

GLOSSARY/INDEX

A

Abbreviated electron configuration, of multi-electron atoms 433–436

Absolute zero Zero kelvins (0 K), the lowest possible temperature, equivalent to $-273.15\text{ }^{\circ}\text{C}$. It is the point beyond which motion can no longer be decreased. 18

Accuracy How closely a measured value approaches the true value of the property. 20

Acetaldehyde, determining Lewis structure 464–465

Acetamide 668

Acetate ion, solubility of compounds with 141

Acetic acid 162–165, 664
dissolved in water 164
formulas 162
freezing point of 162
glacial 162
molecular structure of 162
as organic acid 162
production 528, 654
solubility in water 593
taste of 160
uses 162, 654
as weak acid 163

Acetone 666
boiling point of 546
evaporation of 536
use 567
vapor pressure of 540

Acetylene 451, 662
molecular structure of 451
water solubility of 580

Acid. *See also* Arrhenius acid
binary. *See* Binary acid
bleach and 188
Brønsted-Lowry 188–192
conjugate acids and bases 189
carboxylic acid. *See* Carboxylic acid
characteristics 160
classification of strong or weak 166, 176–177
defined 188
diprotic. *See* Diprotic acid
identifying 176–177
monoprotic. *See* Monoprotic acid
names and formulas of 168–170
oxyacid. *See* Oxyacid
pH 178–179
polyprotic. *See* Polyprotic acid
in saliva 177
strong 165
Study Sheet, indentifying 176

taste of 177
triprotic. *See* Triprotic acid
types 162
weak 163–165

Acid-base reaction 180–188
strong acid with hydroxide base 181–185
uses 180
writing equations 183

Acidic paper, preserving books with 187

Acidic solution A solution with a significant concentration of hydronium ions, H_3O^+ . 160

Acid rain 167
pH and 178

Acrylamide 621

Activated complex 611

Activation energy The minimum energy necessary for reactants to reach the activated complex and proceed to products. 612

Active site A specific section of the protein structure of an enzyme in which the substrate fits and reacts. 690

Actual yield The amount of product that is actually obtained in a chemical reaction. 382

Adams, Mike 674

Addition, rounding off for 299–300

Addition polymer A polymer that contains all of the atoms of the original reactant in its structure. This category includes polyethylene, polypropylene, and poly(vinyl chloride). 693–694

Adipic acid 351

Adults
effects of ionizing radiation on 730
fingerprints of 541

Aerosol can 541

Agent Orange 364

Aging, oxidizing agents and 212

Agitation, rate of solution and 590–591
Agricultural Research Service of North Carolina State University 266

AIDS 673

Air 509–510
density of 302
gases in 510
internal combustion engine and 492
in lungs 493

Air bags 526

Air pollution
catalytic converters and 221
ozone and 266–267
volatile organic solvents and 514

Alanine (Ala, A)
silk and 690
structure of 678

Alar 361

Alcohol Compounds that contain a hydrocarbon group with one or more -OH groups attached. 84, 663. *See also* Methanol, Ethanol, and 2-propanol
hydrogen bonds and 555

Aldehyde A compound that has a hydrogen atom or a hydrocarbon group connected to a -CHO group. 665

Aldol, molecular structure of 669

Alka-Seltzer 526

Alkaline earth metals Group 2 (or 2A) on the periodic table; *See also* Beryllium, Magnesium, and Calcium 43
ion charges of 97

Alkali metals Group 1 (or 1A) on the periodic table; *See also* Lithium, Sodium, Potassium, and Cesium 43
ion charges of 96–97

Alkane A hydrocarbon (a compound composed of carbon and hydrogen) in which all of the carbon-carbon bonds are single bonds. 661

Alkene A hydrocarbon that has one or more carbon-carbon double bonds. 662

Alkyne A hydrocarbon that has one or more carbon-carbon triple bonds. 662

Alpha emission The process of releasing an alpha particle by atoms that have too many protons to be stable. 720
nuclear equations for 723–725

Alpha helix 680–681

Alpha particle The emission from radioactive nuclides that is composed of two protons and two neutrons in the form of a helium nucleus. 720
effects on body 730–731
penetration of the body 731

Alternate Synthetic Pathways Award 621
Alternative Solvents/Reaction Conditions Award 272

Alum. *See* Aluminum sulfate

Aluminum 44
ion formation 49, 97

Aluminum bromide, production and use 235

Aluminum chloride 108

Aluminum fluoride, production and use 401

- Aluminum hydroxide, dissolving in acid 184
- Aluminum oxide 132
- Aluminum sulfate
old books and 187
production and use 410
water purification 374
- Americium-241 and smoke detectors 735
- Amide** A compound with the general formula RCONR, in which each R represents hydrogen atoms or hydrocarbon groups. 668
in digestion 689
as peptide bond 680
- Amine** A compound with the general formula R₃N, in which R represents a hydrogen atom or a hydrocarbon group (and at least one R group being a hydrocarbon group). 667–668
- 1-Aminobutane 667
- Aminopeptidase 688
- Amino acid** The monomer that forms the protein polymers. They contain an amine functional group and a carboxylic acid group separated by a carbon. 678–679
in origin of life 640–642
protein formation and 680
in silk 690
- Ammonia 173–174
covalent bond formation 451
hydrogen bonds and 555
Lewis structure of 81
molecular geometry 469
molecular shape of 87
origin of life and 641
pH of 179
production 504, 621
uses 173, 570
weak base 173–174
- Ammonium carbonate, use 653
- Ammonium chloride, crystal structure of 101
- Ammonium ion
covalent bond formation 452
Lewis structure 101
solubility of compounds with 141
- Ammonium nitrate, in cold packs 264
- Ammonium perchlorate, space shuttle and 245
- Ammonium phosphate, fertilizers and 213
- Ammonium sulfide, use 108
- Amount of substance, base unit of 10
- Amphère, as unit of measure 11
- Amphetamine 582
- Amphoteric substance** A substance that can act as either a Bronsted-Lowry acid or a Bronsted-Lowry base, depending on the circumstances. 191
- Amylase 688
- Amylopectin 676–677
- Amylose 676–677
- Analogies, to electron behavior 414
- Anastas, Paul T. 5
- Anderson, Carl 437
- Androstenedione 686, 687
- Aniline, production and use 399, 402
- Animal fat 585
- Anion** An ion formed from an atom that has gained one or more electrons and thus has become negatively charged. 49
formation 95–96
in batteries 225–226
in classifying types of compounds 78
in ionic bond formation 75–76
monatomic 96
naming 98–99, 104–106
polyatomic 101–103
structure of ionic compounds 100
writing formulas 107–108
- Anode** The electrode at which oxidation occurs in a voltaic cell. It is the source of electrons and is the negative electrode. 225
- Antacid 126, 506
- Antarctica, ozone hole over 271
- Anthropogenic sources, of methyl bromide 272
- Anti-electron (positron) 437
- Antimatter 437
- Antioxidant, aging and 212
- Antiparticle 437
- Antiseptic, iodine as 556
- Application, in scientific method 8–9
- Aquamarine 362
- Aqueous solution** A solution in which water is the solvent. 134
- Arene** (or aromatic compound) A compound that contains the benzene ring. 662–663
- Arginine (Arg, R), structure of 679
- Argon
in air 510
in incandescent light bulbs 496
in neon lights 509
- Aromatic.** *See* Arene A compound that contains the benzene ring.
- Aromatic compounds. Compounds that contain the benzene ring. *See* Arene
- Arrhenius, Svante August 160
- Arrhenius acid** According to the Arrhenius theory, any substance that generates hydronium ions, H₃O⁺, when added to water. 160–167. *See also* Acid
binary acid 162
compared to Brønsted/Lowry acids 188–192
defined 160
names and formulas for 168–170
organic (or carbon-based) acid 162
oxyacids 162
reactions with bases 180–187
strong and weak 163–166
- Arrhenius base** A substance that produces hydroxide ions, OH⁻, when added to water. 174–178. *See also* Base
compared to Brønsted/Lowry bases 188–192
defined 173
reactions with acids 180–187
strong and weak 173–176
- Arsenic (As)
bonding patterns of 452
most common bonding pattern 455
- Asparagine (Asn, N), structure of 679
- Aspartame 705, 711
- Aspartic acid (Asp, D)
in salt bridges 682
structure of 679
- Asphalt, London forces in 556–557
- Asymmetry, in polar molecules 552, 553
- Atmosphere, layers 268
- Atmosphere (atm), as unit of pressure 485
- Atmospheric pressure 485
boiling-point temperature and 545–546
- Atom** The smallest part of the element that retains the chemical characteristics of the element itself. 46–48
atomic numbers of 51
chemical bonds between 73–77
in chemical reactions 126–128
counting by weighing 331–334
electron 48
electron configurations and orbital diagrams 424, 431, 456
excited and ground state 421
as formula unit 339
mass numbers of 51–52
molar mass of 335–336
nuclear reactions of 720–724
nuclear stability of 718
oxidation numbers of 213–220
protons, neutrons, and electrons 47

- radioactive decay of 720–724
size of 47
size of nucleus 47
structure of 46–50
- Atomic mass** The weighted average of the masses of the naturally occurring isotopes of an element.
calculations 336
defined 333
relative 333
- Atomic mass unit (u or amu)** One-twelfth the mass of an atom of carbon-12. Carbon-12 is the isotope of carbon that contains 6 protons, 6 neutrons, and 6 electrons. 47, 332–333
- Atomic number** The number of protons in an atom's nucleus. It establishes the element's identity. 51
in nuclear equations 722–726
in nuclides 716–717
- Atomic orbitals
1s 416–418
2p 421
2s 419–420
3d 422
electron cloud 418
electron spin and 426
for first 10 elements 427
order of filling 425, 428–430
probability and 418
relative energies 420
shapes 419
- Atomic weight *See also* Atomic mass 333
- Attraction. *See also* Gravitational attraction; Electrostatic attraction; Strong force; Particle-particle attractions
between gas particles 484
between liquid particles 534
intermolecular 547–557
particle-particle attraction 547–562
- Aurum 41
- Automobile Exhaust 71
- Average, weighted 331
- Avogadro's Law** Volume and the number of gas particles are directly proportional if the temperature and pressure are constant. 491
- Avogadro's number** The number of atoms in 12 g of carbon 12. To four significant figures, it is 6.022×10^{23} . 333–334
- B**
- Bacon, Roger 287
- Bacteria 236
tooth decay and 186
- Baking powder 73
- Balance, electronic 23, 300
- Balanced chemical equation
coefficient 127
coefficients to conversion factors 369–370
in equation stoichiometry 368–375
- Balancing chemical equations 128–133
steps in 129
Study Sheet 129
- Ball-and-stick model** A representation of a molecule that uses balls for atoms and sticks for covalent bonds. 54
of acetic acid molecule 162
for acetylene 471
for boron trifluoride 470
for ethane 471
for methane 468
for organic molecules 660
of ammonia 87
of methane 87
of water 88
- Band of stability** On a graph of the numbers of neutrons versus protons in the nuclei of atoms, the portion that represents stable nuclides. 719
- Barium ion, solubility of compounds with 141
- Barium sulfate 143
- Barnes, Randy 687
- Base 173–177. *See also* Arrhenius base
Arrhenius 174
Brønsted-Lowry 188–192
carbonate 175
classification of strong or weak 176–177
conjugate 190
defined 173
identifying 175–176
in acid-base reactions 180–188
pH 178–179
strong 173
Study Sheet, indentifying 176
weak 174–175
- Base units** The seven units from which all other units in the SI system of measurement are derived. 10–11
table of 11
- Basic solution** A solution with a significant concentration of hydroxide ions, OH⁻. 173
- Battery** A device that has two or more voltaic cells connected together. The term is also used to describe any device that converts chemical energy into electrical energy using redox reactions. 224–229. *See also* Voltaic cell
defined 224, 225
dry cell 226–227
nickel-cadmium batteries 228
rechargeable 228
zinc-air 229
- Beef fat 584–585
- Bends, the 596
- Benitoite 362
- Bent geometry** The molecular geometry formed around an atom with two bond groups and two lone pairs or two bond groups and one lone pair. 469
- Benzedrine 582
- Benzene 351
- Berkelium (Bk) 725
- Beryllium (Be)
electron configuration and orbital diagram 426
formation of 742
- Beta emission** The conversion of a neutron to a proton, which stays in the nucleus, and an electron, called a beta particle in this context, which is ejected from the atom. 720
nuclear equations for 723–725
- Beta particle** A high-velocity electron released from radioactive nuclides that have too many neutrons. 720
effects on body 730–731
penetration of the body 731
- Beta sheet 680
- Big Bang 742
- Binary acid** Substances that have the general formula of HX(aq), where X is one of the first four halogens: HF(aq), HCl(aq), HBr(aq), and HI(aq). 162
formulas 168
naming 168
- Binary covalent compound** A compound that consists of two nonmetallic elements.
memorized names 90
names without prefixes 93
naming 91–92
prefixes used to name 91
recognizing from formulas 91
recognizing from names 93
systematic names 90–92
writing formulas 93–94
- Binary ionic compound** An ionic compound whose formula contains one symbol for a metal and one symbol for a nonmetal. 104

