

General, Organic & Biological Chemistry 7TH EDITION

ATP
Osmotic
Cis-trans
Mole
NADH
Sublimation
Density
Elements
Isoelectronic
Biochemical
Monosaccharide
Mitochondrion
Supersaturated
Subshell
Covalent
Prostaglandin
Polymer
Exothermic
Organic
Orbital
Mole
Hydrolysis
Neutron
ADP
DNA
Micelle
Salt
Alkane
Half-life
Polyamide
Equation
Proton
Metabolism
Nucleotide
Chemical
Phosphorylation
Glycolysis
Transferase
Alcohol
Aromatic
Polyatomic
Nonmetal
Riboflavin
Glucose
Cytochrome
Dilution
Fission
Peptide
Electrolyte
Citrate
Kinetic
Redox
Hemoglobin
Molecules
Gluconeogenesis
Triacylglycerol
Heterocyclic
Cholesterol
Energy
Amine
Anticodon

Ion
Atoms
Elements
Molecules
Isotopes
Radioactive
Stereoisomerism
Carbohydrate
Electron
Cofactor
Ionization
Dissociation
Enzyme
Hemiacetal
Pheromone
Periodic
Mole
Hydrolysis
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Triacylglycerol
Heterocyclic
Cholesterol
Energy
Amine
Anticodon

Pressure
Catalyst
Protein
Combustion
Lipogenesis
Hydrocarbon
Polyfunctional
Pyruvate
Vitamin
Bonds
Omega-3
Hydrocarbon
Proteolytic
Chiral
Ester

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Redox
Hemoglobin
Molecules
Gluconeogenesis
Triacylglycerol
Heterocyclic
Cholesterol
Energy
Amine
Anticodon

H. Stephen Stoker

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	Group IA	Group IIA	Group IIIB	Group IVB	Group VB	Group VIB	Group VIIB	Group VIII	Group VIII	Group VIII	Group IB	Group IIB	Group IIIA	Group IVA	Group VA	Group VIA	Group VIIA	Group VIIIA	
1	1 H 1.01	2 He 4.00																	
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18	
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95	
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80	
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29	
6	55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)	
7	87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (263)	105 Db (262)	106 Sg (266)	107 Bh (267)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Nh (284)	114 Fl (289)	115 Mc (288)	116 Lv (292)	117 Ts (293)	118 Og (294)	

Atomic number
Symbol
Atomic mass

24
Cr
52.00

Nonmetals
Metals

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th (232)	91 Pa (231)	92 U (238)	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

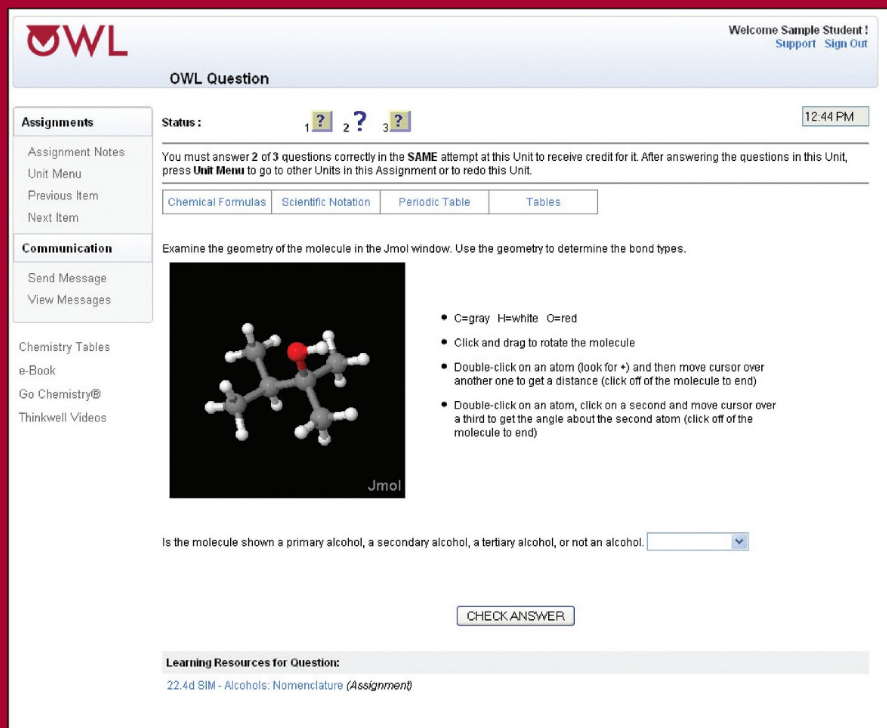
Atomic Numbers and Atomic Masses of the Elements

Based on ^{12}C . Numbers in parentheses are the mass numbers of the most stable isotopes of radioactive elements.

