave is zero. (7.3)

Nomenclature: The names of substances and the rules for devising names. (2.9)

Nonbonding Domain: A region in the valence shell of an atom that holds an unshared pair of electrons and that influences the shape of a molecule. (9.2)

Nonbonding Molecular Orbital: A molecular orbital that has no net effect on the stability of a molecule when populated with electrons and that is localized on one atom in the molecule. (9.7)

Nonelectrolyte: A compound that in its molten state or in solution cannot conduct electricity. (4.2)

Nonlinear Molecule: A molecule in which the atoms do not lie in a straight line. (9.2)

Nonmetal: A nonductile, nonmalleable, nonconducting element that tends to form negative ions (if it forms them at all) far more readily than positive ions and whose oxide is likely to show acidic properties. (2.4)

Nonmetallic Element: An element without metallic properties; an element with poor electrical conductivity. (2.4)

Nonoxidizing acid: An acid in which the anion is a poorer oxidizing agent than the hydrogen ion (e.g., HCl, H₂SO₄, H₃PO₄). (5.3)

Nonpolar Covalent Bond: A covalent bond in which the electron pair(s) are shared equally by the two atoms. (8.4)

Nonpolar Molecule: A molecule that has no net dipole moment. (9.3)

Nonvolatile: Descriptive of a substance with a high boiling point, a low vapor pressure, and that does not evaporate. (12.6)

Normal Boiling Point: The temperature at which the vapor pressure of a liquid equals 1 atm. (11.6)

Nuclear Binding Energy: See *Binding Energy, Nuclear*.

Nuclear Chain Reaction: A self-sustaining nuclear reaction. (20.8)

Nuclear Equation: A description of a nuclear reaction that uses the special symbols of isotopes, that describes some kind

of nuclear transformation or disintegration, and that is balanced when the sums of the atomic numbers on either side of the arrow are equal and the sums of the mass numbers are also equal. (20.3)

Nuclear Fission: See *Fission*.

Nuclear Fusion: See *Fusion*.

Nuclear Radiation: Alpha, beta, or gamma radiation emitted by radioactive nuclei. (20.3)

Nuclear Reaction: A change in the composition or energy of the nuclei of isotopes accompanied by one or more events such as the radiation of nuclear particles or electromagnetic energy, transmutation, fission, or fusion. (13.4, 20.3)

Nucleic Acids: Polymers in living cells that store and translate genetic information and whose molecules hydrolyze to give a sugar unit (ribose from ribonucleic acid, RNA, or deoxyribose from deoxyribonucleic acid, DNA), a phosphate, and a set of four of the five nitrogen-containing, heterocyclic bases (adenine, thymine, guanine, cytosine, and uracil). (22.8)

Nucleon: A proton or a neutron. (2.2)

Nucleus: The hard, dense core of an atom that holds the atom's protons and neutrons. (2.2)

Nylon 6,6: A polymer of a six-carbon dicarboxylic acid and a six-carbon diamine. (22.6)

O

Observation: A statement that accurately describes something we see, hear, taste, feel, or smell. (1.2)

Octahedral Molecule: A molecule in which a central atom is surrounded by six atoms located at the vertices of an imaginary octahedron. (9.1)

Octahedron: An eight-sided figure that can be envisioned as two square pyramids sharing the common square base. (9.1)

Octet (of Electrons): Eight electrons in the valence shell of an atom. (8.1)

Octet Rule: An atom tends to gain or lose electrons until its outer shell has eight electrons. (8.1, 8.3)

Odd–Even Rule: When the numbers of protons and neutrons in an atomic nucleus are both even, the isotope is more likely to be stable than when both numbers are odd. (20.4)

Open System: A system that can exchange both matter and energy with its surroundings. (6.3)

Open-End Manometer: See *Manometer*.

Optical Isomers: Stereoisomers other than geometric (cis–trans) isomers and that include substances that can rotate the plane of plane-polarized light. (21.8)

Orbital: An electron waveform with a particular energy and a unique set of values for the quantum numbers n , l , and m_l . (7.3)

Orbital Diagram: A diagram in which the electrons in an atom's orbitals are represented by arrows to indicate paired and unpaired spins. (7.5)

Order (of a Reaction): The sum of the exponents in the rate law is the *overall* order. Each exponent gives the order of the reaction with respect to a specific reactant. (13.3)

Ore: A substance in the earth's crust from which an element or compound can be extracted at a profit. (21.4)

Organic Acid: An acid that contains the

carboxyl group, $\text{—}\overset{\text{O}}{\parallel}{\text{C}}\text{—OH}$. (8.3, 22.6)

Organic Chemistry: The study of the compounds of carbon that are not classified as inorganic. (2.6, 22.1)

Organic Compound: Any compound of carbon other than a carbonate, bicarbonate, cyanide, cyanate, carbide, or gaseous oxide. (2.6)

Orthorhombic Sulfur: The most stable allotrope of sulfur, composed of S₈ rings. (21.2)

Osmosis: The passage of solvent molecules, but not those of solutes, through a semipermeable membrane; the limiting case of dialysis. (12.8)

Osmotic Membrane: A membrane that allows passage of solvent, but not solute particles. (12.8)

Osmotic Pressure: The back pressure that would have to be applied to prevent osmosis; one of the colligative properties. (12.8)

Outer Electrons: The electrons in the occupied shell with the largest principal quantum number. An atom's electrons in its valence shell. (7.6)

Outer Shell: The occupied shell in an atom having the highest principal quantum number (n). (7.6)

Overall Order of Reaction: The sum of the exponents on the concentration terms in a rate law. (13.3)

Overlap of Orbitals: A portion of two orbitals from different atoms that share the same space in a molecule. (9.4)

Oxidation: A change in which an oxidation number increases (becomes more positive). A loss of electrons. (5.1)

Oxidation Number: The charge that an atom in a molecule or ion would have if all of the electrons in its bonds belonged entirely to the more electronegative atoms; the oxidation state of an atom. (5.1)

Oxidation State: See *Oxidation Number*.