- Binding energy** The amount of energy released when a nucleus is formed. 737
- Biocatalyst 621
- Biochemistry** The chemistry of biological systems. 674–687
- Biomolecule 674–687
amino acids and protein 678–682
carbohydrate 674–677
how form 640–642
steroid 685–686
triglycerides 683
- Bismuth, in the creation of element 111 52
- Bitter taste 177
- Blake, William 413
- Bleach
dangerous combination with acid 188
pH of 179
- Blocks, in periodic table 428–429
- Blood
pH of 179
- Blue litmus paper, detecting acids with 180
- Boiling** The conversion of liquid to vapor anywhere in the liquid rather than just at the top surface. 542–546
defined 544
how bubbles form 542–544
- Boiling-point temperature** The temperature at which a liquid boils. It is also the temperature at which the equilibrium vapor pressure of the liquid becomes equal to the external pressure acting on the liquid. 544
effect of external pressure 544–546
strengths of attractions and 546
- Bond. *See* Chemical bond
- Bond angle** The angle formed by straight lines (representing bonds) connecting the nuclei of three adjacent atoms. 86, 468
- Bond dipole** A polar covalent bond, which has an atom with a partial positive charge and an atom with a partial negative charge. 549
- Bond polarity, predicting 548–552
- Books, preserving 187
- Boron (B)
brain cancer treatment and 741
covalent bonding pattern 454
covalent bond formation 453
electron configuration and orbital diagram 426
nuclear power plant control rods and 740
- Boron trifluoride 453
- Bovine pancreatic trypsin inhibitor (BPTI) 680–682
- Boyle's Law** The pressure of a gas is inversely proportional to the volume it occupies if the number of gas particles and the temperature are constant. 486–487
- Brain, intoxicating liquids and 89
- Brain cancer, treatment for 741
- Brandes, Jay A. 641
- Breathing 493
- Bristlecone pines and carbon-14 dating 734
- Bromide ion, solubility of compounds with 141
- Bromine (Br)
in halons 272
most common bonding pattern 455
structure 55
use 570
- Bromomethane, and threshold limit value, or TLV 522
- Brønsted-Lowry acid** A substance that donates protons, H^+ , in a Brønsted-Lowry acid-base reaction. *See* Acid, Brønsted-Lowry
- Brønsted-Lowry acid-base reaction** A chemical reaction in which a proton, H^+ , is transferred. *See* Acid-base reaction, Brønsted-Lowry
- Brønsted-Lowry base** A substance that accepts protons, H^+ , in a Brønsted-Lowry acid-base reaction. *See* Base, Brønsted-Lowry
- Bubbles
in boiling liquid 544
how form in liquid 542–544
in soft drinks 596
- Bunsen burner, hottest part of flame 314
- Bureau International des Poids et Mesures (BIPM) 11
- Butadiene 524
- Butane, molecular structure of 82
- 1,4-Butanediol (BD) 354
- Butanoic acid
molecular structure of 583, 664
solubility of 583
- 2-Butanone 666
- Butylated hydroxytoluene (BHT) 662
- Butyl ethyl ether 660
- Butyric acid 664
- C**
- Cadaverine 667
- Cadmium (Cd)
in nickel-cadmium batteries 228
nuclear plant control rods and 740
- Caffeine 597
removal from coffee 515
taste of 159
- Calamine 364
- Calcium (Ca), ion formation 97
- Calcium carbide, production 402
- Calcium carbonate 126, 264, 616
acid rain and 167
as antacid 506
formation in pipes of 144
in limestone caverns 204
natural sources of 144
oil production and 186
precipitation reaction 137–140
solubility in water 593
- Calcium chloride 126
- Calcium dihydrogen phosphate, production and use 407
- Calcium hydrogen sulfite, production and use 243
- Calcium nitrate 108, 137–138
- Calcium phosphide (or photophor), empirical formula for 348
- Calorie (with an uppercase C), Cal** The dietary calorie. In fact, a Calorie is a kilocalorie or 4184 joules. 257
- calorie (with a lowercase c), cal** A common energy unit. Equivalent to 4.184 joules. 257
- Cancer, boron fusion and 741
- Capsaicin 583
- Carbohydrate** Sugar, starch, and cellulose. Also called saccharides. 674–677
- Carbon-13 733
- Carbon-14, radioactive decay of 733
- Carbon-14 dating** The process of determining the age of an artifact that contains material from formerly living plants or animals by analyzing the ratio of carbon-14 to carbon-12 in the object. 733–734
- Carbonate ion 175
reaction with acids 185
solubility of compounds with 141
in weak bases 175
- Carbonic acid 597
- Carbon (C) 48
bonding pattern 82
combustion and 219
covalent bond formation 450–451
diamond as 47
electron configuration and orbital diagram 426–427

- in heavy-ion therapy 52
- isotopes of 333
- medical use 52
- most common bonding pattern 455
- in pig iron 509
- Carbon black 381
- Carbon dioxide
 - in automobile exhaust 71
 - as dry ice 255
 - catalytic converter and 221
 - in combustion reactions 219
 - decaffeinating coffee and 515
 - global warming and 384
 - greenhouse gas 597
 - Lewis structure of 83
 - polarity 552
 - in soft drinks 596
 - solid to gas 576
 - solubility in water 593
 - spray painting and 514
 - supercritical 514
- Carbon dioxide torpedos 597
- Carbon monoxide
 - catalytic converters and 221
 - covalent bond formation 453
 - in hydrogen gas production 622
 - incomplete combustion and 221
 - Lewis structure of 453
 - as pollutant 221
 - in synthesis gas 622
- Carbon tetrachloride, use and production 526
- Carboxylic acid** A compound that have a hydrogen atom or a hydrocarbon group connected to a -COOH (or $\text{-CO}_2\text{H}$) group. 162, 185, 664
 - in acid-base reactions 185
 - forming name of 169
- Carboxypeptidase, in digestion 688
- Carnegie Institution 641
- Carothers, W. H. 691
- Catalyst** A substance that speeds a chemical reaction without being permanently altered itself. 270, 618–621, 621
 - automobile catalytic converter 221
 - chlorine atoms as 271
 - from chlorofluorocarbons 271
 - defined 270
 - equilibrium and 638–639
 - green chemistry and 621
 - homogeneous and heterogeneous 620–621
 - nitrogen oxides as 270
 - in producing hydrogen gas 622
- Catalytic converter 221, 620–621
- Cathode** The electrode at which reduction occurs in a voltaic cell. It is the positive electrode. 225
- Cation** An ion formed from an atom that has lost one or more electrons and thus has become positively charged. 49
 - formation of 95, 96–97
 - monatomic
 - naming 99
 - roles in body 100
 - names 105
 - polyatomic 101
 - produced by ionizing radiation 730
- Celgene Corporation 673
- Cellulose 674, 676–677
 - molecular structure of 677
- Celsius scale 18–19
 - Celsius to Fahrenheit conversion 312–314
 - Celsius to Kelvin conversion 312–314
- Cesium (Cs), electron configuration of 434
- Cesium-137 730
- Cesium chloride, crystal structure of 101–102
- Chain-growth (or addition) polymers** A polymer that contains all of the atoms of the original reactant in its structure. This category includes polyethylene, polypropylene, and poly(vinyl chloride). 693
- Chain reaction** A process in which one of the products of a reaction initiates another identical reaction. 739
- Chapter Objectives 6
- Charge
 - in atoms 47
 - in chemical bonds 76, 548–551
 - in HCl molecules 74
 - in hydrogen bonds 553
 - of ions 95–98
 - in London forces 556
 - in molecules 552–553
 - in water molecules 87
- Charge cloud, for electrons 48, 418–421
- Charles' Law** The pressure of a gas is inversely proportional to the volume it occupies if the number of gas particles and the temperature are constant. 489
- Chemical bond** An attraction between atoms or ions in chemical compounds. Covalent bonds and ionic bonds are examples. 73–77. *See also* Ionic bond; Covalent bond
 - angles between 86–88, 468–474
 - double bond 83
 - energy and 253–254
 - ionic bond 75–77
 - most common bonding patterns 83
 - nonpolar covalent 74
 - polar covalent 74
 - predicting bond type 77–79, 548–549
 - summary 76
 - triple bond 83
- Chemical change. *See* Chemical reaction
- Chemical compound. *See* Compound
- Chemical Elements. *See* Element
- Chemical engineering 609
- Chemical equation 126–133
 - for acid-base reactions 183–187
 - balancing 128–133
 - polyatomic ions 129, 132
 - Study Sheet 129
 - chemical calculations and 367
 - complete 140
 - complete ionic 139
 - heat and 128
 - interpreting 126–128
 - molecular 140
 - net ionic 140
 - physical states and 127
 - special conditions and 127–128
- Chemical equilibrium. *See* Equilibrium
- Chemical formula** A concise written description of the components of a chemical compound. It identifies the elements in the compound by their symbols and indicates the relative number of atoms of each element with subscripts. 70–71. *See also* Chemical nomenclature
 - for acids 168–170
 - for binary covalent compounds 93
 - in chemical equations 127
 - conversion factors from 342–345
 - for monatomic ions 98
 - of polyatomic ions 103
 - of polymers 691–694
- Chemical nomenclature
 - binary acids 168
 - binary covalent compounds 90–94
 - memorized Names 90
 - names without prefixes 93
 - naming 91–92
 - prefixes used to name 91
 - recognizing from formulas 91
 - recognizing from names 93
 - systematic names 90–92
 - ionic 104–108
 - oxyacids 169
 - summary 171–172

- Chemical reaction** The conversion of one or more pure substances into one or more different pure substances. 126
- acid-base 180–189
 - chemical equations for 126–128
 - collision theory for 610
 - combination 218
 - combustion 219–221
 - completion 164
 - converting to names 171–172
 - decomposition 219
 - double-displacement 136
 - endothermic 264–265
 - energy and 263–265
 - equilibrium constants for 626–631
 - exothermic 263–264
 - general process, collision theory 610–616, 658–664, 674–680, 688–694, 690–696, 716–722
 - neutralization 180–187
 - oxidation-reduction 208–211
 - precipitation 137–143. *See also* Precipitation reaction
 - predicting extent of 626–629
 - rate 616–620
 - concentration effect 617–618
 - temperature effect 616–617
 - reversible 163, 621–622
 - reversible reaction and equilibrium 621–625
 - single-displacement 222
 - synthesis 218
 - types of 218–224
- Chemistry** The structure and behavior of matter. 4. *See also* Organic chemistry; Biochemistry
- combinatorial 673
 - Green. *See* Green Chemistry
 - nuclear 715–725
 - organic 657–672
 - suggestions for studying 5
- Chemists 4
- Children
- effects of ionizing radiation on 730
 - fingerprints of 541
- Chili peppers 583
- Chloral hydrate 464
- Chloride ion 49
- in sodium chloride 70
 - solubility of compounds with 141
- Chlorine (Cl)
- as anion 75–76
 - bleach and 188
 - catalyst for ozone destruction 618–620
 - in chlorofluorocarbons 270
 - diatomic molecules of 55
 - electrolysis and 227
 - in ionic bonds 75
 - ion formation 95
 - Lewis structure of 80
 - most common bonding pattern 455
 - product of the electrolysis of salt 39
 - reaction with alkali metals 42
 - structure 55
 - threshold limit value, or TLV, and 522
 - use and production 525, 604
 - valence electrons 456
- Chlorine-36 734
- Chlorine gas, molecules of 80
- Chlorobutane, formation of 382
- Chlorofluorocarbon, CFC** Compound composed of just carbon, chlorine, and fluorine. 270–272
- damage to ozone 270
 - polystyrene foam and 272
 - substitutes 272
- 1-Chloropropane, melting point of 313
- Chocolate, taste of 177
- Cholesterol, structure of 685–686
- Chromite 384
- Chromium(III) oxide 108
- as catalyst 622
 - catalytic converter and 221
 - empirical formula of 346
 - production and use 401, 408
- Chromium (Cr), sources of 365
- Chyme 688
- Chymotrypsin, in digestion 688
- Citric acid 160
- taste of 177
- Citrine 362
- Clark, Desmond 733
- Classification of Matter 70–73, 126–129, 160–163, 168–171, 178–183, 188–191, 208–211, 213–216, 218–221, 224–227, 250–253, 263–269
- mixture 71
 - pure substance 71
 - Study Sheet 72, 500, 507, 512, 550
- Classifying compounds 78
- Cleaning with soap and detergent 586–587
- Clean Air Act of 1967 523
- Clinton, Bill 5
- Coal, acid rain and 167
- Cobalt-60
- cancer radiation treatment and 731
 - food irradiation and 735
 - gamma ray emission and 722
- Coefficients** The numbers in front of chemical formulas in a balanced chemical equation. 127
- Coffee
- pH of 179
 - removing caffeine 515
- Cold-start emissions, catalytic converters and 221
- Cold packs 264
- Collision theory** A model for the process of chemical change. 610–616, 658–664, 674–680, 688–696, 716–722
- orientation 615
 - steps 610–612
 - summary 615–616
- Combination (or synthesis) reaction**
- The joining of two or more elements or compounds into one product. 218
- Combinatorial chemistry 673
- Combined gas law equation 500
- Combustion analysis, empirical and molecular formulas from 353
- Combustion reaction** Rapid oxidation accompanied by heat and usually light. 219–220
- incomplete 221
 - Study Sheet 220
- Complete (or molecular) equation** A chemical equation that includes uncharged formulas for all of the reactants and products. The formulas include the spectator ions, if any. 140
- Complete combustion 219–220
- Complete electron configuration 430–432
- Complete ionic equation** A chemical equation that describes the actual form for each substance in solution. For example, ionic compounds that are dissolved in water are described as separate ions. 139
- Completion reaction 164
- Compound** A substance that contains two or more elements, the atoms of these elements always combining in the same whole-number ratio. 70
- binary covalent 90
 - binary ionic 104
 - classification 78
 - element versus 70
 - ionic 78
 - molar masses of 337–341
 - molecular 78
 - as pure substance 70–73
- Computer-based tools that accompany this text 7
- Concentration** The number of particles per unit volume. For gases, it is usu-

