EXHIBIT “Q”

Principles of Modern Chemistry

Fifth Edition

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Cover: Zinc Reacts with aqueous hydrochloric acid to give hydrogen gas and aqueous zinc chloride. *(Charles D. Winters)*

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Index/Glossary

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Absolute entropy (*S*) The entropy of a substance referred to a zero of entropy at a temperature of absolute zero, 252

Absolute temperature scale The temperature scale on which the zero corresponds to absolute zero, 102–103

Absolute zero The theoretical minimum of temperature, at which the entropy of a crystalline pure substance becomes equal to zero, 102

Absorbance Natural logarithm of the ratio of light intensity passing through a reference cell to the light intensity passing through the sample cell in a spectrophotometer, 604

Absorption coefficient Quantity used to specify how the amount of light absorbed at a given wavelength by a pure compound depends on the length of the sample cell, 604

Absorption spectroscopy Spectroscopy in which the intensity of light absorbed by a system is measured as a function of wavelength, 518, 604

Acceleration (*a*) The rate of change of velocity, A.12

Accuracy The degree of agreement between a measured value and the true value, A.5

Acetaldehyde, 727f

Acetaminophen, 738f

Acetic acid, 162, 163, 735

Acetylene, 68f, 719–720

Acetylsalicylic acid, 670f

Acid A substance capable of donating hydrogen ions, 162, 318
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- strength of, 324–331
- strong, 322, 342–343
- types of, 162t
- weak, 324–325
  - equilibria involving, 331–334
  - strong base titration with, 343–346

Acid anhydride A compound that forms an acid upon addition of water, 319–320

Acid ionization constant The equilibrium constant that relates the concentration of an acid to the concentrations of the products of its ionization, 325

Acid ionization strength, 325

Acid precipitation, 353

Acid rain Rain having a concentration of dissolved acids such that its pH is less than about 5.6, 629

Acid–base reactions
- description of, 161–162
- titration, 162–163

Acid–base titration An analytical method for determining the amount of acid or base in a sample, 341
- curve, 341
- description of, 162–163
- strong acid with a strong base, 342–343

Actinide element An element from Ac to Lr in the periodic table of the elements, 49, A.47

Actinium, A.47

Activated complex A transient species formed by the collision of reacting molecules that can break apart to form products; the activated complex lies at the maximum in a plot of energy *versus* progress along the reaction path, 454–456

Activation energy (E_a) The energy term in the Arrhenius equation that gives the temperature dependence of the rate constant; E_a is obtained from the slope of a plot of ln k against $1/T$; interpreted as the minimum collision energy in an encounter between molecules for reaction to ensue, 454

Active site of enzyme The site on an enzyme at which a reaction takes place, 461

Activity [1] (a_i) For a dilute gas, the ratio of the partial pressure to a reference pressure of 1 atm; for a dilute solute species, the ratio of the concentration to a reference concentration of 1 M, 280

Activity [2] (*A*) The disintegration rate of a collection of unstable nuclei, 483

Activity coefficient (γ_i) A correction factor that relates the activity of a nonideal gaseous species to its partial pressure, or the activity of a species in a nonideal solution to its concentration, 280–281

Actual yield The amount of a product of a chemical reaction that is found to form experimentally, 41

Addition polymerization A reaction in which monomers react to form polymers without net loss of atoms, 823

Adiabatic compression, 242

Adiabatic expansion, 242

Adiabatic process A process occurring in a system that is thermally insulated from its surroundings, so $q = 0$, 221–223

Air, composition of, 95, 95t

Air pollutants, 628

Alanine, 838t

Alchemists, 3

Alcohol An organic compound characterized by the functional group, 724–725

Aldehyde An organic compound characterized by the $-\overset{\overset{O}{\|}}{C}-H$ functional group, 727

Algebraic equations, A.19–A.21

Alkali halide A compound formed by reaction of an element from Group I of the periodic table with an element from Group VII, 50

Alkali metal An element of Group I of the periodic table, 50, A.39

Alkaline dry cell A primary cell having an alkaline electrolyte and using the reaction $Zn(s) + 2\ MnO_2(s) + H_2O(\ell) \rightarrow Zn(OH)_2(s) + Mn_2O_3(s)$ to generate a voltage, 407

Alkaline-earth metal An element of Group II of the periodic table, 50, 702, A.40

Alkanes A saturated hydrocarbon, 715
- branched-chain, 717–719
- cyclic, 717
- straight-chain, 715, 715t

Alkene A hydrocarbon with one or more double bonds between carbon atoms, 719–721

Alkyl halide An organic compound the molecules of which have a halogen atom bonded to an alkyl group, 723–724