Oxidation–Reduction Reaction: A chemical reaction in which changes in oxidation numbers occur. (5.1)

Oxidizing Acid: An acid in which the anion is a stronger oxidizing agent than H⁺ (e.g., HClO₄, HNO₃). (5.3)

Oxidizing Agent: The substance that causes oxidation and that is itself reduced. (5.1)

Oxoacid: An acid that contains oxygen besides hydrogen and another element (e.g., HNO_3 , H_3PO_4 , H_2SO_4). (4.4, 15.2)

Oxoanion: The anion of an oxoacid (e.g., ClO_4^- , SO_4^{2-}). (15.2)

Oxygen Family: Group VIA in the periodic table—oxygen, sulfur, selenium, tellurium, and polonium. (2.3)

Ozone: A very reactive allotrope of oxygen with the formula O_3 . (21.2)

P

Pairing Energy: The energy required to force two electrons to become paired and occupy the same orbital. (21.9)

Paramagnetism: The weak magnetism of a substance whose atoms, molecules, or ions have one or more unpaired electrons. (7.4)

Partial Charge: Charges at opposite ends of a dipole that are fractions of full $1+$ or $1-$ charges. (8.4)

Partial Pressure: The pressure contributed by an individual gas to the total pressure of a gas mixture. (10.6)

Partial Pressure, Law of (Dalton's Law of Partial Pressures): The total pressure of a mixture of gases equals the sum of their partial pressures. (10.6)

Pascal (Pa): The SI unit of pressure equal to 1 newton m^{-2} ; $1 \text{ atm} = 101,325 \text{ Pa}$. (10.2)

Pauli Exclusion Principle: No two electrons in an atom can have the same values for all four of their quantum numbers. (7.4)

Peptide Bond: The amide linkage in molecules of polypeptides. (22.7)

Percentage by Mass (Percentage by Weight): (a) The number of grams of an element combined in 100 g of a compound. (3.3) (b) The number of grams of a substance in 100 g of a mixture or solution. (12.5)

Percentage Composition: A list of the percentages by weight of the elements in a compound. (3.3)

Percentage Concentration: A ratio of the amount of solute to the amount of solution expressed as a percent. (4.1)

Weight/weight: Grams of solute in 100 g of solution.

Weight/volume: Grams of solute in 100 mL of solution.

Volume/volume: Volumes of solute in 100 volumes of solution.

Percentage Ionization: An equation that quantifies the ionization of a substance in solution. (16.2)

Percentage ionization

$$= \frac{\text{amount of substance ionized}}{\text{initial amount of substance}} \times 100\%$$

Percentage Yield: The ratio (taken as a percent) of the mass of product obtained to the mass calculated from the reaction's stoichiometry. (3.6)

Period: A horizontal row of elements in the periodic table. (2.3)

Periodic Table: A table in which symbols for the elements are displayed in order of increasing atomic number and arranged so that elements with similar properties lie in the same column (group). (Inside front cover, 2.3)

pH: $-\log [\text{H}^+]$. (15.5)

Phase: A homogeneous region within a sample. (1.3)

Phase Diagram: A pressure–temperature graph on which are plotted the temperatures and the pressures at which equilibrium exists between the states of a substance. It defines regions of T and P in which the solid, liquid, and gaseous states of the substance can exist. (11.12)

Photon: A unit of energy in electromagnetic radiation equal to $h\nu$, where ν is the frequency of the radiation and h is Planck's constant. (7.1)

Photosynthesis: The use of solar energy by a plant to make high-energy molecules from carbon dioxide, water, and minerals. (6.4)

Physical Change: A change that is not accompanied by a change in chemical makeup. (1.3)

Physical Law: A relationship between two or more physical properties of a system, usually expressed as a mathematical equation, that describes how a change in one property affects the others.

Physical Property: A property that can be specified without reference to another substance and that can be measured without causing a chemical change. (1.4)

Physical State: The condition of aggregation of a substance's formula units, whether as a solid, a liquid, or a gas. (1.4)

Pi Bond (π Bond): A bond formed by the sideways overlap of a pair of p orbitals and that concentrates electron density into two separate regions that lie on opposite sides of a plane that contains an imaginary line joining the nuclei. (9.6)

Pig Iron: The impure iron made by a blast furnace. (21.4)

$\text{p}K_a$: $-\log K_a$. (16.1)

$\text{p}K_b$: $-\log K_b$. (16.1)

$\text{p}K_w$: $-\log K_w$. (15.5)

Planar Triangular Molecule: A molecule in which a central atom holds three other atoms located at the corners of an equilateral triangle and that includes the central atom at its center. (9.1)

Plane-Polarized Light: Light in which all the oscillations occur in one plane. (21.8)

Planck's Constant (h): The ratio of the energy of a photon to its frequency; $6.6260755 \times 10^{-34} \text{ J Hz}^{-1}$. (7.1)

pOH: $-\log [\text{OH}^-]$. (15.5)

Plasma: An electrically neutral, very hot gaseous mixture of nuclei and unattached electrons. (20.8)

Polar Covalent Bond (Polar Bond): A covalent bond in which more than half of the bond's negative charge is concentrated around one of the two atoms. (8.4)

Polar Molecule: A molecule in which individual bond polarities do not cancel and in which, therefore, the centers of density of negative and positive charges do not coincide. (8.4)

Polarizability: A term that describes the ease with which the electron cloud of a molecule or ion is distorted. (11.2)

Polyatomic Ion: An ion composed of two or more atoms. (2.8)