- ally described in terms of moles of gas particles per liter of container. Substances in solution are described with molarity (moles of solute per liter of solution). 617
 disruption of equilibrium and 634
 equilibrium constants and 626–629
 rate of reaction and 617–618
- Condensation** The change from vapor to liquid. 534
 dynamic equilibrium between evaporation and 537–539
 rate of 537
- Condensation (or step-growth) polymer** A polymer formed in a reaction that releases small molecules, such as water. This category includes nylon and polyester. 691
- Condensation reaction** A chemical reaction in which two substances combine to form a larger molecule with the release of a small molecule, such as water. 680
- Condensed formula 659
- Confirmation, in scientific method 9
- Conjugate acid** The molecule or ion that forms when one H^+ ion is added to a molecule or ion. 189
- Conjugate acid-base pair** Two molecules or ions that differ by one H^+ ion. 189–190
- Conjugate base** The molecule or ion that forms when one H^+ ion is removed from a molecule or ion. 190
- Conservation of Energy, Law of 252
- Control rods** Rods containing substances such as cadmium or boron (which are efficient neutron absorbers), used to regulate the rate of nuclear fission in a power plant and to stop the fission process if necessary. 740
- Conversion factor** A ratio that describes the relationship between two units. 288–290
 atomic mass as 335
 density as 303
 English-metric 292
 in equation stoichiometry 372
 formula mass as 340
 from percentage 306
 metric-metric 289
 molecular mass as 337
 percentage 306
- Cooling, in evaporation 536–537
- Copper(II) ion, voltaic cells and 224–226
- Copper(II) oxide, in catalytic converter 221
- Copper sulfate, reaction with zinc 222–223
- Corliss, Jack 641
- Corundum 359
- Counting by weighing 331–333
- Covalent bonding patterns 454–455
- Covalent bond** A link between atoms that results from their sharing two electrons. 54
 common bonding patterns 454
 double bonds 83
 formation of 74
 most common bonding patterns 455
 polar or nonpolar 548
 triple bond 83
- Creatine 687
- Critical temperature 514
- Cronenberg, David 7
- Crude oil 556–557
- Crystals** Solid particles whose component atoms, ions, or molecules are arranged in an organized, repeating pattern. 139
- Cubic centimeter 15
- Cubic meter 12
- Cyanide ion, determining Lewis structure 461–462
- Cycle, in electromagnetic radiation 261
- Cyclopropane 713
- Cysteine (Cys, C)
 disulfide bonds between 682
 structure of 679
- D**
- d block, on periodic table 428–429
- Dacron, as polyester 693
- Dalton's Law of Partial Pressures** The total pressure of a mixture of gases is equal to the sum of the partial pressures of each gas. 509–513, 547–551, 621–625
- Dead Sea Scrolls 734
- Decaffeination 515
- Decimal place
 calculators and 294
 measurements and 293
 rounding for addition and subtraction and 299
- Decomposition reaction** The conversion of one compound into two or more simpler substances. 219
- Denature** To change the tertiary structure of a protein, causing it to lose its natural function. 689
- Density, mass** Mass divided by volume. 301–305
 calculating for gases 498
 of common substances 302
 definition 301
 determination of 304–305
 substance identification and 302
 temperature and 301
 units of 302
- Designing Safer Chemicals Award 5
- Detergent 587
 cleaning with 586–587
 pH and 179
- Deuterium 50–51
 in heavy water 313
- DEZ treatment 187
- Diamond 47
 atoms in 48, 334
 London forces in 558–559
- Diatomic** Composed of paired atoms. The diatomic elements are H_2 , N_2 , O_2 , F_2 , Cl_2 , Br_2 , and I_2 . 55
- Dichlorine monoxide, production and use 247
- Dichloromethane, in decaffeinating coffee 515
- Dietary calorie, Cal Equivalent to 4.184 kJ 257
- Dietary Supplement and Health Act of 1994 687
- Diethyl ether, structure of 665
- Diethyl zinc (DEZ), in book preservation 187
- Difference in electronegativity, in predicting bond type and polarity 548–549
- Digestion** The process of converting large molecules into small molecules that can move into the blood stream to be carried throughout the body. 688–690
- Digestive enzymes 688–690
- Digital readouts 23
- Dihydrogen phosphate, as amphoteric 191
- Dimensional analysis. *See* Unit analysis
- Dimethyl ether, Lewis structure for 464
- Dipole** A molecule that contains an asymmetrical distribution of positive and negative charges.
 bond 549
 induced 556–557
 instantaneous 556–557

- Dipole-dipole attraction** The intermolecular attraction between the partial negative end of one polar molecule and the partial positive end of another polar molecule. 547
hydrogen bonds and 554
London forces and 556
- Diprotic acid** An acid that can donate two hydrogen ions per molecule in a reaction. 162
- Dirac, Paul Adrien 437
- Direct-contact method 515
- Disaccharide** Sugar molecule composed of two monosaccharide units. 676
digestion products 688
- Dispersion forces. *See* London forces
- Disproof, in scientific method 9
- Disruption of equilibrium 634–640
catalysts and 638–639
concentrations and 634–637
Le Chatelier's Principle 638–640
- Distance, between particles of gases 484
- Distillation, of salt water 39
- Disulfide bond** A covalent bond between two sulfur atoms on cysteine amino acids in a protein structure. 682
- Division, rounding off for 294
- DNA (deoxyribonucleic acid)
aging and 212
hydrogen bonding in 554
- Dolomite rock, hard water and 144
- Dopamine, Parkinson's disease and 8
- Double-displacement reaction** A chemical reaction that has the form: $AB + CD \rightarrow AD + CB$ 136
acid-base 184
precipitation 136–139
- Double-exchange reaction. *See* Double-displacement reaction
- Double-replacement reaction. *See* Double-displacement reaction
- Double bond** A link between atoms that results from the sharing of four electrons. It can be viewed as two 2-electron covalent bonds. 83, 451
- Dow Chemical Company 272
- Drug design 673
- Dry cell battery, chemistry of 226–227
- Dry ice 576
- Dynamic equilibrium** A system that has two equal and opposing rates of change, from state A to state B and from state B to state A. There are constant changes between state A and state B but no net change in the amount of components in either state.. *See* Equilibrium
- E**
- E.I. Du Pont de Nemours and Company 691
- Earth, elemental composition of 743
- Electric cars, zinc-air batteries in 229
- Electric current, base unit of 11
- Electric field, in electromagnetic radiation 261
- Electric power plant, using nuclear fission 738–741
- Electric spark, ozone created by 266
- Electrode** A electrical conductor placed in the half-cells of a voltaic cell. 225
- Electrolysis** The process by which a redox reaction is pushed in the non-spontaneous direction or the process of applying an external voltage to a voltaic cell, causing electrons to move from what would normally be the cell's cathode toward its anode. 227
- Electrolyte** The portion of a voltaic cell that allows ions to flow. 226
- Electromagnetic radiation. *See* Radiant energy
- Electron** A negatively charged particle found outside the nucleus of an atom. 48, 414–418
in atoms 48–50
in batteries 224
as beta decay 720–721
in chemical bonds 74, 448–454
constructing Lewis structures and 456
electronegativity and 548
in ions 48–50
in isotopes 50–51
like guitar strings 414–416
in metallic elements 56
in multi-electron atoms 424
octets of 80
in oxidation-reduction reactions 208–211
particle interpretation of the wave character 418
as standing wave 416
valence 79
waveform of 416
- Electron-dot symbol** A representation of an atom that consists of its elemental symbol surrounded by dots representing its valence electrons. 79–80, 83, 450
- Electronegativity** A measure of the electron attracting ability of an atom in a chemical bond. 548–551
Study Sheet 550
- Electron capture** In radioactive nuclides that have too few neutrons, the combination of an electron with a proton to form a neutron, which stays in the nucleus. 721
nuclear equations for 723–725
- Electron cloud 48, 418
- Electron configuration** A description of the complete distribution of an element's electrons in atomic orbitals. 424, 426–427
abbreviated 433–436
Study Sheet 431, 456
- Electron group geometry** A description of the arrangement of all the electron groups around a central atom in a molecule or polyatomic ion, including the lone pairs. 469
- Electron sharing, in chemical bonds 74
- Electron spin 424, 426
- Electron transfer, in chemical bond formation 75–76
- Electron volt (eV)** An energy unit equivalent to 1.6×10^{-19} joules. It is often used to describe the energy associated with nuclear changes. 737
- Electroplating 227
- Electrostatic force (or electromagnetic force)** The force between electrically charged particles. 718
- Element** A substance that cannot be chemically converted into simpler substances; a substance in which all of the atoms have the same number of protons and therefore the same chemical characteristics. 38–57
artificial 52
atomic mass of 335
compound versus 70–71
diatomic 55
electronegativities of 548
electron configurations and orbital diagrams 431, 456
isotopes of 50–51
list of common 41
magic numbers for 737
making new elements 52
metallic 56–57
metalloids or semimetals 44
metals 43
molar masses of 335–336
names of 40, 41–42
naturally occurring isotopes 51
nonmetals 43
nuclear stability of 718–719

- in ordinary substances 69
 origin of 742
 oxidation numbers of 213–218
 particle interactions 558
 periodic table of 42–46
 as pure substances 71
 solids, liquids, and gases 45
 structure of 46–57
 symbols for 41
 table of percent abundances in
 Earth's crust, waters, and atmosphere 743
- Element 111, creation of 52
 Element 114, creation of 52
 Emerald 362
- Empirical formula** A chemical formula that includes positive integers that describe the simplest ratio of the atoms of each element in a compound. 346
 calculating 346–350
 converting to molecular formula 350–353
 Study Sheet 348
- Enamel 186
- Endergonic changes** Changes that absorb energy 253
 energy diagram 614–615
- Endothermic change** A change that leads a system to absorb heat energy from the surroundings. 265
- Energy** The capacity to do work. 250–252
 activation 612–614
 chemical bonds and 253–254
 chemical changes and 263–265
 conservation of. *See* Law of Conservation of Energy
 endergonic (or endogonic) changes 253
 of events 258
 exergonic (or exogonic) changes 254
 exothermic 264
 in food 258
 heat 259–260
 kinetic. *See* Kinetic Energy, KE
 nuclear 737–742
 of photons 260–262
 potential 252–253
 radiant 260–262
 storage in the body 674
 thermal energy 259
 units of 257
 water formation and 257
- Energy diagram 614–615
 Energy level. *See* Principal energy level
 Engineering, chemical 609
- English-metric unit conversion factors 292, 369
 English system, metric system versus 14, 291
 Environment, chemistry and 4
 Environmentally Benign Chemistry. *See* Green Chemistry
 Environmental Protection Agency 5, 728
- Enzyme** A naturally occurring catalyst. 618, 688–690
 digestive 688–690
 metallic cations in 100
 why specific 690
- Epictetus 288
 Epinephrine 582
- Equation. *See* Chemical equation, Nuclear equation; Ideal gas equation
- Equation stoichiometry** Calculations that make use of the quantitative relationships between the substances in a chemical reaction to convert the amount of one substance in the chemical reaction to the amount of a different substance in the reaction. 371–375
 ideal gases and 502–509
 molarity and 388–392
 Study Sheet 391
- Equilibrium 621–622
 disruption of 634–640
 dynamic 538–540
 effect of catalyst 638–639
 effect on changing concentrations 634–637
 gas solutions and 594–595
 heterogeneous 630–631
 homogeneous 624
 Le Chatelier's Principle and 638–640
 reversible reactions and 621–633
 saturated solution and 592–593
 ski shop analogy for 625
- Equilibrium constant** A value that describes the extent to which reversible reactions proceed toward products before reaching equilibrium. 626–629
 calculating values for 627–628
 extent of reaction and 629
 with heterogeneous equilibria 630–632
 table of 628
 temperature and 632–633
 writing expressions for 626–627
- Equilibrium constant expression** An expression showing the ratio of the concentrations of products to the concentrations of reactants for a reversible reaction at equilibrium. 626
- Equilibrium vapor pressure** The partial pressure of vapor above a liquid in a closed system with a dynamic equilibrium between the rate of evaporation and the rate of condensation. 539–540
 in bubble formation 543–544
 temperature and 540
- Ester** A compound with two hydrocarbon groups surrounding an oxygen atom. 666–667
 in fingerprints 541
 olestra as 684–685
- Estradiol, structure of 686
 Ethanamide 668
 Ethane 82
 solubility in hexane 581
- 1,2-Ethanediol 663
 Ethanoic acid 664
 Ethanol (or ethyl alcohol)
 in combustion reactions 219
 density of 301
 hydrogen bonds in 554–555
 as intoxicating liquid 89
 Lewis structure 84
 mixing with water 576–577
 production of 628
 solubility in water 593
- Ethene. *See* Ethylene
- Ether** A compound with two hydrocarbon groups surrounding an oxygen atom. 665
- Ethylene (or ethene) 451
 polyethylene formation and 693
- Ethylene dibromide 272
 Ethylene glycol 663
 in polyester formation 692
- Ethylene oxide, use and production 527
 Ethyl alcohol. *See* Ethanol
 Ethyl butanoate 667
 Ethyne. *See* Acetylene
- Evaporation** The conversion of a liquid to a gas. 37, 535–536
 cooling and 536
 rate of. *See* Rate of evaporation
- Exact numbers, significant figures and 295
- Examples, in this book 6
- Excited state** The condition of an atom that has at least one of its electrons in orbitals that do not represent the lowest possible potential energy. 421
- Exercises, in this book 6