Element	Symbol	Atomic Number	Atomic Mass	Element	Symbol	Atomic Number	Atomic Mass
Actinium	Ac	89	(227)	Meitnerium	Mt	109	(276)
Aluminum	Al	13	26.98	Mendelevium	Md	101	(258)
Americium	Am	95	(243)	Mercury	Hg	80	200.59
Antimony	Sb	51	121.76	Molybdenum	Mo	42	95.94
Argon	Ar	18	39.95	Neodymium	Nd	60	144.24
Arsenic	As	33	74.92	Neon	Ne	10	20.18
Astatine	At	85	(210)	Neptunium	Np	93	(237)
Barium	Ba	56	137.33	Nickel	Ni	28	58.69
Berkelium	Bk	97	(247)	Niobium	Nb	41	92.91
Beryllium	Be	4	9.01	Nitrogen	N	7	14.01
Bismuth	Bi	83	208.98	Nobelium	No	102	(259)
Bohrium	Bh	107	(264)	Osmium	Os	76	190.23
Boron	B	5	10.81	Oxygen	O	8	16.00
Bromine	Br	35	79.90	Palladium	Pd	46	106.42
Cadmium	Cd	48	112.41	Phosphorus	P	15	30.97
Calcium	Ca	20	40.08	Platinum	Pt	78	195.08
Californium	Cf	98	(251)	Plutonium	Pu	94	(244)
Carbon	C	6	12.01	Polonium	Po	84	(209)
Cerium	Ce	58	140.12	Potassium	K	19	39.10
Cesium	Cs	55	132.91	Praseodymium	Pr	59	140.91
Chlorine	Cl	17	35.45	Promethium	Pm	61	(145)
Chromium	Cr	24	52.00	Protactinium	Pa	91	(231)
Cobalt	Co	27	58.93	Radium	Ra	88	(226)
Copernicium	Cn	112	(285)	Radon	Rn	86	(222)
Copper	Cu	29	63.55	Rhenium	Re	75	186.21
Curium	Cm	96	(247)	Rhodium	Rh	45	102.91
Darmstadtium	Ds	110	(271)	Roentgenium	Rg	111	(280)
Dubnium	Db	105	(262)	Rubidium	Rb	37	85.47
Dysprosium	Dy	66	162.50	Ruthenium	Ru	44	101.07
Einsteinium	Es	99	(252)	Rutherfordium	Rf	104	(263)
Erbium	Er	68	167.26	Samarium	Sm	62	150.36
Europium	Eu	63	151.96	Scandium	Sc	21	44.96
Fermium	Fm	100	(257)	Seaborgium	Sg	106	(266)
Fluorine	F	9	19.00	Selenium	Se	34	78.96
Francium	Fr	87	(223)	Silicon	Si	14	28.09
Gadolinium	Gd	64	157.25	Silver	Ag	47	107.87
Gallium	Ga	31	69.72	Sodium	Na	11	22.99
Germanium	Ge	32	72.64	Strontium	Sr	38	87.62
Gold	Au	79	196.97	Sulfur	S	16	32.07
Hafnium	Hf	72	178.49	Tantalum	Ta	73	180.95
Hassium	Hs	108	(277)	Technetium	Tc	43	(98)
Helium	He	2	4.00	Tellurium	Te	52	127.60
Holmium	Ho	67	164.93	Terbium	Tb	65	158.93
Hydrogen	H	1	1.01	Thallium	Tl	81	204.38
Indium	In	49	114.82	Thorium	Th	90	(232)
Iodine	I	53	126.90	Thulium	Tm	69	168.93
Iridium	Ir	77	192.22	Tin	Sn	50	118.71
Iron	Fe	26	55.85	Titanium	Ti	22	47.87
Krypton	Kr	36	83.80	Tungsten	W	74	183.84
Lanthanum	La	57	138.91	Uranium	U	92	(238)
Lawrencium	Lr	103	(262)	Vanadium	V	23	50.94
Lead	Pb	82	207.19	Xenon	Xe	54	131.29
Lithium	Li	3	6.94	Ytterbium	Yb	70	173.04
Lutetium	Lu	71	174.97	Yttrium	Y	39	88.91
Magnesium	Mg	12	24.31	Zinc	Zn	30	65.41
Manganese	Mn	25	54.94	Zirconium	Zr	40	91.22