Polydentate Ligand: A ligand that has two or more atoms that can become simultaneously attached to a metal ion. (21.5)

Polymer: A substance consisting of macromolecules that have repeating structural units. (22.6)

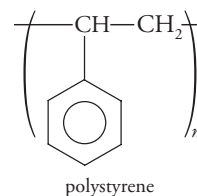
Polymerization: A chemical reaction that converts a monomer into a polymer. (22.6)

Polypeptide: A polymer of α -amino acids that makes up all or most of a protein. (22.7)

Polyprotic Acid: An acid that can furnish more than one H^+ per molecule. (4.3)

Polysaccharide: A carbohydrate whose molecules can be hydrolyzed to hundreds of monosaccharide molecules. (22.7)

Polystyrene: An addition polymer of styrene with the following structure. (22.6)



Position of Equilibrium: The relative amounts of the substances on both sides of the double arrows in the equation for an equilibrium. (4.3, 11.8)

Positive Charge: A type of electrical charge possessed by certain particles such as the proton. A positive charge is attracted by a negative charge and is repelled by another positive charge. (2.2)

Positron (β^+): A positively charged particle with the mass of an electron. (20.3)

Post-transition Metal: A metal that occurs in the periodic table immediately to the right of a row of transition elements. (2.8)

Potential: See *Volt*.

G-14 Glossary

Potential Energy (PE): Stored energy. (6.1)

Potential Energy Diagram: A diagram indicating the conversion of kinetic energy to potential energy and back again as atoms or molecules collide and then recoil in a chemical reaction. (13.5)

Precipitate: A solid that separates from a solution usually as the result of a chemical reaction. (4.1)

Precipitation Reaction: A reaction in which a precipitate forms. (4.1, 4.5)

Precision: How reproducible measurements are; the fineness of a measurement as indicated by the number of significant figures reported in the physical quantity. (1.6)

Pre-exponential Factor: A number or variable that precedes the exponential part of a number. (13.6)

Pressure: Force per unit area. (6.5, 10.2)

Pressure–Concentration Law: See *Vapor Pressure–Concentration Law*.

Pressure–Solubility Law (Henry’s Law): The concentration of a gas dissolved in a liquid at any given temperature is directly proportional to the partial pressure of the gas above the solution. (12.4)

Pressure–Temperature Law (Gay-Lussac’s Law): The pressure of a given mass of gas is directly proportional to its Kelvin temperature if the volume is kept constant. $P \propto T$. (10.3)

Pressure–Volume Law (Boyle’s Law): The volume of a given mass of a gas is inversely proportional to its pressure if the temperature is kept constant. $V \propto 1/P$. (10.3)

Pressure–Volume Work (P – V Work): The energy transferred as work when a system expands or contracts against the pressure exerted by the surroundings. At constant pressure, $w = -P\Delta V$. (6.5)

Primary Cell: A galvanic cell (battery) not designed to be recharged; it is discarded after its energy is depleted. (19.8)

Primitive Cubic Unit Cell: A cubic unit cell that has atoms only at the corners of the cell. (11.9)

Principal Quantum Number (n): The quantum number that defines the principal energy levels and that can have values of 1, 2, 3, . . . , ∞ . (7.3)

Products: The substances produced by a chemical reaction and whose formulas follow the arrows in chemical equations. (2.5)

Propagation Step: A step in a chain reaction for which one product must serve in a succeeding propagation step as a reactant and for which another (final) product accumulates with each repetition of the step. (Facets of Chemistry 13.1)

Property: A characteristic of matter. (1.4)

Propyl Group: $\text{CH}_3\text{CH}_2\text{CH}_2-$. (22.2)

Protein: A macromolecular substance found in cells that consists wholly or mostly of one or more polypeptides that often are combined with an organic molecule or a metal ion. (22.7)

Proton (p or H^+): (a) A subatomic particle, with a charge of $1+$ and a mass of 1.0072765 u ($1.6726217 \times 10^{-24} \text{ g}$) and that is found in atomic nuclei. (2.2) (b) The name often used for the hydrogen ion and symbolized as H^+ . (4.3)

Proton Acceptor: A Brønsted base. (15.1)

Proton Donor: A Brønsted acid. (15.1)

Pure Substance: An element or a compound. (1.3)

Q

Qualitative Analysis: The use of experimental procedures to determine what elements are present in a substance. (4.8)

Qualitative Observation: Observations that do not involve numerical information. (1.5)

Quanta: Packets of electromagnetic radiation now commonly called photons. (7.1)

Quantitative Analysis: The use of experimental procedures to determine the percentage composition of a compound or the percentage of a component of a mixture. (4.8)

Quantitative Observation: An observation involving a measurement and numerical information. (1.5)

Quantized: Descriptive of a discrete, definite amount as of *quantized energy*. (7.2)

Quantum: The energy of one photon. (7.1)

Quantum Mechanics: See *Wave Mechanics*.

Quantum Number: A number related to the energy, shape, or orientation of an orbital, or to the spin of an electron. (7.2)

Quantum Theory: The physics of objects that exhibit wave/particle duality.

R

R: See *Gas Constant, Universal*.

Rad (rd): A unit of radiation-absorbed dose and equal to 10^{-5} J g^{-1} or 10^{-2} Gy . (20.6)

Radioactive Decay: The change of a nucleus into another nucleus (or into a more stable form of the same nucleus) by the loss of a small particle or a gamma ray photon. (20.3)

Radioactive Disintegration Series: A sequence of nuclear reactions beginning with a very long-lived radionuclide and ending with a stable isotope of lower atomic number. (20.3)

Radioactivity: The emission of one or more kinds of radiation from an isotope with unstable nuclei. (20.3)

Radiological Dating: A technique for measuring the age of a geologic formation or an ancient artifact by determining the ratio of the concentrations of two isotopes, one radioactive and the other a stable decay product. (13.4, 20.7)

Radionuclide: A radioactive isotope. (20.3)

Raoult’s Law: See *Vapor Pressure–Concentration Law*.