- Exergonic changes** Changes that release energy. 254
energy diagram 614
- Exhaust 71
- Exhaust systems, catalytic converters and 221
- Exothermic change** A change that leads to heat energy being released from the system to the surroundings. 264
- Expansion, of solids 35
- Experimentation, in scientific method 8–9
- External kinetic energy 259
- F**
- f block, of elements 429
- Fahrenheit scale 18–19
Fahrenheit to Celsius conversion 312–313
- Family** All the elements in a given column on the periodic table; also called group. 43
- Fat 683
digestion products 688
- Fertilizer
ammonia and 621
nitric acid and 496
- Feynman, Richard 418
- 15-minute rule 6, 7
- Fingerprints 541
- Fireworks
calcium nitrate in 108
light emitted from 421
- Fire extinguishers, sodium carbonate in 175
- Fission** Nuclear reaction that yields energy by splitting larger atoms to form more stable, smaller atoms. 738–739
- Flame retardant, phosphates in 103
- Flashtubes 523
- Flerov Laboratory of Nuclear Reactions 52
- Fluorapatite, tooth decay and 186
- Fluoride ion, tooth decay and 186
- Fluorine (F)
covalent bond formation 449–450
diatomic molecules of 55
electron configuration and orbital diagram 427
how made 365
hydrogen bonds and 553
most common bonding pattern 455
oxidation numbers and 214
production of 396–397
structure of 55
valence electrons of 449
- Fluorine-18
positron emission tomography and 732
- Food
Calories in 258
digestion of 688–690
- food, important substances in 674–685
- Food and Drug Administration (FDA) 515
- Food irradiation 735
- Force, weight as 16
- Forensic chemistry 541
- Formaldehyde 652, 665
determining Lewis structure 460–461
in herbicide formation 621
production and use 237, 653
- Formic acid, molecular structure of 664
- Formula. *See* Chemical formula; Empirical formula; Molecular formula
- Formula mass** The weighted average of the masses of the naturally occurring formula units of the substance. It is the sum of the atomic masses of the atoms in a formula unit. 340–341
calculations 341
- Formula unit** A group represented by a substance's chemical formula, that is, a group containing the kinds and numbers of atoms or ions listed in the chemical formula. 339
- Fortrel® 693
- Fractional charge, in chemical bonds 74
- France, zinc-air batteries in 229
- Free radicals Particles with unpaired electrons. 730
- Fructose 674–675
- Functional group** A small section of an organic molecule that to a large extent determines the chemical and physical characteristics of the molecule. 662
- Furnace method 368
- Fusion** Nuclear reaction that yields energy by combining smaller atoms to make larger, more stable ones. 738, 742
- G**
- Galactose 674–675
- Galapagos Islands, global warming experiments at 385
- Galileo Galilei 9
- Gallium-67, radioactive decay of 724
- Galvanizing nails 132
- Gamma aminobutanoic acid, gamma aminobutyric acid, or GABA 669
intoxicating liquids and 89
- Gamma ray A stream of high-energy photons. 261, 722
antimatter and 437
harmful effects of 730–731
penetration of the body 731
in radioactive decay 722
- Gas** The state in which a substance can easily change shape and volume. 34, 37–38.
Avogadro's Law 491
in book preservation 187
breathing and 493
calculations
equation stoichiometry 502
Study Sheet 507–508
using the combined gas law equation 500–502
Study Sheet 500
using the ideal gas equation 494–499
Study Sheet 495
using the molar volume at STP 503
- Charles' Law 489
concentration effect on reaction rates 617
- Dalton's Law of Partial Pressures 509–513, 547–551
study sheet 512
- densities of 302
- equilibrium constants and 626–627
- expansion 575
- Gay-Lussac's Law 488
- greenhouse gases 384–385
- heterogeneous equilibria and 630–632
- ideal 485
- ideal gas calculations 494–502
- instrument-carrying balloons and 493
- internal combustion engine and 492
- liquids changing from and into 534–536
- model 484
- molar volume 503
- noble 43
- partial pressure of 509–513, 595
- particle collisions 484
- pressure 485
- pressure and industrial safety 501–502
- properties of 485
- race cars and air density 499
- real 484

- relationships between properties 484–491
- relationship between number of gas particles and pressure 490
- relationship between number of gas particles and volume 491
- relationship between pressure and temperature 488
- relationship between volume and pressure 486–487
- relationship between volume and temperature 489
- solubility of 594–595
- typical particle velocities 484
- universal gas constant 494
- vapor as 534
- volume occupied by particles 484
- Gaseous elements 45
- Gasoline 221, 661
- in catalytic converters 221
- combustion of 219
- composition of 82
- in internal combustion engines 492
- Gastric juice 506
- pH and 179
- Gas pressure. *See also* Gas
- boiling-point temperature and external 542–544
- breathing and 493
- in bubble formation 542–544
- in combined gas law equation 500–502
- Dalton's Law of partial pressures 509–513
- equilibrium vapor 539–541
- in gas stoichiometry 502–509
- in ideal gas equation 494
- internal combustion engine and 492
- number of gas particles and 490
- standard 503
- temperature and 488
- volume and 486–487
- Gas stoichiometry 502–509
- Gay-Lussac's Law** The pressure of a gas is inversely proportional to the volume it occupies if the number of gas particles and the temperature are constant. 488
- Geometric sketch 86
- Geometry 467–471. *See* Molecular shape
- Study Sheet 472
- German Cancer Research Center 52
- Gesellschaft für Schwerionenforschung (GSI) 52
- Gide, Andre 33
- Giga (G) prefix 13
- Girard, Georges 11
- Glacial acetic acid 162
- Glioma 741
- Global warming 384–385, 597, 621, 673, 687, 741
- Glucose 674–675
- empirical and molecular formulas of 346
- Glutamic acid, structure of 679
- Glutamine, structure of 679
- Glycerol or glycerin 663
- Glycine, structure of 678
- Glycogen 676–677
- Gold (Au)
- atom of 47
- as malleable 43
- origin of name 41
- scanning tunneling microscope image of 46
- Gold-198, radioactive decay of 724
- Graduated cylinder 21
- Gravitational attraction, weight and 16
- Greenhouse gases 384, 597
- Greenspan, Alan 48
- Green Chemistry 5
- decaffeinating coffee and 515
- Designing Safer Chemicals Award 5
- development of new and better catalysts 621, 673, 687, 741
- Green Chemistry Challenge Awards 5
- Green Chemistry Program 5
- Making Chemicals from Safer Reactants 351
- Sea-Nine antifoulant and 5
- spray paint and 514
- Ground state** The condition of an atom whose electrons are in the orbitals that give it the lowest possible potential energy. 421
- Group** All the elements in a given column on the periodic table; also called family. 43
- Guitar strings, like electrons 414–416
- H**
- Half-life** The time it takes for one-half of a sample to disappear. 726–728
- Half-reaction** Separate oxidation or reduction reaction equation in which electrons are shown as a reactant or product. 210
- Halogen
- bonding pattern 81
- covalent bond formation 454
- ion formation 95
- London forces in 556–557
- in periodic table 43
- Halons 272
- Hard water, soaps and detergents in 587
- Hearst, William Randolph 167
- Heat** The thermal energy that is transferred from a region of higher temperature to a region of lower temperature as a consequence of the collisions of particles. 260
- in chemical equations 128
- in endothermic reactions 265–266, 614–615
- as energy 260
- transfer 259–260
- Heat of reaction 264
- Heavy-ion therapy 52
- Heavy water, freezing point of 313
- Heidelberg Radiology Clinic 52
- Helium
- to avoid the bends 596
- formation 742
- Helium-4, in treating brain cancer 741.
- See also* Alpha particles
- Hematite 363
- Hemoglobin 221
- carbon monoxide poisoning and 221
- iron ions in 100
- Heptane, octane rating and 661
- Heterogeneous catalyst** A catalyst that is in the same phase as the reactants (so that all substances are gases or all are in solution). 620
- Heterogeneous equilibrium** An equilibrium in which the reactants and products are not all in the same phase (gas, liquid, solid, or aqueous). 630–631
- Hexane, solubility in 578–581
- 1-Hexanol 660
- 3-Hexanol, molecular structure of 660
- High-density polyethylene (HDPE) 693
- Histidine, structure of 679
- Homogeneous catalyst** A catalyst that is in the same phase as the reactants (so that all substances are gases or all are in solution). 620
- Homogeneous equilibrium** An equilibrium system in which all of the components are in the same phase (gas, liquid, solid, or aqueous). 624
- Hormone 685
- Huber, Claudia 641
- Hydrazine, production and use 410
- Hydride ion 98

- Hydriodic acid
 forming name of 168
 production and use 407, 654
- Hydrobromic acid, forming name of 168
- Hydrocarbon** Compounds that contain only carbon and hydrogen. 82, 557
 catalytic converters and 221
 in combustion reactions 219
 in internal combustion engines 492
 London forces among 556–557
 solubility of 579
- Hydrochloric acid 160–161, 621
 as binary acid 162
 dissolving basic hydroxides 184
 dissolving in water 160
 dissolving limestone 186
 in formation of magnesium chloride 247
 forming name of 168
 in gastric juices 506
 in processing corn syrup 160
 production and use 74, 161, 236, 325, 525
 reaction with calcium carbonate 126
 as strong acid 163, 165, 166
- Hydrochlorofluorocarbons (HCFCs) 272
- Hydrofluoric acid
 forming name of 166
 light bulbs and 237
 used to make CFCs 236
- Hydrogenation** A process by which hydrogen is added to an unsaturated triglyceride to convert double bonds to single bonds. This can be done by combining the unsaturated triglyceride with hydrogen gas and a platinum catalyst. 683
- Hydrogen (H)
 in acid-base reactions 180–192
 acids and 160–165
 atomic orbitals 416–423
 from Big Bang 742
 in Brønsted-Lowry acids and bases 188–190
 combustion 126, 219, 263
 covalent bond formation 450
 electronegativity of 548
 formation from water 219
 formation of hydrogen molecules 450
 in formation of water 126–127
 ion formation 96
 isotopes of 50–51
 nuclear fusion of 742
 oxidation number of 214
 position on periodic table 45
 production and use 244, 621–624
 structure 54
 in synthesis gas 622
- Hydrogen atom, electron waveforms in 416–423
- Hydrogen bond** The intermolecular attraction between a nitrogen, oxygen, or fluorine atom of one molecule and a hydrogen atom bonded to a nitrogen, oxygen, or fluorine atom in another molecule. 553–555
 in ethanol/water solutions 576
 predicting existence of 559
 in proteins 682
- Hydrogen bromide, threshold limit value, or TLV 522
- Hydrogen carbonate ion
 as amphoteric 191
 as weak base 175
- Hydrogen chloride 74
 chemical bonds in 74
 dipole-dipole attractions 547
 dissolved in water 160
 Lewis structure of 80–81
 solubility in water 593
- Hydrogen cyanide 621
 molecular geometry of 471
- Hydrogen fluoride
 hydrogen bonds and 553
 Lewis structure of 81
- Hydrogen halides, as polar molecules 553
- Hydrogen iodide, Lewis structure of 81
- Hydrogen peroxide
 aging and 212
 composition of 73
 dark bottles and 243
 empirical and molecular formulas of 346
 as oxidizing agent 212
- Hydrogen sulfate ion 188
 as cleaning agent 188
 as weak acid 166
- Hydrogen sulfide
 Lewis structure of 81
 threshold limit value, or TLV 522
- Hydrolysis** A chemical reaction in which larger molecules are broken down into smaller molecules by a reaction with water in which a water molecule is split in two, each part joining a different product molecule. 689
- Hydronium ion** H_3O^+ 160–161
 in acid-base reactions 180–185
 acids and 160–166
 pH and 178–180
- Hydrophilic** (“water loving”) A polar molecule or ion (or a portion of a molecule or polyatomic ion) that is attracted to water. 582
- Hydrophobic** (“water fearing”) A nonpolar molecule (or a portion of a molecule or polyatomic ion) that is not expected to mix with water. 582
- Hydrothermal vent 641–642
- Hydroxide ion
 covalent bond formation 453
 Lewis structure of 101
 solubility of compounds with 141
- Hydroxides Compounds that contain hydroxide ions. 173
- Hydroxyapatite, in tooth enamel 186
- 3-Hydroxybutanal 669
- 17-Hydroxyprogesterone, molecular structure of 686
- Hypochlorite ion
 in bleach 188
 sunlight and swimming pools 241
- Hypothesis, in scientific method 8–9
- ## I
- Ideal Gas** A gas for which the ideal gas model is a good description. 485
 calculations involving 494–502
 equation stoichiometry and 502–507
- Ideal gas constant (R) 494
- Ideal Gas Equation 494–499
 combined gas law equation and 500
 equation stoichiometry and 504–509
- Ideal gas model** The model for gases that assumes (1) the particles are point-masses (they have mass but no volume) and (2) there are no attractive or repulsive forces between the particles. 485
- Incandescent light bulbs 496
- Induced dipole 556
- Industrial chemistry 4, 5
- Infrared (IR) radiation 262
- Inner transition metals** The 28 elements at the bottom of the periodic table. 44
- Insoluble substances 140–141, 578–581
- Instantaneous dipole 556
- Intermolecular attraction** Attraction between molecules. 553–557
 dipole-dipole attraction 547
 hydrogen bonds 553–555

London forces 556–557

Internal combustion engine 492
 effects of weather on 498
 gases and 492

Internal kinetic energy. *See* Thermal Energy

International System of Measurement 10–19
 abbreviations 13
 metric prefixes 12–13
 units derived from base units 12

Intestines 689

Intoxicating liquids 89

Iodide ion, solubility of compounds with 141

Iodine (I)
 beta emission and 720
 diatomic molecules of 55
 electron capture and 721
 London forces and 556
 most common bonding pattern 455
 name of 41
 production and use 235
 structure of 55
 tincture of 556

Iodine-125
 electron capture by 736
 radioactive decay of 721

iodine-131 730–731

Iodine pentafluoride, production and use 243, 405

Ion Any charged particle, whether positively or negatively charged. 48–50
 anion 49. *See also* Anion
 cation 49. *See also* Cation
 charges on monatomic 98
 formation of 75
 monatomic anion charges 96
 monatomic anion names 98
 monatomic cation. *See* Cation, monatomic
 polyatomic. *See* Polyatomic ion
 predicting charges 95–98
 size of 100
 spectator 139–140
 symbols for 49

Ionic bond The attraction between a cation and an anion. 75–77
 in ionic compounds 78
 predicting existence of 548–551

Ionic compound A compound that consists of ions held together by ionic bonds. 78, 94–108
 as bases 175
 binary 104, 107, 208–210
 formulas to names 104–106
 formula mass of 340–341

names to formulas 107–108
 polyatomic ions is 101–103
 reactions of acids with 181
 recognizing from formulas 104
 solubility of 141
 solution of 133–135
 as strong and weak bases 175
 structure of 100–102
 types of 104
 uses of 94, 102

Ionizing radiation Alpha particles, beta particles, and gamma photons, which are all able to strip electrons from atoms as they move through matter, leaving ions in their wake. 730

Iridium (Ir), in catalytic converter 221

Iridium-192, checking pipe joints and 735

Iron(II) sulfate, in global warming experiments 385

Iron(III) sulfate, formula mass calculations for 341, 343

Iron-59 736

Iron (Fe)
 electron configuration and orbital diagram for 432
 formation of 743
 formation of pig 218, 509
 global warming and 384–385
 as limiting reactant in global warming 384

Island of stability, of nuclides 719

Isobutene, use 662

Isoleucine (Ile, I), molecular structure of 678

Isomers Compounds that have the same molecular formula but different molecular structures. 464
 Lewis structures of 464–465
 of organic compounds 658

Isooctane 661

Isopropyl alcohol. *See* 2-propanol

Isotopes Atoms that have the same number of protons but different numbers of neutrons. They have the same atomic number but different mass numbers. 50–52
 of artificial elements 52
 atomic numbers of 51
 of carbon 333
 mass numbers of 51
 in nuclear reactions 722
 symbol for 716–717