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The screenshot shows the OWL Question interface. At the top, it says "OWL Question" and "Welcome Sample Student 1". Below that, there's a "Status" section with three question icons (1, 2, 3) and a timer showing "12:44 PM". A message states: "You must answer 2 of 3 questions correctly in the SAME attempt at this Unit to receive credit for it. After answering the questions in this Unit, press **Unit Menu** to go to other Units in this Assignment or to redo this Unit." There are tabs for "Chemical Formulas", "Scientific Notation", "Periodic Table", and "Tables". The main question asks to "Examine the geometry of the molecule in the Jmol window. Use the geometry to determine the bond types." Below this is a 3D ball-and-stick model of a molecule in a Jmol window. To the right of the model are instructions: "C=gray H=white O=red", "Click and drag to rotate the molecule", "Double-click on an atom (look for *) and then move cursor over another one to get a distance (click off of the molecule to end)", and "Double-click on an atom, click on a second and move cursor over a third to get the angle about the second atom (click off of the molecule to end)". Below the model is a dropdown menu with the text "Is the molecule shown a primary alcohol, a secondary alcohol, a tertiary alcohol, or not an alcohol." and a "CHECK ANSWER" button. At the bottom, there are "Learning Resources for Question:" and a link to "22.4d SIM - Alcohols: Nomenclature (Assignment)".

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General, Organic, and Biological

CHEMISTRY

SEVENTH EDITION

H. Stephen Stoker
Weber State University



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Brief Contents

Preface xi

PART I GENERAL CHEMISTRY

1	Basic Concepts About Matter	1
2	Measurements in Chemistry	24
3	Atomic Structure and the Periodic Table	53
4	Chemical Bonding: The Ionic Bond Model	85
5	Chemical Bonding: The Covalent Bond Model	112
6	Chemical Calculations: Formula Masses, Moles, and Chemical Equations	145
7	Gases, Liquids, and Solids	172
8	Solutions	203
9	Chemical Reactions	235
10	Acids, Bases, and Salts	265
11	Nuclear Chemistry	306

PART II ORGANIC CHEMISTRY

12	Saturated Hydrocarbons	339
13	Unsaturated Hydrocarbons	380
14	Alcohols, Phenols, and Ethers	419
15	Aldehydes and Ketones	466
16	Carboxylic Acids, Esters, and Other Acid Derivatives	495
17	Amines and Amides	539

PART III BIOLOGICAL CHEMISTRY

18	Carbohydrates	580
19	Lipids	641
20	Proteins	694
21	Enzymes and Vitamins	742
22	Nucleic Acids	787
23	Biochemical Energy Production	841
24	Carbohydrate Metabolism	883
25	Lipid Metabolism	917
26	Protein Metabolism	950

Answers to Selected Exercises A-1

Index/Glossary I-1

Contents

Preface xi

PART I GENERAL CHEMISTRY



1 Basic Concepts About Matter 1

- 1-1 Chemistry: The Study of Matter 1
- 1-2 Physical States of Matter 2
- 1-3 Properties of Matter 3
- 1-4 Changes in Matter 6
- 1-5 Pure Substances and Mixtures 7

CHEMISTRY AT A GLANCE *Use of the Terms Physical and Chemical* 8

- 1-6 Elements and Compounds 10

CHEMISTRY AT A GLANCE *Classes of Matter* 11

- 1-7 Discovery and Abundance of the Elements 13
- 1-8 Names and Chemical Symbols of the Elements 15
- 1-9 Atoms and Molecules 18
- 1-10 Chemical Formulas 20

CHEMICAL CONNECTIONS

- 1-A *Carbon Monoxide: A Substance with Both “Good” and “Bad” Properties* 5
- 1-B *Elemental Composition of the Human Body* 14

2 Measurements in Chemistry 24

- 2-1 Measurement Systems 24
- 2-2 Metric System Units 25
- 2-3 Exact and Inexact Numbers 29
- 2-4 Uncertainty in Measurement and Significant Figures 30

CHEMISTRY AT A GLANCE *Significant Figures* 32

- 2-5 Significant Figures and Mathematical Operations 33
- 2-6 Scientific Notation 36
- 2-7 Conversion Factors 40

CHEMISTRY AT A GLANCE *Conversion Factors* 42

- 2-8 Dimensional Analysis 43
- 2-9 Density 45
- 2-10 Temperature Scales 48

CHEMICAL CONNECTIONS

- 2-A *Body Density and Percent Body Fat* 47
- 2-B *Normal Human Body Temperature* 50

3 Atomic Structure and the Periodic Table 53

- 3-1 Internal Structure of an Atom 53
- 3-2 Atomic Number and Mass Number 55
- 3-3 Isotopes and Atomic Masses 58

CHEMISTRY AT A GLANCE *Atomic Structure* 61

- 3-4 The Periodic Law and the Periodic Table 62
- 3-5 Metals and Nonmetals 65
- 3-6 Electron Arrangements Within Atoms 67