Rare Earth Metals: The lanthanides. (2.3)

Rate: A ratio in which a unit of time appears in the denominator, for example, 40 miles hr^{-1} or $3.0 \text{ mol L}^{-1} \text{ s}^{-1}$. (13.2)

Rate Constant (k): The proportionality constant in the rate law; the rate of reaction when all reactant concentrations are 1 M . (13.3)

Rate Law: An equation that relates the rate of a reaction to the molar concentrations of the reactants raised to powers. (13.3)

Rate of Reaction: How quickly the reactants disappear and the products form and usually expressed in units of $\text{mol L}^{-1} \text{ s}^{-1}$. (13.1)

Rate-Determining Step (Rate-Limiting Step): The slowest step in a reaction mechanism. (13.7)

Reactant, Limiting: See *Limiting Reactant*.

Reactants: The substances brought together to react and whose formulas appear before the arrow in a chemical equation. (2.5)

Reaction Coordinate: The horizontal axis of a potential energy diagram of a reaction. (13.5)

Reaction Quotient (Q): The numerical value of the mass action expression. See *Mass Action Expression*. (14.2)

Reactivity: A description of the tendency for a substance to undergo reaction. For a metal, it is the tendency to undergo oxidation. (8.5)

Red Phosphorus: A relatively unreactive allotrope of phosphorus. (21.2)

Redox Reaction: An oxidation–reduction reaction. (5.1)

Reducing Agent: A substance that causes reduction and is itself oxidized. (5.1)

Reduction: A change in which an oxidation number decrease (becomes less positive and more negative). A gain of electrons. (5.1)

Reduction Potential: A measure of the tendency of a given half-reaction to occur as a reduction. (19.2)

Refining: The industrial conversion of a compound (ore) containing a desired element into a pure form of the element. (21.4)

Refractory: A high-melting heat-resistant material used to line furnaces and rocket engines, and to shield the space shuttle from the high heat of re-entry. (21.4)

Rem: A dose in rads multiplied by a factor that takes into account the variations that different radiations have in their damage-causing abilities in tissue. (20.6)

Replication: In nucleic acid chemistry, the reproductive duplication of DNA double helices prior to cell division. (22.8)

Representative Element: An element in one of the A groups in the periodic table. (2.3)

Resonance: A concept in which the actual structure of a molecule or polyatomic ion is represented as a composite or average of two or more Lewis structures, which are called the resonance or contributing structures (and none of which has real existence). (8.7)

Resonance Energy: The difference in energy between a substance and its principal resonance (contributing) structure. (8.7)

Resonance Hybrid: The actual structure of a molecule or polyatomic ion taken as a composite or average of the resonance or contributing structures. (8.7)

Resonance Structure: A Lewis structure that contributes to the hybrid structure in resonance-stabilized systems; a contributing structure (8.7)

Reverse Reaction: In a chemical equation, the reaction as read from right to left. (4.3)

Reversible Process: A process that occurs by an infinite number of steps during which the driving force for the change is just barely greater than the force that resists the change. (18.7)

Reversible Reaction: A reaction capable of proceeding in either the forward or reverse direction. (13.5, 14.7, 18.7)

Ring, Carbon: A closed-chain sequence of carbon atoms. (22.1)

RNA: Ribonucleic acid; a nucleic acid that gives ribose, phosphate ion, adenine, uracil, guanine, and cytosine when hydrolyzed. It occurs in several varieties. (22.8)

Roasting: Heating a sulfide ore in air to convert it to an oxide. (21.4)

Rock Salt Structure: The face-centered cubic structure observed for sodium chloride, which is also possessed by crystals of many other compounds. (11.9)

Root Mean Square Speed (rms Speed): The square root of the average of the speeds-squared of the molecules in a substance. (10.8)

Rydberg Equation: An equation used to calculate the wavelengths of all the spectral lines of hydrogen. (7.2)

S

Salt: An ionic compound in which the anion is not OH^- or O^{2-} and the cation is not H^+ . (4.2, 4.3)

Salt Bridge: A tube that contains an electrolyte that connects the two half-cells of a galvanic cell. (19.1)

Saponification: The reaction of an organic ester with a strong base to give an alcohol and the salt of the organic acid. (22.5)

Saturated Organic Compound: A compound whose molecules have only single bonds. (22.2)

Saturated Solution: A solution that holds as much solute as it can at a given temperature. A solution in which there is an equilibrium between the dissolved and the undissolved states of the solute. (4.1) (17.1)

Scanning Tunneling Microscope (STM): An instrument that enables the imaging of individual atoms on the surface of an electrically conducting specimen. (2.1)

Scientific Law: See *Law*.

Scientific Method: The observation, explanation, and testing of an explanation by additional experiments. (1.2)

Scientific Notation: The representation of a quantity as a decimal number between 1 and 10 multiplied by 10 raised to a power (e.g., 6.02×10^{23}). (1.5)

Scintillation Counter: A device for measuring nuclear radiation that contains a sensor composed of a substance called a *phosphor* that emits a tiny flash of light when struck by a particle of ionizing radiation. These flashes can be magnified electronically and automatically counted. (20.6)

Second Law of Thermodynamics: Whenever a spontaneous event takes place, it is accompanied by an increase in the entropy of the universe. (18.4)

Second-Order Reaction: A reaction with a rate law of the type: rate = $k[A]^2$ or rate = $k[A][B]$, where *A* and *B* are reactants. (13.3)

Secondary Cell: A galvanic cell (battery) designed for repeated use; it is able to be recharged. (19.8)