Alkyl side groups, 718t

Alkyne A hydrocarbon containing one or more triple bonds, 719–721

Alloy A macroscopically homogeneous mixture of two or more metals, 770

Alpha decay (α-decay) A mode of radioactive decay in which a nuclide emits an alpha particle, 481

Alpha helix (α-helix) A spiral structure taken on by some portions of protein molecules, 840

Alpha particle (α-particle) (^4_2He or $^4_2\alpha^{2+}$) The nucleus of the helium atom when emitted in radioactive decay, 481

Alumina The compound Al_2O_3, which appears in several different crystalline forms, 797–798

Aluminosilicate A mineral containing aluminum, silicon, and oxygen, 781–782

Aluminum, 414–416, A.40

Americium (Am), A.47

Conjugated π electron system A molecule or portion of a molecule in which double or triple bonds alternate with carbon–carbon single bonds, and electrons are delocalized across several atoms, 591
Conjugated molecules, 591–592
Conjugated systems, 611
Consecutive equilibria, 284
Conservation of energy, law of In a chemical change, an equal amount of energy exists before and after the change, 4, 27. *See also* **First law of thermodynamics**
Conservation of mass, law of In a chemical change, an equal quantity of matter exists before and after the change, 4, 8–9
Conservation of matter, 4
Constraint a portion of the apparatus in a thermodynamic experiment; it holds one of the properties of the system at a constant value throughout the experiment, 196
Contact process A means for the production of sulfuric acid in which sulfur dioxide is oxidized to sulfur trioxide by oxygen on a vanadium oxide catalyst, 691, 692f
Continuous process A chemical process in which reactants are fed in and products removed continuously, 669
Controlled precipitation, 362
Convection The net flow of one region of a fluid with respect to another region, 132
Coordinate covalent bond A covalent bond in which the shared electrons are both supplied by one of the bonded atoms; results from the interaction of a Lewis base and a Lewis acid, 319
Coordination complex A compound in which metal atoms or ions are bonded via coordinate covalent bonds to anions or neutral molecules that supply electron pairs, 376, 640–641
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    description of, 645
    linear, 647–648
    square-planar, 647–648, 653–654
    tetrahedral, 647–648, 653–654
    three-dimensional, 646–647
Coordination number The number of coordinate bonds formed by a central metal atom to donor atoms in a coordination complex, 641–642
Coordination sphere The ligands coordinated to a metal ion or atom, 641
Copper (Cu), 677–679, A.45
Core (of earth), 779
Core electron An electron that lies lower in energy than the valence electrons and plays only a minor role in chemical bonding, 54
Correlation, 596
Correlation diagram A diagram that shows the relative energy of the molecular orbitals in a molecule and their derivation from the atomic orbitals of the constituent atoms, 573
Corrosion A destructive chemical process in which metals are spontaneously oxidized, 411–413
Cortisone, 740f, 741
Coulomb (C) The SI unit of electric charge; equal to 1 A s, A.15
Coulomb energy Potential energy arising from electrical repulsions and attractions; $V(r) = q_1q_2/4\pi\varepsilon_0 r$, A.16
Coulomb force The electrostatic attraction between particles of dissimilar charge or the repulsion between particles of similar charge, 57–58, 134, 523, A.15
Coulomb meters, 75
Coulomb's law The dependence of the force between two charges q_1 and q_2 on their separation r; $F = q_1q_2/4\pi\varepsilon_0 r^2$, A.16
Coulomb stabilization energy, 60–63
Covalent bond A bond formed by the sharing of two or more electrons between two atoms, 48 *See also* **Coordinate covalent bond**
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  shared electron pair, 66
Covalent compound A compound formed from electron sharing; tends to be low-melting, low-boiling, and nonconducting, 67
  binary, 82–83, 83t
Covalent crystals A crystal in which structure is maintained by covalent bonds, 763
Covalent fluorides, 703–704
Cracking The degradation of longer chain alkanes to shorter chain alkenes by means of heat or catalysts, 720
Crick, Francis (British biologist), 842
Critical point The point in the phase diagram at which the gas–liquid coexistence curve terminates, 146
Cross-linking, 826–827
Critical pressure (P_c) The pressure above which the distinction between gas and liquid disappears, 146
Critical temperature (T_c) The temperature above which a gas cannot be liquefied, 146
Cross-linked polymer A polymer in which individual chains are linked together by lateral bonds that increase the rigidity of the structure, 826–827
Crude oil. *See* Petroleum refining
Crust (of earth), 779
Cryolite, 415
Crystal
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Crystal field splitting energy The amount by which the (otherwise equal) energy levels for the *d* electrons of a metal ion are split by the electrostatic field of the surrounding ligands in a coordination complex, 650
Crystal field stabilization energy The energy-lowering in a coordination complex relative to that in a spherical crystal field, 651
Crystal field theory A model for coordination complexes in which the central metal is treated as ionically bonded to surrounding ligands, 649–651
Crystal lattice A three-dimensional array of points that embodies the pattern of repetition in a crystalline solid, 750
Crystal system A category (one of seven) into which a crystalline solid can be classified on the basis of the symmetry of its diffraction pattern, 750
Crystalline solid A solid that possesses long-range order at the atomic or molecular level in its structure, 749–767
Crystallography, 748
Cubic close packing A scheme of packing of equal spheres in which each sphere has 12 immediate neighbors and the symmetry of the lattice generated from the positions of the spheres is cubic, 754–756
Cubic system A category (one of seven) into which a crystalline solid can be classified on the basis of the symmetry of its diffraction pattern, 750
Curie (Ci) A unit of activity; equal to $3.7 \times 10^{10}\ s^{-1}$, 484
Curie, Marie (French chemist), 7, 17
Curie, Pierre (French chemist), 17
Curium, A.47
Curve
  areas under, A.25–A.27
  energy, 27–28
  slope of, A.23–A.24
Cyclic process A process in which a system is taken from some initial state through a series of other states and then back to the original state, 241–244
Cycloalkane A saturated hydrocarbon with one or more closed rings of carbon atoms, 717
Cyclobutane, 718f
Cyclohexane, 718f
Cyclopropane, 718f
Cysteine, 839t