Isovaleraldehyde 665–666

J

Jeans, James Hopwood 48

Jesus of Nazareth 734

Jewelry, elements in 41

Joule, J The accepted SI unit for energy. 257

K

Kaposi's sarcoma 673

Kelvin, a temperature unit 19

Kelvin scale 11, 18–19
 gas temperature and 485
 temperature conversions for 312–314

Kerosene, London forces and 556

Ketone A compound that have a hydrogen atom or a hydrocarbon group connected to a -CHO group. 666

Kettering, Charles F. 414

Khirbat Qumrân 734

Kilocalorie (kcal, Cal) 257

Kilogram (kg) 11

Kilojoule (kJ) 258

Kilometer (km) 13

Kilopascal (kPa) 485

Kilo (k) prefix 13

Kinetic energy, KE The capacity to do work resulting from the motion of an object. 251
 chemical reactions and 263–264
 in formation of water 263
 internal and external 259
 mass and 251
 of reactant molecules 611–612
 solution of ammonium nitrate and 264
 velocity and 251

Kinetic molecular theory. *See* Particle nature of matter

Knockout drops 464

Krypton, light bulbs and 499

Krypton-81 717, 734

L

Lactase, in digestion 688

Lactic acid, in cosmetic lotion 205

Lactose, or milk sugar 676

Laskowski, Edward R. 687

Latent fingerprints 541

Lawrence Laboratory 725

Law of Conservation of Energy
 Energy can be neither created nor destroyed, but it can be transferred from one system to another and changed from one form to another. 252

- L-dopa 8
- Lead(II) ion, solubility of compounds with 141
- lead-206, in radioactive decay series 729
- Lead-acid batteries, chemistry of 229
- Lead (Pb)
in creating elements 110 52
density of 301
gasoline and 244
- Lebowitz, Fran 287
- Leclanché cell 226–227
- Length 14–15
range of 15
- Leucine (Leu, L), structure of 678
- Levi, Primo 3
- Levodopa, in Parkinson's disease 8
- Levodopa, in Parkinson's disease 8
- Lewis electron-dot symbols 79
- Lewis structure** A representation of a molecule that consists of the elemental symbol for each atom in the molecule, lines to show covalent bonds, and pairs of dots to indicate lone pairs. 80–84, 450, 455–465
general steps for drawing 458, 484
resonance and 465–467
simple procedure 83–85
Study Sheet 456–457
- Le Chatelier's principle** If a system at equilibrium is altered in a way that disrupts the equilibrium, the system will shift so as to counter the change. 638–640
- Libraries, of drugs 673
- Life
hydrogen bonds and 554
origin of 640–641
- Light bulbs
argon gas in 512
filament evaporation in 496, 499
flash tubes 523
fluorescent 521
- “Like dissolves like” guideline, for solubility 578–581
- Lime 245
- Limestone 186, 616
acid rain and 167
increasing permeability of 161
- Limestone caverns 204
- Limiting reactant** The reactant that runs out first and limits the amount of product that can form. 376–381
global warming and 384–385
how chosen 376–377
Study Sheet 380
- Linear geometry** The geometric arrangement that keeps two electron groups as far apart as possible. It leads to angles of 180° between the groups. 471
- Linear molecules 471, 472
- Line drawing 582, 659
- Ling Po 7
- Liquid** The state in which a substance has a constant volume at a constant temperature but can change its shape. 34, 36
boiling 542–544
dissolving gases in 594
dissolving solids in 588–593
dynamic equilibrium between vapors and 595
heterogeneous equilibria and 630–631
- Liquid-liquid solutions 136
- Liquid elements 45
- Liter 12
- Lithium-7, in treating brain cancer 741
- Lithium (Li)
from Big Bang 742
electron configuration and orbital diagram 426
formation of 742
- Lithium batteries 229
- Lithium hydroxide, uses 173
- Litmus, detecting acids and bases with 180
- London forces** The attractions produced between molecules by instantaneous and induced dipoles. 556–557
molecular size and 556
- Lone pair** Two electrons that are not involved in the covalent bonds between atoms but are important for explaining the arrangement of atoms in molecules. They are represented by pairs of dots in Lewis structures. 80, 450
- Los Angeles, photochemical smog in 266
- Low-density polyethylene (LDPE) 693
- Lucretius 177
- Luminous intensity, base unit for 11
- Luminous tubes 501
- Lungs, gases in 493
- Lye. *See* Sodium hydroxide
- Lye soap 586
- Lysine (Lys, K)
molecular structure of 679
in salt bridges 682
- M**
- “Mickey Finn” sedative 464
- Magic numbers and nuclear stability 52, 737
- Magnesium (Mg), meals ready to eat (MREs) and 573
- Magnesium chloride, production and use 247
- Magnesium oxide 106
- Magnesium sulfate, use 205
- Magnetic field, in electromagnetic radiation 261
- Magnetic resonance imaging (MRI) 732
- Main-group element** The elements in groups 1, 2, and 13 through 18 (the “A” groups) on the periodic table; also called representative elements. 44
- Malleable** Capable of being extended or shaped by the blows of a hammer. 43
- Maltase, in digestion 688
- Maltose, molecular structure of 676
- Manganese (Mn)
in dry cell batteries 226–227
how made 360
- Manganese(II) oxide, naming 105
- Manganese(II) phosphate
production and use 242
uses 205
- Manganese dioxide, in dry cell batteries 226–227
- Marble, acid rain and 167
- Margarine 683
- Martin, John 384–385
- Mass** The amount of matter in an object. Mass can also be defined as the property of matter that leads to gravitational attractions between objects and therefore gives rise to weight. 16–17
base unit of 11
density and 301–303
of elements and compounds 342–346
English-metric unit conversions of 309
kinetic energy and 251
measuring 16–17
percentage by 306–307
range of 17
weighted average 331
weight and 16–17
- Mass density** Mass divided by volume (usually called density). 301–305
as conversion factor 303–305
- Mass number** The sum of the number of protons and neutrons in an atom's nucleus. 51
binding energy versus 738

- in nuclear equations 723
- in nuclides 716
- Mass percentage 306
- Matches, chemicals in 131
- Matter** Anything that has mass and takes up space. 16
 - chemistry and 4
 - classification of 70–73
 - existence of 437
 - origin of 742
 - as solid, liquid, or gas 34–38
- Mayo Clinic 687
- Meals ready to eat (MRE) 573
- Measurement 9, 9–23
 - digital readouts 23
 - International System of 10–11
 - reporting values from 20
 - trailing zeros and 22
 - uncertainty in 20–23, 293
- Medicine, uses of radioactive substances in 731–732
- Mega (M) prefix 13
- Meitner, Lise 40
- Meniscus, in measurement 21
- Menstrual cycles, hormones in 686
- Menthol 584
- Metal-nonmetal compounds
 - bonds in 549
 - formulas and names of 104
- Metallic bond** The attraction between the positive metal cations that form the fundamental structure of a solid metal and the negative charge from the mobile sea of electrons that surround the cations. 558
- Metallic elements 44
 - attractive forces in 558–559
 - ion charges of 96–98
- Metalloids or semimetals** The elements that have some but not all of the characteristics of metals. 44
 - bonding patterns of 457
 - in periodic table 44
- Metals** The elements that (1) have a metallic luster, (2) conduct heat and electric currents well, and (3) are malleable. 43, 56–57
 - electrolysis to purify 227
 - forming cations 95
 - sea of electrons model 57
- Meter 10, 11
- Methamphetamine, molecular structure of 582–583
- Methamphetamine hydrochloride 582–583
- Methane 82, 447
 - combustion of 250
 - covalent bond formation 451
 - in hydrogen gas production 621–624
 - molecular shape 86–87, 468
 - solubility in water 593
- Methanethiol, in natural gas 219
- Methanoic acid 664
- Methanol 447
 - density of 304
 - hydrogen bonds and 555
 - as polar molecule 553
 - production and use 244, 527, 627
 - water solubility of 580
- Methionine (Met, M), structure of 679
- 3-Methylbutanal 665–666
- Methylene chloride, in decaffeinating coffee 515
- 2-Methylpropene 662
- Methyl alcohol 83. *See also* Methanol
- Methyl bromide 272
 - determining Lewis structure 458–459
 - ozone layer and 3
 - threshold limit value, or TLV, and 522
- Methyl cyanoacrylate, molecular structure of 473
- Methyl ethyl ketone or MEK, molecular structure of 666
- Metric-metric unit conversions 289–291
- Metric prefixes 12–13
 - table of 13
- Metric system 10. *See also* International System of Measurement
- MeV (million electron volts) 737
- Microwaves 262
- micro (μ) prefix 13
- Mifepristone 705
- Milk, pH of 179
- Millimeter of mercury (mmHg), as unit of pressure 485
- milli (m) prefix 13
- Miscible** Can be mixed in any proportion without any limit to solubility. 576
- Mixture** A sample of matter that contains two or more pure substances and has variable composition. 71
 - of gases 509
- Model** A simplified approximation of reality.
 - calculating 387
 - collision theory as 610–616
 - of gases 37
 - ideal gas 485
 - of liquids 36
 - of metallic elements 56
 - of solids 34–35
 - strengths and weaknesses of 448
 - valence-bond 449–454
- Moderator** A substance in a nuclear reactor that slows neutrons as they pass through it. 740
- Molarity** (abbreviated M) Moles of solute per liter of solution. 387–392
 - equation stoichiometry and 388–392
- Molar mass** The mass in grams of one mole of substance. 335–338
 - from atomic mass 335
 - calculations using atomic mass 336
 - calculations using ionic formula mass 341
 - calculations using molecular mass 338
 - in equation stoichiometry 370–374
 - in ideal gas equation 495
 - from ionic formula mass 340
 - from molecular mass 337–338
- Molar volume at STP 503
- Mole (mol)** The amount of substance that contains the same number of particles as there are atoms in 12 g of carbon 12. 11, 333–334
 - in equation stoichiometry 502–509
 - in ideal gas equation 503
- Molecular compound** A compound composed of molecules. In such compounds, all of the bonds between atoms are covalent bonds. 78
 - attractive forces in 559
 - in oxidation-reduction reactions 211
 - water solubility of 579
- Molecular dipole** A molecule with an asymmetrical distribution of positive and negative charge. 547
- Molecular equation.** *See* Complete equation
- Molecular formula** The chemical formula that describes the actual numbers of atoms of each element in a molecule of a compound. 346
 - from empirical formula 350–353
 - empirical formulas versus 346
 - Study Sheet 352
- Molecular geometry** The description of the arrangement of all the atoms around a central atom in a molecule or polyatomic ion. This description does not consider lone pairs. 467–474. *See also* Geometry

- Molecular mass** The weighted average of the masses of the naturally occurring molecules of a molecular substance. It is the sum of the atomic masses of the atoms in a molecule. 337–338
 calculating 338
 in calculating molecular formulas 350–351
- Molecular models 54
- Molecular polarity, predicting 552
- Molecular Shape 86–88
 ball-and-stick model 86
 geometric sketch 86
 space-filling model 86
- Molecular size, London forces and 556–557
- Molecule** An uncharged collection of atoms held together with covalent bonds. 54
 covalent bonds in 448–454
 diatomic 55
 as formula unit 339
 of hydrogen 54
 in molar mass 337
 shapes of 86–87, 467–474
- Momentum, of particles in evaporation 535
- Monatomic anions** Negatively charged particles, such as Cl^- , O^{2-} , and N^{3-} , that contain single atoms with a negative charge. 96. *See also* Anion, monatomic
 charges 96
 naming 98
- Monatomic cation** Positively charged particles, such as Na^+ , Ca^{2+} , and Al^{3+} , that contain single atoms with a positive charge. 97. *See also* Cation, monatomic
 formation 96–97
 naming 99
 roles in body 100
- Monatomic ion, charges 98
- Monoethanolamine 637
- Monomer** The repeating unit in a polymer. 676
 in addition polymers 693
 in polysaccharides 676–677
 in proteins 678
- Monoprotic acid** An acid that donates one hydrogen ion per molecule in a reaction. 162
- Monosaccharide** Sugar molecule with one saccharide unit. 674
- Monosodium glutamate (MSG), taste and 177
- Monsanto Company 621
- Moss Landing Marine Laboratories 384
- Mount Everest, atmospheric pressure at the top 545
- MTBE 665
- Multiplication
 rounding off for 294–299
 significant figures for 294–299
- Mylar, as polyester 693
- N**
- Names
 for acids 168–170
 for binary covalent compounds 90
 for chemical compounds 171–172
 for elements 40–41
 for ionic compounds 98–106
 for organic compounds 661
- Nano (n) prefix 13
- Natrium 41
- Natural gas 447
- Nature, elements found in 40
- Neon (Ne)
 electron configuration and orbital diagram 427
 luminous tubes and 501
 in neon lights 501, 513
- Nerve cells
 intoxicating liquids and 89
 taste and 177
- Net ionic equation** A chemical equation for which the spectator ions have been eliminated, leaving only the substances actively involved in the reaction. 140
- Net rate of solution 589–591
- Neutralization reaction** A chemical reaction between an acid and a base. *See* Acid-base reaction
- Neutron** An uncharged particle found in the nucleus of an atom. 47
 in nuclear fission 738–739
 as nuclear glue 718
 nuclear stability and 718–719
- Newton (N), a unit of force 16
- NiCd batteries. *See* Nickel-Cadmium batteries
- Nickel (Ni), in the creation of elements 110 and 111 52
- Nickel-60, gamma ray emission by 722
- Nickel-cadmium battery, chemistry of 228
- Nicotine 361
- Nippoldt, Todd B. 687
- Nitrate ion
 resonance and 465–467
 solubility of compounds with 141
- Nitric acid
 acid rain and 167
 formation of 640
 forming name of 169
 production and use 241
 reaction with sodium hydroxide 181–183, 181–185
 solution of 181
 as strong acid 165
- Nitride ion, forming name of 98
- Nitril hydratase 621
- Nitrogen-13, radioactive decay of 724
- Nitrogen-14, in radiocarbon dating 726
- Nitrogen (N)
 covalent bond formation 451
 diatomic molecules of 55
 electron configuration and orbital diagram 427
 ion formation 96
 Lewis structure 83
 liquid 257
 London forces and 558
 most common bonding pattern 81, 455
 structure of 55
 triple bonds in 83
- Nitrogen dioxide
 acid rain and 167
 nitric acid and 640
 ozone production and 266–267
 threshold limit value, or TLV and 522
- Nitrogen molecules, velocities of 484
- Nitrogen monoxide 620
 in acid rain 167
 catalytic breakdown of 620
 how made 496
 oxidation-reduction and 211
- Nitrogen narcosis 596
- Nitrogen oxides
 in automobile exhaust 257
 ozone and 266–267
- Nitroglycerine, in decomposition reactions 219
- Nitrosyl chloride, production and use 655
- Nitrosyl fluoride, molecular geometry 473
- Nitrous oxide, formation of 130
- Noble gases, structure 53
- Node** The locations in a waveform where the intensity of the wave is always zero. 415
- Nomenclature. *See* Chemical nomenclature