Secondary Quantum Number (ℓ): The quantum number whose values can be 0, 1, 2, . . . , ($n - 1$), where *n* is the principal quantum number. (7.3)

Seesaw Shaped Molecule: A description given to a molecule in which the central atom has five electron pairs in its valence shell, one of which is a lone pair and the others are used in bonds to other atoms. See also *Distorted Tetrahedron*. (9.2)

Selective Precipitation: A technique that uses differences in the solubilities of specific salts to separate ions from each other. (17.3)

Semiconductor: A substance that conducts electricity weakly. (2.4)

Shell: All of the orbitals associated with a given value of *n* (the principal quantum number). (7.3)

SI (International System of Units): The modified metric system adopted in 1960 by the General Conference on Weights and Measures. (1.5)

Side Reaction: A reaction that occurs simultaneously with another reaction (the main reaction) in the same mixture to produce by-products. (3.6)

Sievert (Sv): The SI unit for dose equivalent. The dose equivalent *H* is calculated from *D* (the dose in grays), *Q* (a measure of the effectiveness of the radiation at causing harm), and *N* (a variable that accounts for other modifying factors). $H = DQN$. (20.6)

Sigma Bond (σ Bond): A bond formed by the head-to-head overlap of two atomic orbitals and in which electron density becomes concentrated along and around the imaginary line joining the two nuclei. (9.6)

Significant Figures (Significant Digits): The digits in a physical measurement that are known to be certain plus the first digit that contains uncertainty. (1.6)

Simple Cubic Unit Cell: See *Primitive Cubic Unit Cell*.

Simplest Formula: See *Empirical Formula*.

Single Bond: A covalent bond in which a single pair of electrons is shared. (8.3)

Single Replacement Reaction: A reaction in which one element replaces another in a compound; usually a redox reaction. (5.4)

Skeletal Structure: A diagram of the arrangement of atoms in a molecule, which is the first step in constructing the Lewis structure. (8.6)

Skeleton Equation: An unbalanced equation showing only the formulas of reactants and products. (5.2)

Slag: A relatively low melting mixture of impurities that forms in a blast furnace or other furnaces used to refine metals. (21.4)

Smelting: A process in which a metal oxide is heated with a reducing agent in order to obtain the free metal. (21.3)

Solid: One of the states of matter. A solid consists of tightly packed atomic or molecular sized particles held rigidly in place. (1.4)

Solubility: The ratio of the quantity of solute to the quantity of solvent in a saturated solution and that is usually expressed in units of (g solute)/(100 g solvent) at a specified temperature. (4.1)

Solubility Product Constant (K_{sp}): The equilibrium constant for the solubility of a salt and that, for a saturated solution, is equal to the product of the molar concentrations of the ions, each raised to a power equal to the number of its ions in one formula unit of the salt. (17.1) See also *Acid Solubility Product*.

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Solubility Rules: A set of rules describing salts that are soluble and those that are insoluble. They enable the prediction of the formation of a precipitate in a metathesis reaction. (4.5)

Solute: Something dissolved in a solvent to make a solution. (4.1)

Solution: A homogeneous mixture in which all particles are of the size of atoms, small molecules, or small ions. (1.3, 4.1)

Solvation: The development of a cage-like network of a solution's solvent molecules about a molecule or ion of the solute. (12.1)

Solvation Energy: The enthalpy of the interaction of gaseous molecules or ions of solute with solvent molecules during the formation of a solution. (12.2)

Solvent: A medium, usually a liquid, into which something (a solute) is dissolved to make a solution. (4.1)

sp Hybrid Orbital: A hybrid orbital formed by mixing one s and one p atomic orbital. The angle between a pair of sp hybrid orbitals is 180° . (9.5)

sp^2 Hybrid Orbital: A hybrid orbital formed by mixing one s and two p atomic orbitals. sp^2 hybrids are planar triangular with the angle between two sp^2 hybrid orbitals being 120° . (9.5)

sp^3 Hybrid Orbital: A hybrid orbital formed by mixing one s and three p atomic orbitals. sp^3 hybrids point to the corners of a tetrahedron; the angle between two sp^3 hybrid orbitals is 109.5° . (9.5)

sp^3d Hybrid Orbital: A hybrid orbital formed by mixing one s , three p , and one d atomic orbital. sp^3d hybrids point to the corners of a trigonal bipyramid. (9.5)

sp^3d^2 Hybrid Orbital: A hybrid orbital formed by mixing one s , three p , and two d atomic orbitals. sp^3d^2 hybrids point to the corners of an octahedron. (9.5)

Specific Heat (Specific Heat Capacity): The quantity of heat that will raise the temperature of 1 g of a substance by 1°C , usually in units of $\text{cal g}^{-1}\text{ }^\circ\text{C}^{-1}$ or $\text{J g}^{-1}\text{ }^\circ\text{C}^{-1}$. (6.3)

Spectator Ion: An ion whose formula appears in an ionic equation identically on both sides of the arrow, that does not participate in the reaction, and that is excluded from the net ionic equation. (4.2)

Spectrochemical Series: A listing of ligands in order of their ability to produce a large crystal field splitting. (21.9)

Speed of Light (c): The speed at which light travels in a vacuum; $3.00 \times 10^8 \text{ m s}^{-1}$. (7.1)

Spin Quantum Number (m_s): The quantum number associated with the spin of a subatomic particle and for the electron can have a value of $+\frac{1}{2}$ or $-\frac{1}{2}$. (7.4)

Spontaneous Change: A change that occurs by itself without outside assistance. (18.2)

Square Planar Molecule: A molecule with a central atom having four bonds that point to the corners of a square. (9.2)

Square Pyramid: A pyramid with four triangular sides and a square base. (9.2)

Stability Constant: See *Formation Constant*.