***d* orbitals** A hydrogen atom orbital for which $\ell = 2$; *d* orbitals always have two angular nodes, 541–543, 656
Dalton (Da), A unit of mass; equal to one atomic mass unit, 473
Dalton, John (British chemist), 10, 13–14, 106
Dalton's law The total pressure of a gas mixture is the sum of the pressures that would be measured separately if each of the components were present by itself, 106–107

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Hydrogen burning A stage in the evolution of stars during which hydrogen is converted into helium by nuclear fusion reactions, 494
Hydrogen fluoride, 327f, 700
Hydrogen sulfide, 376f
Hydrogenation The absorption of hydrogen by a substance in a chemical reaction, 730
Hydrogen–oxygen fuel cell, 409–410, 410f
Hydrolysis The reaction of a substance with water, in particular the reaction of an ion in which the pH of the water changes from neutral, 335–336
Hydrometallurgy Processes that involve the extraction of metals from ores with aqueous solutions, 678
Hydronium ion The H_3O^+ ion, present in high concentrations in acidic solutions , 318f, 338
Hydrophilic Having a strong affinity for water, 772
Hydrophobic Lacking affinity for water, 772
Hydroxide ion The OH^- ion, present in enhanced concentrations in basic aqueous solutions, 320
solubility of, 372–374
Hypothesis The temporary assumption that a proposed statement is true while its validity is tested in a series of experiments, 3