- Nonmetals** The elements that do not have the characteristics of metals. Some of the nonmetals are gases at room temperature and pressure, some are solids, and one is a liquid. Various colors and textures occur among the nonmetals. 43
forming anions 95
most common bonding patterns 83
- Nonpolar covalent bond** A covalent bond in which the difference in electron-attracting ability of two atoms in a bond is negligible (or zero), so the atoms in the bond have no significant charges. 74
predicting existence of 548–551
- Nonpolar molecular substance, solubility and 578–579
- Normal boiling-point temperature** The temperature at which the equilibrium vapor pressure of the liquid equals one atmosphere. 545
- North Carolina State University 266
- Notation, for nuclides 716–717
- Nuclear chemistry** The study of the properties and behavior of atomic nuclei. 715
- Nuclear decay series** A series of radioactive decays that lead from a large unstable nuclide, such as uranium-238, to a stable nuclide, such as lead-206. 729
- Nuclear energy 737–742
- Nuclear equation** The shorthand notation that describes nuclear reactions. It shows changes in the participating nuclides' atomic numbers (the number of protons) and mass numbers (the sum of the numbers of protons and neutrons). 722–726
- Nuclear fission 738–739
- Nuclear fusion 742
- Nuclear power plant 740–741
- Nuclear reaction** A process that results in a change in an atomic nucleus (as opposed to a chemical reaction, which involves the loss, gain, or sharing of electrons). 722–726
- Nuclear reactors 738–741
- Nuclear stability 718–719, 737–738
- Nucleon number** The sum of the numbers of protons and neutrons (nucleons) in the nucleus of an atom. It is also called the mass number. 716
- Nucleons** The particles that reside in the nucleus of atoms (protons and neutrons). 716
- Nucleus** The extremely small, positively charged core of the atom. 47
of atom 47
creation of new elements and 52
electrons around 416–422
of helium atoms 53
mass number and 51
stability of 718
- Nuclide** A particular type of nucleus that is characterized by a specific atomic number (*Z*) and nucleon number (*A*). 716
band of stability of 719
in nuclear equations 722–726
radioactive 727
symbol 716–717
uses for radioactive (table) 736
- Numbers, exact or not 295
- Nutrients, for phytoplankton 384
- Nylon 691
molecular structure of 691
production of 350, 691–692
- Nylon-66 350–351
- O**
- “Oil rig” mnemonic 209
- Objectives 6
- Observation, in scientific method 8–9
- Octane rating 661
- Octet of electrons 80–81, 456–457
- Oil 186, 556–557
- Oil industry 186
- Olestra 684–685, 742–743
- Oligopeptide 680
- Open-chain forms, of monosaccharides 674–675
- Orange juice, pH of 179
- Orbitals *See* Atomic orbitals
- Orbital diagram** A drawing that uses lines or squares to show the distribution of electrons in orbitals and arrows to show the relative spin of each electron. 424, 426–427
Study Sheet 431, 456
- Organic acid** Carbon-based acids. 162
- Organic chemistry** The branch of chemistry that involves the study of carbon-based compounds. 82, 658–672
- Organic compound 658–672
alcohol 663
aldehyde 665
alkane 661
alkene 662
alkyne 662
amide 668
amine 667–668
arene 662–663
carboxylic acid 664
condensed formula 659
ester 666–667
ether 665
how to describe 658–660
ketone 666
line drawing 582, 659
table of types 670–671
- Organophosphorus compounds 361
- Oxalic acid 664
uses 160
- Oxidation** Any chemical change in which at least one element loses electrons, either completely or partially. 208–209, 211
- Oxidation-reduction reaction** The chemical reactions in which there is a complete or partial transfer of electrons, resulting in oxidation and reduction. These reactions are also called redox reactions. 208–211
within batteries 224–229
half-reaction 210
oxidation 208
oxidation numbers (or states) 213–218
reduction 209
uses of 207
- Oxidation number (or state)** A tool for keeping track of the flow of electrons in redox reactions. 213–218
assignment of oxidation numbers 214
Study Sheet 214
- Oxidation state. *See* Oxidation number
- Oxidizing agent** A substance that gains electrons, making it possible for another substance to lose electrons and be oxidized. 210
aging and 212
defined 210
oxidation numbers and 213–218
ozone as 266
- Oxoacid. *See* Oxyacid
- Oxyacid (oxoacid)** Molecular substances that have the general formula $H_aX_bO_c$. In other words, they contain hydrogen, oxygen, and one other element represented by X; the a, b, and c represent subscripts. 162
names for 169
as polar molecule 553

Oxygen (O)

- absorbing ultraviolet radiation 269
- bonding patterns 81, 455
- in combustion reactions 219–221
- covalent bond formation 452–453
- diatomic molecules of 55
- electronegativity of 548
- electron configuration and orbital diagram 427
- in formation of water 126–127
- in internal combustion engines 492
- ion formation 95–96
- oxidation numbers for 214
- in ozone layer 269
- structure 55

Ozone 266–273

- absorbing ultraviolet radiation 269
- chlorine catalyzed destruction 618–620
- damage from chlorofluorocarbons 270
- destruction 269–270
 - as greenhouse gas 384
 - as pollutant 266
 - process of destruction 610–614
 - ultraviolet radiation and 269
 - uses 266

Ozone hole 271

Ozone layer

- CFCs and 270
- effect of halons on 272
- formation of 269

P

p block, of elements 428–430

Paint spraying, preventing air pollution 514

Palladium, in catalytic converter 221

Pancreatic amylase, in digestion 688

Pancreatic lipase, in digestion 688

Paper, saving acidic 187

Parkinson's disease 7–8

- positron emission tomography and 437
- scientific method and 7–8

Partially hydrogenated triglycerides 683–684

Partial charge

- in chemical bonds 74, 548–551
- in hydrogen bonds 553
- in London forces 556–557

Partial electron transfer in oxidation-reduction reactions 211

Partial pressure The portion of the total pressure that one gas in a mixture of gases contributes. Assuming ideal

gas character, the partial pressure of any gas in a mixture is the pressure that the gas would yield if it were alone in the container. 509

- effect on gas solubility 595
- equilibrium vapor pressure as 539–540

Particle-particle attractions 547, 621

summary 558–559

Particles

- in atoms 47
- attractive forces among 547–560
- in collision theory 610
- in condensation 534
- in evaporation 535–536
- in gases 37
- in liquids 36
- radiant energy as 260–261
- in solids 34–35
- space occupied 37

Particle nature of matter 34–38

- gas 34, 37–38
- liquid 34, 36
- solids 34–35

Pascal (Pa), pressure unit 485

Pearl ash, empirical formula for 349

Pentane

- hexane solubility of 578
- in solution 136
- water solubility of 578

Pepper, spiciness of 583

Pepsin, in digestion 688

Peptide A substance that contains two or more amino acids linked together by peptide bonds. 680

- how form 640–642

Peptide bond An amide functional group that forms when the carboxylic acid group on one amino acid reacts with the amine group of another amino acid. 680

Percentage 306–307

- as conversion factor 306
- by mass, definition 306
- by volume 306

Percentage calculations 306–307, 311

- in calculating empirical formulas 349
- in calculating molecular formulas 353

Percent yield The actual yield divided by the theoretical yield times 100. 382–384

- why less than 100% 382–383

Periodic table of the elements 42–46

- electronegativity and 548
- group number 43

group or family 43

hydrogen, position on periodic table 45

metals, nonmetals, and metalloids 44

modern model of the atom and 428–436

order of filling of atomic orbitals and 428–430

periods 45

representative (or main-group) elements, transition metals, and inner transition metals 44

Periods The horizontal rows on the periodic table. 45

Peroxides, oxidation numbers of 214

Petroleum 556–557

pH 178–179

acid rain and 178

Pharmaceuticals 673

Phenylalanine (Phe, F), molecular structure of 679

Phosgene gas, production and use 655

Phosphate, production 213

Phosphate ion, solubility of compounds with 141

Phosphate rock, in furnace method 330

Phosphide ion 98

Phosphoric acid 188

forming name of 169

furnace method of preparation 330

neutralizing 390

production of 368

reaction with sodium hydroxide 184

in toilet bowl cleaners 188

uses 160, 163

Phosphorus (P)

bonding pattern 81

covalent bond formation 452

in furnace method 368

ion formation 96

London forces in 558

most common bonding pattern 455

in oxidation-reduction reactions 215

in photophor 347

production of 213, 408

Phosphorus pentachloride, production and use 246

Phosphorus tribromide 383

Phosphorus trichloride, production and use 630

Photochemical smog, formation of 266–267

Photons Tiny, massless packets or particles of radiant energy. 260

- Photophor, empirical formula for 347
- Physical states, in chemical equations 127
- Physics
- chemistry and 34
 - of electrons 414–423
 - origin of matter and 640–641
- Phytoplankton, global warming and 384–385
- Pico (p) prefix 13
- Pig iron, formation of 509
- Plastic fingerprints 541
- Platinum (Pt) 56
- as catalyst 640
 - in catalytic converters 221, 620
 - density of 302
- Plutonium-239
- half-life 727
 - in radioactive wastes 728
 - radioactive decay 727
- Plutonium (Pu), in creation of new elements 52
- Polarity
- of amphetamine and epinephrine 582
 - of bonds 548–549
 - of capsaicin 583
 - molecular 552
 - predicting in molecules 552–553
 - solubility and 578
- Polar covalent bond** A covalent bond in which electrons are shared unequally, leading to a partial negative charge on the atom that attracts the electrons more and to a partial positive charge on the other atom. 74
- dipole-dipole attractions and 547–548
 - predicting in molecules 548–552
- Polar molecular substance, solubility and 578–579
- Polonium-210, radioactive decay of 724
- Polonium-218, in radioactive decay 729
- Poly(ethylene terephthalate) 695
- Poly(vinyl chloride), PVC 694–695
- Polyatomic ion** A charged collection of atoms held together by covalent bonds. 101–103
- balancing equations and 129, 132
 - formulas and names 103
 - with hydrogen 103
 - Lewis structures 101
 - nonsystematic names 103
- Polychlorinated biphenyl (PCB) 353
- Polyester 692–693
- Polyethylene 693
- Polymer** A large molecule composed of repeating units. 676
- addition 693–694
 - formulas for 691
 - polysaccharides as 676–677
 - proteins as 680
 - synthetic 690–695
- Polypeptide 680. *See also* Protein
- nylon as 691
 - silk as 690
- Polypropylene 694–695
- Polyprotic acid** An acid that can donate more than one hydrogen ion per molecule in a reaction. 162
- Polysaccharide** Molecule with many saccharide units. 676
- digestion products 688
- Polystyrene 694–695
- chlorofluorocarbons and 272
- Positron** A high-velocity anti-electron released from radioactive nuclides that have too few neutrons. 437, 721
- discovery of 437
- Positron emission** In radioactive nuclides that have too few neutrons, the conversion of a proton to a neutron, which stays in the nucleus, and a positron, which is ejected from the nucleus. 721
- nuclear equations for 723–725
- Positron emission tomography (PET) 437, 732
- Potassium-40
- radioactive decay of 721
 - uses for 721
- Potassium carbonate, empirical formula determination 349
- Potassium chlorate, production and use 398
- Potassium hydroxide, production and use 173, 245
- Potassium nitrate
- production and use 237
 - in voltaic cells 226
- Potassium perchlorate, production and use 399
- Potassium permanganate, production and use 401
- Potassium phosphate 141
- Potato chips 684
- Potential energy (PE)** A retrievable, stored form of energy an object possesses by virtue of its position or state. 252
- chemical reactions and 263–265
 - electron orbitals and 420
 - in formation of water 263
 - stability and 252–254
- Precipitate** A solid that comes out of solution. 137
- Precipitation** The process of forming a solid in a solution. 137
- tooth decay and 186
- Precipitation reaction** A reaction in which one of the products is insoluble in water and comes out of solution as a solid. 137–143
- of calcium carbonate 137–140
 - Study Sheet 142
 - writing equations for 142–143
- Precision** The closeness in value of a series of measurements of the same entity. The closer the values of the measurements, the more precise they are. 20
- in reporting measured values 293
- Prefixes. *See* Metric prefixes
- Preserving books 187
- Presidential Green Chemistry Challenge Award 272, 621
- Pressure** Force per unit area. *See* Gas pressure
- Pressure cooker 544
- Primary battery** A battery that is not rechargeable. 228
- Primary protein structure** The sequence of amino acids in a protein molecule. 680
- Principal energy level** A collection of orbitals that have the same potential energy for a hydrogen atom, except for the first (lowest) principal energy level, which contains only one orbital (1s). 420
- Probabilities, electron behavior and 414, 418
- Products** The substances that form in a chemical reaction. Their formulas are on the right side of the arrow in a chemical equation. 127
- Progesterone, molecular structure of 686
- Proline (Pro, P), molecular structure of 679
- Propane 82
- 1,2,3-Propanetriol 663
- 2-Propanol
- hydrogen bonds in 554
 - Lewis structure 84
 - molecular structure of 554
- 2-Propanone 666
- Propionic acid
- molecular structure of 580
 - water solubility 580