Stabilization Energy: See *Resonance Energy*.

Standard Atmosphere: See *Atmosphere, Standard*

Standard Cell Notation: A way of describing the anode and cathode half-cells in a galvanic cell. The anode half-cell is specified on the left, with the electrode material of the anode given first and a vertical bar representing the phase boundary between the electrode and the solution.

Double bars represent the salt bridge between the half-cells. The cathode half-cell is specified on the right, with the material of the cathode given last. Once again, a single vertical bar represents the phase boundary between the solution and the electrode. (19.1)

Standard Cell Potential (E°_{cell}): The potential of a galvanic cell at 25°C and when all ionic concentrations are exactly $1 M$ and the partial pressures of all gases are 1 atm . (19.2)

Standard Conditions of Temperature and Pressure (STP): Standard reference conditions for gases. 273 K (0°C) and 1 atm (760 torr). (10.4)

Standard Enthalpy Change (ΔH°): See *Standard Heat of Reaction*.

Standard Enthalpy of Formation (ΔH°_f): See *Standard Heat of Formation*.

Standard Entropy (S°): The entropy of 1 mol of a substance at 25°C and 1 atm . (18.5)

Standard Entropy Change (ΔS°): The entropy change of a reaction when determined with reactants and products at 25°C and 1 atm and on the scale of the mole quantities given by the coefficients of the balanced equation. (18.5)

Standard Entropy of Formation (ΔS°_f): The value of ΔS° for the formation of one mole of a substance from its elements in their standard states. (18.5)

Standard Free Energy Change (ΔG°): $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$. (18.6)

Standard Free Energy of Formation (ΔG°_f): The value of ΔG° for the formation of one mole of a compound from its elements in their standard states. (18.6)

Standard Heat of Combustion (ΔH°_c): The enthalpy change for the combustion of one mole of a compound under standard conditions. (6.8)

Standard Heat of Formation (ΔH°_f): The amount of heat absorbed or evolved when one mole of the compound is formed from its elements in their standard states. (6.8)

Standard Heat of Reaction (ΔH°_r): The enthalpy change of a reaction when determined with reactants and products at 25°C and 1 atm and on the scale of the mole quantities given by the coefficients of the balanced equation. (6.6)

Standard Hydrogen Electrode: See *Hydrogen Electrode*.

Standard Molar Volume: See *Molar Volume, Standard*.

Standard Reduction Potential E°_{cell} : The reduction potential of a half-reaction at 25°C when all ion concentrations are $1 M$ and the partial pressures of all gases are 1 atm . Also called standard electrode potential. (19.2)

Standard Solution: Any solution whose concentration is accurately known. (4.8)

Standard State: The condition in which a substance is in its most stable form at 25°C and 1 atm . (6.6, 6.8)

Standing Wave: A wave whose peaks and nodes do not change position. (7.3)

Starch: A polymer of glucose used by plants to store energy. (22.7)

State Function: A quantity whose value depends only on the initial and final states of the system and not on the path taken by the system to get from the initial to the final state. (P , V , T , H , S , and G are all state functions.) (6.2)

State of a System: The set of specific values of the physical properties of a system—its composition, physical form, concentration, temperature, pressure, and volume. (6.2)

State of Matter: A physical state of a substance: solid, liquid, or gas. See also *Standard State*. (1.4)

Stereoisomerism: The existence of isomers whose structures differ only in spatial orientations (e.g., geometric isomers and optical isomers). (21.8)

Stock System: A system of nomenclature that uses Roman numerals to specify oxidation states. (2.9)

Stoichiometric Equivalence: The ratio by moles between two elements in a formula or two substances in a chemical reaction. (3.2)

Stoichiometry: A description of the relative quantities by moles of the reactants and products in a reaction as given by the coefficients in the balanced equation. (3 Introduction)

Stopcock: A valve on a buret that is used to control the flow of titrant. (4.8)

Stored Energy: See *Potential Energy*.

STP: See *Standard Conditions of Temperature and Pressure*.

Straight-Chain Compound: An organic compound in whose molecules the carbon atoms are joined in one continuous open-chain sequence. (22.1)

Strong Acid: An acid that is essentially 100% ionized in water. A good proton donor. An acid with a large value of K_a . (4.3)

Strong Base: Any powerful proton acceptor. A base with a large value of K_b . A metal hydroxide that dissociates essentially 100% in water. (4.3)

Strong Electrolyte: Any substance that ionizes or dissociates in water to essentially 100%. (4.2, 4.3)

Structural Formula (Lewis Structure): A chemical formula that shows how the

atoms of a molecule or polyatomic ion are arranged, to which other atoms they are bonded, and the kinds of bonds (single, double, or triple). (8.3)

Subatomic Particles: Electrons, protons, neutrons, and atomic nuclei. (2.2)

Sublimation: The conversion of a solid directly into a gas without passing through the liquid state. (11.3)

Subscript: In a chemical formula, a number after a chemical symbol, written below the line, and indicating the number of the preceding atoms in the formula (e.g., CH_4). Subscripts are also used to differentiate many variables such as the acid ionization constant (K_a) and the base ionization constant (K_b). (2.5)

Subshell: All of the orbitals of a given shell that have the same value of their secondary quantum number, ℓ . (7.3)

Substance: See *Pure Substance*.

Substitution Reaction: The replacement of an atom or group on a molecule by another atom or group. (22.2, 22.3)

Superconductor: A material in a state in which it offers no resistance to the flow of electricity.