Ice calorimeter An instrument used to measure amounts of heat flowing into or out of a system, 201, 201f
Ideal gas A hypothetical substance that follows the ideal-gas law exactly under all conditions
compression of, 244–245
expansion of
description of, 244–245
irreversible, 249–250
heat for, 209–210
pressure of, effect on Gibbs free energy, 276
reactions among, 276–279
reversible processes in, 218–224
work for, 209–210
Ideal gas law A relationship between the pressure, volume, temperature, and number of moles of a gas: $PV = nRT$, 103–104, 108
equation of state example of, 117
van der Waals equation of state vs., 118
Ideal solution A solution that conforms to Raoult's law so that the vapor pressures of its components are proportional to their mole fractions in solution
description of, 170
reactions in, 279–280
Igneous rock A rock formed from the crystallization of magma, 784–786
Immiscible liquids Mutually insoluble, as two liquids that separate into two distinct layers, 302
"In excess" Refers to any reactant in a chemical reaction that is not the limiting reactant, 40
Indicator, acid–base A substance the color of which changes noticeably over a fairly small range of pH, 329–331
Indium, A.40
Induced dipole forces The attraction between an ion and a nonpolar molecule or atom based on the induction of a weak dipole by the ion, 135, 136
Induced-dipole–induced-dipole forces The attraction between nonpolar molecules or atoms based on the mutual induction of a weak dipole, 136
Inequality of Clausius, 250
Inert complex A complex in which the ligands exchange only slowly with other ligands, 644
Inert gas. *See* **Noble gas**
Infrared radiation Light of wavelength longer than visible radiation, 507
Infrared spectroscopy, 605–611
Inhibitor A substance that slows the rate of a reaction; a negative catalyst, 461
Initial reaction rate The rate of a chemical reaction at the moment that it begins, before any products can start to react in the reverse direction, 435
Initiation The first stage in a chain reaction, 451
Initiator, 823
Inner core, 53
Inorganic nomenclature, 80
Insecticides, 736–737
Insoluble, 363
Instantaneous rate of chemical reactions The average rate, obtained over progressively shorter time intervals, 435, 435f
Insulator A substance that will not conduct electricity because of the large energy band gap between its occupied valence band and unoccupied conduction band, 812
Integral The area under a curve between two points, A.25–A.26
Integrated rate law A relation that gives the concentration of a reactant or product as a function of time, 440–441
Intensive property of system A property that is independent of the size of a system, and is therefore the same for each of the subsystems into which the system can be divided, 196
Intercept. *See* ***y*-intercept**
Interference The combination of two wave trains; may be constructive or destructive, 529, 753
Interhalogen A compound formed from two different halogen elements, 704
Intermediate-field ligand, 657
Intermolecular contacts, 129
Intermolecular forces An attractive or repulsive interaction among molecules and ions
changes in, 153–154
characteristics of, 133–134
description of, 119–120
in liquids, 138–141
molecular structure created by, 130f, 133–138
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Internal energy (*E*) The sum of the internal kinetic and potential energies of the particles composing a system, 200–201
International System of Units, 25, A.9–A.11
International Union of Pure and Applied Chemistry, 718
Interstellar space, 557–558
Interstitial alloy An alloy in which atoms of one or more additional elements enter the interstitial sites of an iron crystal, making the material stronger and harder than pure iron, 770
Interstitial site A space between atoms in a crystal lattice in which an additional atom can be introduced, 758
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Ion An atom or group of atoms that has lost or gained one or more electrons, thereby becoming electrically charged
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positive, 57–58
selective precipitation of, 374–376
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Ion exchange chromatography, 304t
Ion–dipole forces The interactions between an ion and the oppositely charged ends of a dipole, 135
Ionic bond A bond formed through the Coulomb attraction of two ions of opposite charge; formed from atoms with significantly different electronegativities, 48
description of, 57–58
equilibrium bond length of, 62
formation of, 62–63
Lewis dot diagrams for, 58–59
Ionic compound A compound composed of ions of opposite charge, held together by electrostatic (Coulomb) forces, 58
composition of, 59–60
formulas of, 59–60
names of, 59–60
salts, 58–59
solubility of, 363, 364t
Ionic crystals A crystal held together by Coulomb attractions
characteristics of, 760–761
lattice energy of, 766–767
Ionization energy (*IE*) The minimum energy required to remove an electron from an atom, molecule, or ion that is in its ground state, 51, 55, 555
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Ion–ion forces The Coulombic interactions among ions, 134
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Roasting The conversion of a sulfide ore to an oxide through heating in a furnace, 678
Rock-salt structure of ionic crystals. *See* **Sodium chloride structure of ionic crystals**
Roentgen, Wilhelm, 752
Root-mean-square-speed A measure of the typical speed of molecules at thermal equilibrium; equal to the square root of the average of the squares of the speeds of the molecules, 110–111
Rounding off, A.6
Rubber, 832–833
Rubidium, A.39
Ruthenium, A.44
Rutherford, Ernest, 17–18, 517
Rutherfordium, A.47
Rydberg (Ry) A unit of energy used in atomic spectroscopy; equal to 2.18×10^{-18} J, 525