- Proportionality
 direct 487
 inverse 487
- Propylene
 hexane solubility of 581
 in polypropylene 694
- Propylene glycol, molecular structure of 578
- Protein** Natural polypeptide. 678–679, 680
 alpha helix 680
 beta sheet 680
 digestion products 688
 disulfide bond 682
 hydrogen bond 682
 primary structure 680
 ribbon convention 681
 salt bridge 682
 secondary structure 680
 tertiary structure 681–682
- Proton** A positively charged particle found in the nucleus of an atom. 47
 in artificial elements 52
 in atoms 47–48
 in Bronsted-Lowry acids and bases 188
 in ions 48–49
 in isotopes 50–51
 mass number and 51
 MRI and 732
 nuclear stability and 718–719, 737
 in nuclides 716–717
 origin of the elements and 742
- Publication, in scientific method 9
- Pure substance** A sample of matter that has constant composition. There are two types of pure substances: elements and compounds. 71
- Putrescine, molecular structure of 667
- Q**
- Quantum mechanics 437
- Quick lime, formation of 245
- R**
- Race cars and air density 499
- Radiant energy** Energy that can be described in terms of oscillating electric and magnetic fields or in terms of photons. 260–262
 spectrum 262
 the wave view 261
 wavelength 261
- Radiation
 effects on the body 730–731
 treatment for cancer 731
- Radiator coolants 578
- Radioactive decay** One of several processes that transform a radioactive nuclide into a more stable product or products. 719
 effects on body 730–731
 rates and half-life 726–728
- Radioactive decay series 728–729
- Radioactive emissions
 alpha particle 720
 beta emission 720
 gamma rays 722
 positron emission 721
- Radioactive nuclide** An unstable nuclide whose numbers of protons and neutrons place it outside the band of stability. 719
- Radioactive substances
 smoke detectors, pipe joint check, food irradiation, radioactive tracers 735
 uses 731–736
- Radioactive tracer** A radioactive nuclide that is incorporated into substances that can then be tracked through detection of the nuclide's emissions. 735
- Radiocarbon (or carbon-14) dating**
 The process of determining the age of an artifact that contains material from formerly living plants or animals by analyzing the ratio of carbon-14 to carbon-12 in the object. 733–734
- Radio waves 261, 262
- Radium-226
 half-life 727
 radioactive decay 729
 use 736
- Radon-222
 half-life 727
 lung cancer and 728
 in radioactive decay series 729
- Rags, in paper 187
- Rapture of the deep 596
- Rate of chemical reaction** The number of product molecules that form (perhaps described as moles of product formed) per liter of container per second. 616–620
 concentration effect 617–618
 temperature and 616–617
- Rate of condensation** The number of particles moving from gas to liquid per second. 537
- Rate of evaporation** The number of particles moving from liquid to gas per second. 535–537, 536–537
- strengths of attractions and 536
 surface area and 536
 temperature and 537
 three factors that determine 536
- Rate of solution. *See* Solution, Rate of Ratio
 empirical formulas and 346
 molar 345
 neutron-to-protons 718–719
 stoichiometric 376
- Rational drug design 673
- Reactants** The substances that change in a chemical reaction. Their formulas are on the left side of the arrow in a chemical equation. 127
 equilibrium disruption and 634–636
 limiting 377–381
- Reaction. *See* Chemical reaction
- Reaction Rate. *See* Rate of chemical reaction
- Rechargeable batteries 228
- Recycling 694
- Redox reaction. *See* Oxidation-reduction reaction
- Reducing agent** A substance that loses electrons, making it possible for another substance to gain electrons and be reduced. 210
- Reduction** Any chemical change in which at least one element gains electrons, either completely or partially. 209, 211
- Red giant stars 743
- Red litmus paper, detecting bases with 180
- Reilly, William K. 270
- Relative atomic mass 333
- Relative solubilities 578
- Representative elements** The elements in groups 1, 2, and 13 through 18 (the “A” groups) on the periodic table; also called main-group elements. 44
- Research, in scientific method 8
- Research chemist 609
- Resonance** The hypothetical switching from one resonance structure to another. 465–467
- Resonance hybrid** A structure that represents the average of the resonance structures for a molecule or polyatomic ion. 466
- Resonance structures** Two or more Lewis structures for a single molecule or polyatomic ion that differ in the positions of lone pairs and multiple bonds but not in the positions of the

- atoms in the structure. 466
- Reversible reaction** A reaction in which the reactants are constantly forming products and, at the same time, the products are reforming the reactants. 163, 621–622
 in chemical equilibrium 621–625
 disruption of equilibrium for 634
 equilibrium constants for 626
 percent yield and 382
- Review Skills sections 6
- Rhodium, in catalytic converter 221
- Ribbon convention for proteins 681
- Ring forms, of monosaccharides 674–675
- Roasting 384
- Rohm and Haas Company 5
- Roman numeral, in naming monatomic cations 99
- Roots of nonmetal names 92
- Roscolite 365
- Rounding off 293–301
 for addition and subtraction 299–301
 for multiplication and division 294–299
- Roundup 621
- RU-486 705
- Ruby 359
- S**
- Saccharide** Sugar, starch, and cellulose. Also called carbohydrates. 674–677.
See also Carbohydrate
- Saliva, tooth decay and 186
- Salt. *See* Sodium chloride
- Salt bridge** (in proteins) A covalent bond between two sulfur atoms on cysteine amino acids in a protein structure. 682
- Salt bridge** (in voltaic cells) A device used to keep the charges in a voltaic cell balanced. 226
- Salt taste 177
- Salt water separation 40
- San Simeon, California, protection from acid rain in 167
- Saturated solution** A solution that has enough solute dissolved to reach the solubility limit. 592, 592–593
 dynamic equilibrium and 588–593
 formation of 592–593
- Saturated triglyceride** A triglyceride with single bonds between all of the carbon atoms. 683
- Scale, calcium carbonate in 144
- Schrodinger, Erwin 416
- Science
 chemistry as 7–9
 existence of matter and 437
 mathematics in 413
- Scientific Method 7–9
- Scientific model** A simplified approximation of reality. *See also* Model 34, 56, 448
- Scientific notation 4–5
- Scuba diving, gas solubility and 596
- Sea-Nine antifoulant 5
- Seaborg, Glenn 725
- Seawater, pH and 179
- Sea of electrons model for metals 57
- Second (s), as unit of measurement 11
- Secondary (or storage) battery** A rechargeable battery. 228
- Secondary protein structure** The arrangement of atoms that are close to each other in a polypeptide chain. Examples of secondary structures are alpha helix and beta sheet. 680–681
- Second period elements, electrons in 425–427
- Selenide ion 98
- Selenium
 bonding pattern 81
 covalent bond formation 453
 ion formation 95–96
 most common bonding pattern 455
- Semimetals** The elements that have some but not all of the characteristics of metals. 44
- Serine (Ser, S)
 hydrogen bonds between 682
 molecular structure of 679
- Shape. *See* Molecular shape
- Shell 420. *See also* Principal energy level
- Shroud of Turin 734
- Side-chain, in anion acid 678
- Significant figures** The number of meaningful digits in a value. The number of significant figures in a value reflects the value's degree of uncertainty. A larger number of significant figures indicates a smaller degree of uncertainty. 293–301
 counting the number of 295–296
 zeros and 296
- Silicon (Si) 126
 electronics grade 379
 metallurgical grade 379
 purifying 379–380
 from silicon dioxide 377
- Silicon dioxide
 citrine as 362
 in furnace method 330
 purifying silicon from 379–380
- Silk
 molecular structure of 690
 nylon as substitute for 690
- Silver (Ag)
 density of 302
 ion charges of 99
 melting point of 314
- Silver ion, solubility of compounds with 141
- Silver nitrate, in precipitation reaction 142
- Single-displacement reaction** Chemical change in which atoms of one element displace (or replace) atoms of another element in a compound. 222–223
- Sinkhole 204
- Sixth principal energy level, electron orbitals of 423
- SI System of Measurement. *See* International System of Measurement
- Slaked lime 245
- Smelling salts 653
- Smog
 formation of photochemical 266–267
 nitrogen dioxide in 629
- Smoke detectors 735
- Soap 584, 586–587
- Society for Heavy-Ion Research 52
- Sodium (Na)
 electrolysis and 227
 formation from sodium chloride 219
 ion 75–76
 ion formation 96
- Sodium aluminum sulfate, in baking powder 73
- Sodium bromide, use 600
- Sodium carbonate
 reaction with acid 175
 uses 175
- Sodium chlorate, production and use 244
- Sodium chloride
 electrolysis and 227
 formation 76
 formula mass of 340
 formula unit of 339
 oxidation-reduction and 208–209
 solubility in water 593
 solution in water 133–135
 structure of 100–101, 101
 taste of 177

- Sodium chromate 384
- Sodium dichromate, production and use 400, 408
- sodium dodecyl sulfate (SDS), as detergent 587
- Sodium fluoride, in toothpaste 95
- Sodium hydrogen carbonate
production and use 175, 241
reaction with acids 175
- Sodium hydrogen sulfate, production and use 407
- Sodium hydroxide
aqueous solution of 173
formation 101
in neutralizing phosphoric acid 390
reaction with nitric acid 181–185
uses of 101, 173
- Sodium hypochlorite, production 509, 552, 560, 580, 581
- Sodium ions 49
taste and 177
- Sodium perbromate, production and use 243
- Sodium sulfate, production and use 243, 517
- Sodium tripolyphosphate, production and use 410
- Soft drink, why bubbles form 596
- “Solar system” model of the atom 414
- Solid** The state in which a substance has a definite shape and volume at a constant temperature. 34–35
densities of 301–302
expansion when heated 35
heterogeneous equilibrium and 630–631
- Solid acid, in meals ready to eat 573
- Solid elements 45, 56–57
- Solubility** The maximum amount of solute that can be dissolved in a given amount of solvent. 578–584
gas 594–595
guidelines 578
like dissolves like 578–579
soaps and detergents and 586–587
in water 140–141, 593
guidelines 141
- Solute** The gas in a solution of a gas in a liquid. The solid in a solution of a solid in a liquid. The minor component in other solutions. 136
gas as 594–595
in saturated solution 588
- Solution** A mixture whose particles are so evenly distributed that the relative concentrations of the components are the same throughout. Solutions can also be called homogeneous mixtures.
chemical reactions in 573
dynamic equilibrium and 588–593
formation of 576–577
of ionic compounds 133–135
molarity and 385–392
rate of 589–592
agitation 591
factors that effect 589
surface area 589–590
temperature effect 592
- saturated 592–593
solute and solvent 136
unsaturated 592
why form 574–577
- Solvent** The liquid in a solution of a gas in a liquid. The liquid in a solution of a solid in a liquid. The major component in other solutions. 136
- Sour taste 177
- Space-filling model** A way of representing a molecule to show a somewhat realistic image of the electron-charge clouds that surround the molecule’s atoms. 54, 86
- Spandex®, synthesis of 353
- Special conditions, in chemical equations 127–128
- Special topics
Acid Rain 167
Air Pollution and Catalytic Converters 221
A Greener Way to Spray Paint 514
A New Treatment for Brain Cancer 741
Be Careful with Bleach 188
Big Problems Require Bold Solutions - Global Warming and Limiting Reactants 384
Chemistry and Your Sense of Taste 177
Chemistry Gets the Bad Guys 541
Gas Solubility, Scuba Diving, and Soft Drinks 596
Global Warming, Oceans, and CO₂ Torpedoes 597
Green Chemistry 5
Green Chemistry - Making Chemicals from Safer Reactants 351
Green Chemistry - Substitutes for Chlorofluorocarbons 272
Green Chemistry - The Development of New and Better Catalysts 621
Green Decaf Coffee 515
Hard Water and Your Hot Water Pipes 144
- Harmless Dietary Supplements or Dangerous Drugs 687
- Molecular Shapes, Intoxicating Liquids, and the Brain 89
- Olestra and Low-Fat Potato Chips 684–685
- Other Ozone-Depleting Chemicals 272
- Oxidizing Agents and Aging 212
- Precipitation, Acid-Base Reactions, and Tooth Decay 186
- Recycling Synthetic Polymers 694
- Rehabilitation of Old Drugs and Development of New Ones 673
- Safe and Effective? 354
- Saving Valuable Books 187
- The Big Question - How Did We Get Here? 640
- The Origin of the Elements 742
- Wanted: A New Kilogram 11
- Why Create New Elements? 52
- Why Does Matter Exist, and Why Should We Care About This Question? 437
- Zinc-Air Batteries 229
- Spectator ions** Ions that play a role in delivering other ions into solution to react but that do not actively participate in the reaction themselves. 139
- Spectrum, of radiant energy 261–262
- Spin. *See* Electron spin
- Spinels 359
- Spodumene 365
- Spray paint 514
- Stability** A relative term that describes the resistance to change. 54, 252–254
- Standard kilogram 11
- Standard pressure 503
- Standard temperature 503
- Standard temperature and pressure (STP) 503
gas stoichiometry and 503
gas stoichiometry for conditions other than 504–505
- Standing waves 414–416
- Starch 674, 676
- Stars, element formation and 743
- State, physical 127
- Stationary wave 415
- Steam re-forming 396, 622
- Stearic acid
molecular structure of 664
solubility of 583

Step-growth (or condensation) polymer A polymer formed in a reaction that releases small molecules, such as water. This category includes nylon and polyester. 691