Supercooled Liquid: A liquid at a temperature below its freezing point. An amorphous solid. (11.7)

Supercritical Fluid: A substance at a temperature above its critical temperature. (11.12)

Superheated Liquid: The condition of a substance in its liquid state above its boiling point. (11.7)

Superimposability: A test of structural chirality in which a model of one structure and a model of its mirror image are compared to see if the two could be made to blend perfectly, with every part of one coinciding simultaneously with the parts of the other. (21.8, 22.1)

Supersaturated Solution: A solution that contains more solute than it would hold if the solution were saturated. Supersaturated solutions are unstable and tend to produce precipitates. (4.1)

Surface Tension: A measure of the amount of energy needed to expand the surface area of a liquid. (11.3)

Surfactant: A substance that lowers the surface tension of a liquid and promotes wetting. (11.3)

Surroundings: That part of the universe other than the system being studied and separated from the system by a real or an imaginary boundary. (6.3)

Symmetric: An object is symmetric if it looks the same when rotated, reflected in a mirror, or reflected through a point. (9.3)

System: That part of the universe under study and separated from the surroundings by a real or an imaginary boundary. (6.3, 6.6)

T

$t_{1/2}$: See *Half-Life*.

T-Shaped Molecule: A molecule having five electron domains in its valence shell, two of which contain lone pairs. The other three are used in bonds to other atoms. The molecule has the shape of the letter T, with the central atom located at the intersection of the two crossing lines. (9.2)

Tarnishing: See *Corrosion*.

Temperature: A measure of the hotness or coldness of something. A property related to the average kinetic energy of the atoms and molecules in a sample. A property that determines the direction of heat flow—from high temperature to low temperature. (1.5, 6.1)

Temperature–Volume Law (Charles' Law): The volume of a given mass of a gas is directly proportional to its Kelvin temperature if the pressure is kept constant. $V \propto T$. (10.3)

Termination Step: A step in a chain reaction in which a reactive species needed for a chain propagation step disappears without helping to generate more of this species. (Facets of Chemistry 13.1)

Tetrahedral Molecule: A molecule with a central atom bonded to four other atoms located at the corners of an imaginary tetrahedron. (9.1)

Tetrahedron: A four-sided figure with four triangular faces and shaped like a pyramid. (9.1)

Theoretical Model: See *Model, Theoretical*.

Theoretical Yield: The yield of a product calculated from the reaction's stoichiometry. (3.6)

Theory: A tested explanation of the results of many experiments. (1.2)

Thermal Decomposition: The decomposition of a substance caused by heating it. (21.3)

Thermal Energy: The molecular kinetic energy possessed by molecules as a result of the temperature of the sample. Energy that is transferred as heat. (6.1)

Thermal Equilibrium: A condition reached when two or more substances in contact with each other come to the same temperature. (6.2)

Thermal Property: A physical property, like heat capacity or heat of fusion, that concerns a substance's ability to absorb heat without changing chemically.

Thermochemical Equation: A balanced chemical equation accompanied by the value of ΔH° that corresponds to the mole quantities specified by the coefficients. (6.6)

Thermochemistry: The study of the energy changes of chemical reactions. (6 Introduction)

Thermodynamic Equilibrium Constant (K): The equilibrium constant that is calculated from ΔG° (the standard free energy change) for a reaction at T K by the equation, $\Delta G^\circ = RT \ln K$. (18.9)

Thermodynamics (Chemical Thermodynamics): The study of the role of energy in chemical change and in determining the behavior of materials. (6 Introduction, 18.1)

Third Law of Thermodynamics: For a pure crystalline substance at 0 K, $S = 0$. (18.5)

Titrant: The solution added from a buret during a titration. (4.8)

Titration: An analytical procedure in which a solution of unknown concentration is combined slowly and carefully with a standard solution until a color change of some indicator or some other signal shows that equivalent quantities have reacted. Either solution can be the titrant in a buret with the other solution being in a receiving flask. (4.8)

Titration Curve: For an acid–base titration, a graph of pH versus the volume of titrant added. (16.7)

Torr: A unit of pressure equal to 1/760 atm. 1 mm Hg. (10.2)

Tracer Analysis: The use of small amounts of a radioisotope to follow (trace) the course of a chemical or biological change. (20.7)

Transcription: The synthesis of mRNA at the direction of DNA. (22.8)

Trans Isomer: A stereoisomer whose uniqueness lies in having two groups that project on opposite sides of a reference plane. (21.8, 22.2)

Transition Elements: The elements located between Groups IIA and IIIA in the periodic table. (2.3)

Transition Metals: The transition elements. (2.3)

Transition State: The brief moment during an elementary process in a reaction mechanism when the species involved have acquired the minimum amount of potential energy needed for a successful reaction, an amount of energy that corresponds to the high point on a potential energy diagram of the reaction. (13.5)

Transition State Theory: A theory about the formation and breakup of activated complexes. (13.5)

Translation: The synthesis of a polypeptide at the direction of a molecule of mRNA. (22.8)

Transmutation: The conversion of one isotope into another. (20.5)

Transuranium Elements: Elements 93 and higher. (20.5)

Traveling Wave: A wave whose peaks and nodes move. (7.3)

Triacylglycerol: An ester of glycerol and three fatty acids. (22.7)

Trigonal Bipyramid: A six-sided figure made of two three-sided pyramids that share a common face. (9.1)

Trigonal Bipyramidal Molecule: A molecule with a central atom holding five other atoms that are located at the corners of a trigonal bipyramid. (9.1, 9.2)

Trigonal Pyramidal Molecule: A molecule that consists of an atom, situated at the top of a three-sided pyramid, that is bonded to three other atoms located at the corners of the base of the pyramid. (9.2)

G-18 Glossary

Triple Bond: A covalent bond in which three pairs of electrons are shared. (8.3)

Triple Point: The temperature and pressure at which the liquid, solid, and vapor states of a substance can coexist in equilibrium. (11.12)

Triprotic Acid: An acid that can furnish three H^+ ions per molecule. (4.3)

U

u: See *Atomic Mass Unit*.