s orbitals, 537–540
Sacrificial anode A piece of an active metal (such as magnesium) placed in electrical contact with a metal (such as iron) that is to be protected from oxidation, 413
Salt An ionic compound that does not have OH^- as the anion, 58
chemicals from, 694–696
solubility of, 374
Salt bridge A tube containing a salt solution that is used to connect two half-cells in an electrochemical cell; allows the passage of ions, but prevents mixing of the half-cell electrolytes, 390
Samarium, A.46
Saturated calomel electrode A standard electrode that consists of a platinum wire in contact with a paste of liquid mercury, calomel (Hg_2Cl_2), and a saturated solution of Hg_2Cl_2, 405–406
Saturated hydrocarbon A compound of carbon and hydrogen that contains no double or triple carbon–carbon bonds, 643
Saturated solution A solution in equilibrium with a solid solute, 362
***s*-block element** An element that arises with the filling of an *s* orbital in the building up of the periodic table, 549
Scandium, A.43
Scanning tunneling microscopy, 19, 20f
Scattering The redirection of radiation upon interaction with matter, 752–754
Scattering angle (2θ) The angle between the direction of a diffracted beam in an x-ray diffraction experiment and the direction of the main beam, 754
SCF approximation. *See* **Self-consistent field approximation**
Scheele, Karl Wilhelm, 694
Schottky defect A vacant site in a crystal where the pattern indicates an atom should be found, 768
Schrödinger equation The fundamental equation of quantum mechanics that relates the wave function of one or more particles to their masses and potential energies, 531–534, 544
Scientific law, 3
Scientific notation, A.2–A.3
Scientific revolution, 504
Scintillation counter An instrument for the detection of radioactive decay based on the counting of light pulses produced by radiation when it enters a crystal, 482
Seaborgium, A.47
Second(s) The SI base unit of time, A.9
Second law of motion, 97
Second law of thermodynamics In a real, spontaneous process the entropy of the universe (the system plus its surroundings) must increase; $\Delta S_{univ} > 0$, 239–241
Second order reaction A reaction that has a total order of 2, as determined by the sum of the exponents of the concentration terms in the rate law; if a reaction is second order in a single species A, the concentration of A changes with time according to $1/[A] = 2kt + 1/[A]_0$, 437, 441–442
Secondary Used to designate an organic compound in which a substituent group occupies a site on an atom that has only one hydrogen atom attached to it, 725, 730
Secondary alcohol, 725
Secondary amine, 730
Secondary battery, 408
Secondary cell A battery (galvanic cell) that must can be recharged after its energy has been transferred and its voltage gone to zero, 407
Sedimentary rock A rock formed from the products of weathering of other rocks, 786–787
Selective precipitation The deliberate manipulation of the conditions affecting solubility equilibria to achieve desired separations, 374–376
Selenium, A.42
Self-consistent field approximation method The use of one-electron wave functions for many-electron atoms, 544, 595
Semiconductor A substance having electrical conductivity that is small but still greater than that of an electrical insulator and that increases with temperature
characteristics of, 765, 812–815
n-type, 813
p–*n* junctions, 814–815
p-type, 813
Semimetal A material intermediate in character between a metal and a nonmetal, 50
Semipermeable Allowing passage of small molecules but not of large molecules, 176–177
Sequester To coordinate a species so strongly that it is prevented from taking part in its ordinary reactions, 648
Serine, 838t
Shared electron pair, 66
Shear viscosity The measure of the resistance of a substance to flow, 131
Shell A group of subshells in the electron configuration of an atom that have similar energies, 54, 546, 551
of atoms, 544–546
effective nuclear charge in, 546
filling of, 551t
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solvation, 158
structure of, 52
Shift reaction The reaction of carbon monoxide with water to give carbon dioxide and hydrogen, 271, 675
SI Abbreviation for Système International d'Unités (International System of Units), 25, A.9–A.11
Sialon An alloy of silicon, aluminum, oxygen, and nitrogen, 801
Side-centered unit cell A unit cell having lattice points at the center of one pair of parallel cell faces as well as at the eight corners, 752
Siemens (*S*) The unit of electrical conductance, amperes per volt; reciprocal of the ohm, 806
Sigma (σ) bond A bond resulting from the occupancy of σ molecular orbitals by electrons, 573, 577, 584
Sigma (σ) orbital A molecular orbital with no angular nodes, 573, 577, 584
Significant figures The number of digits used to represent a measured quantity, not counting zeros present for the sole purpose of positioning the decimal point; a measure of the precision of a measurement, A.5–A.7
Silicate A compound containing silicon and oxygen and formed from the linking together of structural units, 779–781
Silicate ceramics Ceramics made from aluminosilicate clay minerals, 791, 793
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Silicon
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Silicon carbide, 801
Silicon nitride, 800–801
Silver, A.45
Simple cubic lattice, 754
Single bond A covalent bond in which a single pair of electrons is shared between the bonded atoms, 65–66
Sintering The partial merging of grains in a solid by diffusion at a temperature less than the melting point, 792
Slope The rate of change of the dependent variable with the independent variable
of curves, A.23–A.24
of line, A.18
Smectic phase of liquid-crystal formation A liquid crystal in which molecules show a preferred orientation and a layered structure, 771
Smelting The melting and reduction of metals from their ores, 414
Soda-lime glass Common glass (of approximate composition $Na_2O{\cdot}CaO{\cdot}(SiO_2)_6$), 794
Sodium, A.39
Sodium chloride structure of ionic crystals An ionic crystal structure that consists of two interpenetrating face-centered cubic lattices of cations and anions, 760