Sterno® 447

Steroid Compounds containing a four-ring structure. 685–686

Stirring, rate of solution and 589–591

Stockings 690

Stoichiometric ratio 376

Stoichiometry. *See* Equation stoichiometry

Stomach

hydrochloric acid in 506

role in digestion 689

Stomach acid 506

Storage battery 228

Stratosphere The second layer of the earth's atmosphere. It extends from about 10 km to about 50 km above sea level. 268

destruction of ozone in 269–271

ozone hole in 271

removal of UV radiation in 269

Strong acid An acid that donates its H^+ ions to water in a reaction that goes completely to products. Such a compound produces close to one H_3O^+ ion in solution for each acid molecule dissolved in water. 163, 165

identifying 176

reactions of strong base with 181–185

Strong base A substance that generates at least one hydroxide ion in solution for every unit of substance added to water. 173

identifying 176

reactions of strong acids with 181–185

Strong force The force that draws nucleons (protons and neutrons) together. 718

Strontium-90 730

Studying chemistry 5

Study Sheets

abbreviated electron configuration 433–436

assignment of oxidation numbers 214

balancing chemical equations 129

basic equation stoichiometry - converting mass of one substance in a reaction to mass of another 372–373

calculating empirical formulas 348

calculating molecular formulas 352

calculations using unit analysis 308

classification of matter 72

combustion reaction 220

converting between mass of element and mass of compound containing the element 345

drawing Lewis structures from formulas 456–457

electronegativity, types of chemical bonds, and bond polarity 550

electron configurations and orbital diagrams 431, 456

equation stoichiometry 372–373, 391, 507–508

equation stoichiometry problems 391

identification of strong and weak acids and bases 176

limiting reactant problems 380

predicting molecular geometry 472

predicting precipitation reactions and writing precipitation equations 142

rounding off numbers calculated using addition and subtraction 299

rounding off numbers calculated using multiplication and division 295

using Dalton's Law of Partial Pressures 512

using the combined gas law equation 500

using the ideal gas equation 495

writing complete electron configurations and orbital diagrams for uncharged atoms 431

writing equations for combustion reactions 220

Styrene, in polystyrene 694

Sublevel or subshell Orbitals that have the same potential energy, same size, and same shape. 421

Sublimation, of dry ice 255, 256

Subshell, of atomic orbitals 421

Substance, base unit of 10–11

Substances

densities of common 302

equation stoichiometry and 368–375

hydrophilic and hydrophobic 582

solubilities of 578–579

uses for radioactive 731–734

Substrate A molecule that an enzyme causes to react. 690

Subtraction, rounding off and 299–301

Sucrase, in digestion 688

Sucrose, solubility in water 593

Sugar 674–676

rate of solution 590

taste of 177

Sulfate ion, solubility of compounds with 141

Sulfur 43–44

bonding pattern 81

combustion and 219

covalent bond formation 453

ion formation 95–96

most common bonding pattern 455

production 244

use and production 525

Sulfuric acid 166

acid rain and 167

in acrylamide synthesis 621

forming name of 169

as oxyacid 162

production 238

reaction with sodium hydroxide 184

as strong acid 166

uses 166

Sulfur dioxide

acid rain and 167

air pollution and 523

in combustion reactions 219

as pollutant and removal 408

Sulfur hexafluoride, threshold limit value, or TLV 522

Sulfur trioxide, in acid rain 167

Sun, nuclear fusion and 742

Supercritical carbon dioxide

decaffeinating coffee and 515

spray paint and 514

Supercritical fluid 514

Supernovas 743

Super glue 473

Surface area, rate of solution and 589–590

Sweet taste 177

Symbols

for elements 41

for nuclides 716

Synthesis gas 622

Synthesis reactions 218

Synthetic polymers 690–695

s block, on periodic table 428–429

T

Tanzanite 363

Taste 177

Technical University of Munich 641

Television waves 262

- Tellurium (Te), bonding patterns of 457
- Temperature** A measure of the average internal kinetic energy of an object. 17–19, 259
- absolute zero 18
 - base unit of 11
 - boiling-point 544
 - Celsius scale 18
 - coldest 19
 - common scales 19
 - in condensation 534
 - critical 514
 - density and 301
 - effect on rate of solution 592
 - equilibrium constants and 632–633
 - equilibrium vapor pressure and 540–541
 - in evaporation 536–537
 - Fahrenheit scale 18–19
 - gases and 485
 - Kelvin scale 18–19
 - measuring 18
 - normal boiling-point 545
 - pressure and 488
 - range of 19
 - rate of reaction and 616–618
 - rate of solution and 592
 - standard 503
 - volume and 489
- Temperature conversions 312–314
- Terephthalic acid, in polyester formation 692
- Tertiary protein structure** The overall arrangement of atoms in a protein molecule. 681
- Testosterone 686
- Tetraboron carbide, production and use 400, 401
- Tetrachloroethene 375
- Tetrahedral molecules 86, 468–469
- Tetrahedral** The molecular shape that keeps the negative charge of four electron groups as far apart as possible. This shape has angles of 109.5° between the atoms. 86
- Tetramethylene glycol 354
- Tetrapeptide 680
- Tetraphosphorus decoxide, in furnace method 330
- Tetraphosphorus trisulfide 131
- Thalidomide 364, 673
- Theoretical yield** The calculated maximum amount of product that can form in a chemical reaction. 382
- Thermal energy** The energy associated with the random motion of particles. 259. *See also* Heat
- Thermometers 18–19
- Thiocyanate 398
- Thionyl chloride, production and use 408
- Thoburn, Steve 292
- Thortveitite 364
- Threonine (Thr, T), molecular structure of 679
- Threshold limit value, or TLV 522
- Time, base unit of 11
- Tin(II) sulfide, melting point of 314
- Tincture of iodine 556
- Tin isotopes 51–52
- Titanium(IV) oxide
- production 528
 - production and use 411
- Titanium (Ti) 56
- production and use 247
- Titanium carbide 381
- Titanium dioxide 632
- production and use 238
- Titration, Web site for 392
- Toothpaste, chemicals in 116
- Tooth decay, acid-base reactions and 186
- Tooth enamel, composition of 186
- Torr, as unit of pressure 485
- Trailing zeros, measurement uncertainty and 22
- Transition metals** The elements in groups 3 through 12 (the “B” groups) on the periodic table. 44
- as catalysts 620
 - in catalytic converters 221
 - in periodic table 44
- Transition state, in chemical reactions 611
- Triacylglycerol 584–585
- Triangular planar. *See* Trigonal planar
- Triglyceride** A compound with three hydrocarbon groups attached to a three carbon backbone by ester functional groups. 584–585, 683–685
- Trigonal planar** (often called triangular planar) The geometric arrangement that keeps three electron groups as far apart as possible. It leads to angles of 120° between the groups. 470
- Trigonal pyramid** The molecular geometry formed around an atom with three bonds and one lone pair. 469
- Trimethylamine 668
- 2,2,4-Trimethylpentane 661
- Trinitrotoluene (TNT) 662–663
- Triple bond** A link between atoms that results from the sharing of six electrons. It can be viewed as three 2-electron covalent bonds. 83, 451
- Triprotic acid** An acid that can donate three hydrogen ions per molecule in a reaction. 163
- Tristearin 584
- Tritium 50–51
- Troposphere The lowest layer of the earth’s atmosphere. It extends from the surface of the earth to about 10 km above the earth. 268
- Trypsin 688
- Tryptophan (Trp, W), molecular structure of 679
- Tungsten (W), in light bulb filaments 496
- Tyrosine (Tyr, Y), molecular structure of 679
- U**
- Ultraviolet radiation 262
- Umami taste 177
- Uncertainty 21
- in measurements 20–22
 - significant figures and 293–301
- Unified mass unit. *See* Atomic mass unit
- Unit** A defined quantity based on a standard. 9–18, 1–3
- abbreviations 1
 - conversions among 288–314
 - of energy 257
 - in international system of measurement 10–12
 - length 14
 - mass 16
 - the importance of putting into equations 497
 - volume 15
- United States, ozone concentrations in 267
- Unit analysis** A general technique for doing unit conversions. 288–292, 330–334, 342–350, 368–372, 376–380, 414–418, 424–428, 448–452
- equation stoichiometry and 370
 - gas stoichiometry and 505
 - Study Sheet 308–309
 - summary of 308–312
- Unit conversions 288–292, 330–334, 342–346, 346–350, 368–372, 376–380, 414–418, 424–428, 448–452
- “something per something” 311
 - common 308–312
 - density and 303, 310, 501–506, 551
 - English-metric 291–292, 310
 - metric-metric 289–291, 310
 - percentage and 307, 311

Universal gas constant, R The constant in the ideal gas equation. 494
in gas stoichiometry 505–509
in ideal gas equation 494–499

Universe

hottest temperatures in 19
origin of elements in 742–743

University of California, Berkeley 725

University of Regensburg 641

Unpaired electrons 79

in valence-bond model 449

Unsaturated solution A solution that has less solute dissolved than is predicted by the solubility limit. 592

Unsaturated triglyceride A triglyceride that has one or more carbon-carbon double bonds. 683

Uranium 381

alpha emission 720

production 402

uranium-238 decay series 729

Uranium(IV) oxide 381

Uranium-234 740

Uranium-235 740

enrichment 381

in fission reactors 740

half-life 727

Uranium-238

in fission reactors 740

half-life 727

nuclide symbol 717

radioactive decay series 729

Uranium-239

in nuclear reactors 740

in nuclear fission 738

Uranium hexafluoride 367, 381

Urea 411

use and production 526, 654

UV-A Ultraviolet radiation in the range of about 320 to 400 nm wavelengths. This is the part of the ultraviolet spectrum that reaches the earth and provides energy for the production of vitamin D. 268

UV-B Ultraviolet radiation in the range of about 290 to 320 nm wavelengths. Most of this radiation is filtered out by the earth's atmosphere, but some reaches the surface of the earth. 268

UV-C Ultraviolet radiation in the range of about 40 to 290 nm wavelengths. Almost all UV-C is filtered out by our atmosphere. 268

V

Valence-bond model 449–454

Valence electrons The electrons that are most important in the formation of chemical bonds. The highest energy s and p electrons for an atom. 79, 449
electron dot symbol 79–80

Valine (Val, V), molecular structure of 678

Value A number and unit that together represent the result of a measurement or calculation. 10

Vanadium(V) oxide, in catalytic converter 221

Vapor A gas derived from a substance that is liquid at normal temperatures and pressures. It is also often used to describe gas that has recently come from a liquid. 534

Vaporization The conversion of a liquid to a gas. 37

Vapor pressure. *See* Equilibrium vapor pressure

Vegetable oil 585

Velocity

of gas particles 484

kinetic energy and 251

of particles in evaporation 535

Vinegar

acetic acid in 162

taste of 177

Vinyl chloride, in poly(vinyl chloride) 694

Visible fingerprints 541

Visible light 262

Vitamin C, aging and 212

Vitamin E, aging and 212

Volatile organic compounds (VOCs) 514

Voltage 227

Voltaic cell A system in which two half-reactions for a redox reaction are separated, allowing the electrons transferred in the reaction to be passed between them through a wire. 224–229

anode 225

cathode 225

common examples 229

electrode 225

electrolyte 226

primary battery 228

salt bridge 226

secondary battery 228

zinc-air batteries 229

Volume (V) 15–16

density and 301

English-metric conversion factors for 292

of gases 485
of ideal gas particles 485

measurement, graduated cylinder 21

number of gas particles and 491

pressure and 486–487

range of 16

temperature and 489

Volume unit, liter 12

W

Wächtershäuser, Günter 641

Water 70

acids and 160–161, 163–164

ammonia and 173–174

attractions 88

bases and 173

boiling point of 18–19, 545

as compound 71

condensation of 534–535

in condensation reactions 689

covalent bond formation 452

density of 302

dissolving sodium chloride in 134–135

evaporation of 535

hard 144

heavy 313

hydrogen bonds in 554

ionizing radiation and 730–731

Lewis structure 81

liquid 88–89

melting point of 18–19

mixing with ethanol 576–577

molecular shape 87–88, 469

in nylon formation 691

pH of 179

as polar molecule 88, 553

producing hydrogen gas from 621–623

in protein formation 680

rate of solution in 589–593

solubility in 578–583

structure of 87–88

Water dissociation constant (K_w) The equilibrium constant for the reaction:
$$\text{H}_2\text{O}(l) \rightleftharpoons \text{H}^+(aq) + \text{OH}^-(aq)$$
 632

Water purification 374

Water solubility 140–141

Water treatment 202

Wave

electrons as 416–423

for guitar strings 414

radiant energy as 260–262

standing 414–415

- Waveform** A representation of the shape of a wave.
 of electron 416
 of guitar strings 415
- Wavelength** The distance in space over which a wave completes one cycle of its repeated form. 261–262
- Weak acid** A substance that is incompletely ionized in water due to the reversibility of the reaction that forms hydronium ions, H_3O^+ , in water. Weak acids yield significantly less than one H_3O^+ ion in solution for each acid molecule dissolved in water. 163, 164
- Weak base** A substance that produces fewer hydroxide ions in water solution than particles of the substance added. 174–175
 ammonia as 173–174
 identifying 176
- Weather balloon 502
- Web site
 for acid-base titration 392
 for acid nomenclature 169
 for animation of acid-base reaction 185
 for animation of a single-displacement reaction 222
 for animation of dissolving ethanol in water 577
 for animation of element structure 56
 for animation of precipitation reaction 140
 for animation of solution of sodium chloride 136
 for animation of strong and weak acids 166
 for animation of the particle nature of matter 38
 for animation of water structure 89
 for balancing redox equations 218, 222
 for calculating element percentages 346
 for changing volume and gas reactions 637
 for combustion analysis 353
 for conversion between element names and formulas 41
 for different electron configurations 436
 for enzyme mechanism 690
 for equilibrium calculations, including pH 633
 for isotope notation 52
 for gas stoichiometry shortcut 506
 for how addition polymers are made 693
 for London forces and polar molecules 558
 for mixtures and equation stoichiometry 375
 for polyatomic ions 103
 for predicting molecular polarity 553
 for predicting relative strengths of attractions 560
 for resonance 467
 for temperature effect on solid and gas solubility 597
 for writing complete ionic and net ionic equations 143
- Weight** A measure of the force of gravitational attraction between an object and a significantly large object, such as the earth or the moon. 16
- Weighted average** A mass calculated by multiplying the decimal fraction of each component in a sample by its mass and adding the results of each multiplication together. 331
- Wine
 pH of 179
 sediment formation 579
- Work** What is done to move an object against some sort of resistance. 250
- X**
 X-rays 262
 X-ray crystallography 673
 Xenon (Xe), reactions 242
 Xenon difluoride 397
- Y**
 Yield. *See* Actual yield; Theoretical yield; Percent yield
- Z**
 Zeros and significant figures 296
 Zinc-air batteries 229
 Zinc (Zn) 56
 batteries and 224–227
 reaction with copper sulfate 222–223
 single-displacement reaction and 222–223
 voltaic cells and 224–226
- Zinc oxide
 in book preservation 187
 oxidation-reduction and 208–209
 in zinc-air batteries 229