Ultraviolet Catastrophe: The term given to the fact that classical physics predicts large amounts of ultraviolet radiation should be emitted from heated materials. In fact, very little ultraviolet radiation is produced. (7 Introduction)

Uncertainty: The amount by which a measured quantity deviates from the true or actual value. (1.6)

Uncertainty Principle: There is a limit to our ability to measure a particle's speed and position simultaneously. (7.7)

Unit Cell: The smallest portion of a crystal that can be repeated over and over in all directions to give the crystal lattice. (11.9)

Unit of Measurement: A reference quantity, such as the meter or kilogram, in terms of which the sizes of measurements can be expressed. (1.5)

Universal Gas Constant (R): See *Gas Constant, Universal*.

Universe: The system and surroundings taken together. (6.3)

Unsaturated Compound: A compound whose molecules have one or more double or triple bonds. (22.2)

Unsaturated Solution: Any solution with a concentration less than that of a saturated solution of the same solute and solvent. (4.1)

V

V-Shaped Molecule: See *Bent Molecule*.

Vacuum: An enclosed space containing no matter whatsoever. A *partial vacuum* is an enclosed space containing a gas at a very low pressure.

Valence Bond Theory (VB Theory): A theory of covalent bonding that views a bond as being formed by the sharing of one pair of electrons between two overlapping atomic or hybrid orbitals. (9.4)

Valence Electrons: The electrons of an atom in its valence shell that participate in the formation of chemical bonds. (7.6)

Valence Shell: The electron shell with the highest principal quantum number, n , that is occupied by electrons. (7.6)

Valence Shell Electron Pair Repulsion Theory (VSEPR Theory): The bonding and nonbonding (lone pair) electron

domains in the valence shell of an atom seek an arrangement that leads to minimum repulsions and thereby determine the geometry of a molecule. (9.2)

Van der Waals' Constants: Empirical constants that make the van der Waals' equation conform to the gas law behavior of a real gas. (10.9)

Van der Waals' Equation: An equation of state for a real gas that corrects V and P for the excluded volume and the effects of intermolecular attractions. (10.9)

Van der Waals' Forces: Attractive forces including dipole–dipole, ion–dipole, and induced dipole forces. (11.2)

Van't Hoff Factor (i): The ratio of the observed freezing point depression to the value calculated on the assumption that the solute dissolves as un-ionized molecules. (12.9)

Vapor Pressure: The pressure exerted by the vapor above a liquid (usually referring to the *equilibrium* vapor pressure when the vapor and liquid are in equilibrium with each other). (10.6, 11.5)

Vapor Pressure–Concentration Law (Raoult's Law): The vapor pressure of one component above a mixture of molecular compounds equals the product of its vapor pressure when pure and its mole fraction. (12.6)

Viscosity: A liquid's resistance to flow. (11.3)

Visible Spectrum: That region of the electromagnetic spectrum whose frequencies can be detected by the human eye. (7.1)

Volatile: Descriptive of a liquid that has a low boiling point, a high vapor pressure at room temperature, and therefore evaporates easily. (11.5)

Volt (V): The SI unit of electric potential or emf in joules per coulomb. (19.2)

$$1 \text{ V} = 1 \text{ J C}^{-1}$$

Voltaic Cell: See *Galvanic Cell*.

VSEPR Theory: See *Valence Shell Electron Pair Repulsion Theory*.

Vulcanized Rubber: Rubber that has been treated with a substance such as sulfur that forms cross-links and improves the properties of the rubber. (22.6)

W

Wave: An oscillation that moves outward from a disturbance. (7.1)

Wave Function (ψ): A mathematical function that describes the intensity of an electron wave at a specified location in an atom. The square of the wave function at a particular location specifies the probability of finding an electron there. (7.3)

Wave Mechanics (Quantum Mechanics): A theory of atomic structure based on the wave properties of matter. (7 Introduction)

Wave/Particle Duality: A particle such as the electron behaves like a particle in some experiments and like a wave in others. (7 Introduction)

Wavelength (λ): The distance between crests in the wavelike oscillations of electromagnetic radiations. (7.1)

Weak Acid: An acid with a low percentage ionization in solution; a poor proton donor; an acid with a low value of K_a . (4.3, 16.1)

Weak Base: A base with a low percentage ionization in solution; a poor proton acceptor; a base with a low value of K_b . (4.3, 16.1)

Weak Electrolyte: A substance that has a low percentage ionization or dissociation in solution. (4.3)

Weighing: The operation of measuring the mass of something using a balance. (1.5)

Weight: The force with which something is attracted to the earth by gravity. (1.3)

Weight Percent: See *Percentage by Mass*.

Wetting: The spreading of a liquid across a solid surface. (11.3)

White Phosphorus: A very reactive allotrope of phosphorus consisting of tetrahedral P_4 molecules. (21.2)

Work (w): The energy expended in moving an opposing force through some particular distance. Work has units of *force* \times *distance*. (6.1, 6.5, 18.1)

X

X Ray: A stream of very high-energy photons emitted by substances when they are bombarded by high-energy beams of electrons or are emitted by radionuclides that have undergone K-electron capture. (20.3)

Y

Yield, Actual: The amount of a product obtained in a laboratory experiment. (3.6)

Yield, Percentage: The ratio, given as a percent, of the quantity of product actually obtained in a reaction to the theoretical yield. (3.6)

Yield, Theoretical: The amount of a product calculated by the stoichiometry of the reaction. (3.6)

Z

Zinc–Manganese Dioxide Dry Cell (Leclanché Cell): A galvanic cell of about 1.5 V involving zinc and manganese dioxide under mildly acidic conditions. (19.8)

Zero-Order Reaction: A reaction that occurs at a constant rate regardless of the concentration of the reactant. (13.3)