CHEMISTRY AT A GLANCE *Shell–Subshell–Orbital Interrelationships* 71

- 3-7 Electron Configurations and Orbital Diagrams 72
- 3-8 The Electronic Basis for the Periodic Law and the Periodic Table 78
- 3-9 Classification of the Elements 80

CHEMISTRY AT A GLANCE *Element Classification Schemes and the Periodic Table* 83

CHEMICAL CONNECTIONS

- 3-A *Dietary Minerals and the Human Body* 68
- 3-B *Electrons in Excited States* 77
- 3-C *Iron: The Most Abundant Transition Element in the Human Body* 82

4 Chemical Bonding: The Ionic Bond Model 85

- 4-1 Chemical Bonds 85
- 4-2 Valence Electrons and Lewis Symbols 87
- 4-3 The Octet Rule 90
- 4-4 The Ionic Bond Model 91
- 4-5 The Sign and Magnitude of Ionic Charge 93
- 4-6 Lewis Structures for Ionic Compounds 95
- 4-7 Chemical Formulas for Ionic Compounds 97
- 4-8 The Structure of Ionic Compounds 98

CHEMISTRY AT A GLANCE *Ionic Bonds and Ionic Compounds* 100

4-9	Recognizing and Naming Binary Ionic Compounds	102
4-10	Polyatomic Ions	106
4-11	Chemical Formulas and Names for Ionic Compounds Containing Polyatomic Ions	108
CHEMISTRY AT A GLANCE <i>Nomenclature of Ionic Compounds</i> 110		
CHEMICAL CONNECTIONS		
4-A	<i>Fresh Water, Seawater, Hard Water, and Soft Water: A Matter of Ions</i>	101
4-B	<i>Tooth Enamel: A Combination of Monatomic and Polyatomic Ions</i>	108
5	Chemical Bonding: The Covalent Bond Model	112
5-1	The Covalent Bond Model	112
5-2	Lewis Structures for Molecular Compounds	114
5-3	Single, Double, and Triple Covalent Bonds	117
5-4	Valence Electrons and Number of Covalent Bonds Formed	118
5-5	Coordinate Covalent Bonds	120
5-6	Systematic Procedures for Drawing Lewis Structures	122
5-7	Bonding in Compounds with Polyatomic Ions Present	126
5-8	Molecular Geometry	127
CHEMISTRY AT A GLANCE <i>The Geometry of Molecules</i> 130		
5-9	Electronegativity	132
5-10	Bond Polarity	134
CHEMISTRY AT A GLANCE <i>Covalent Bonds and Molecular Compounds</i> 138		
5-11	Molecular Polarity	139
5-12	Recognizing and Naming Binary Molecular Compounds	142
CHEMICAL CONNECTIONS		
5-A	<i>Nitric Oxide: A Molecule Whose Bonding Does Not Follow "The Rules"</i>	125
5-B	<i>The Chemical Sense of Smell</i>	131
6	Chemical Calculations: Formula Masses, Moles, and Chemical Equations	145
6-1	Formula Masses	146
6-2	The Mole: A Counting Unit for Chemists	147
6-3	The Mass of a Mole	149
6-4	Chemical Formulas and the Mole Concept	152
6-5	The Mole and Chemical Calculations	154
6-6	Writing and Balancing Chemical Equations	157
6-7	Chemical Equations and the Mole Concept	162
CHEMISTRY AT A GLANCE <i>Relationships Involving the Mole Concept</i> 163		
6-8	Chemical Calculations Using Chemical Equations	164
6-9	Yields: Theoretical, Actual, and Percent	169

CHEMICAL CONNECTIONS

- 6-A *Carbon Monoxide Air Pollution: A Case of Incomplete Combustion* 165
- 6-B *Chemical Reactions on an Industrial Scale: Sulfuric Acid* 168

7 Gases, Liquids, and Solids 172

- 7-1 The Kinetic Molecular Theory of Matter 172
- 7-2 Kinetic Molecular Theory and Physical States 174

CHEMISTRY AT A GLANCE *Kinetic Molecular Theory and the States of Matter* 177

- 7-3 Gas Law Variables 178
- 7-4 Boyle's Law: A Pressure–Volume Relationship 180
- 7-5 Charles's Law: A Temperature–Volume Relationship 182
- 7-6 The Combined Gas Law 184
- 7-7 The Ideal Gas Law 185
- 7-8 Dalton's Law of Partial Pressures 186

CHEMISTRY AT A GLANCE *The Gas Laws* 188

- 7-9 Changes of State 189
- 7-10 Evaporation of Liquids 190
- 7-11 Vapor Pressure of Liquids 191
- 7-12 Boiling and Boiling Point 194
- 7-13 Intermolecular Forces in Liquids 196

CHEMISTRY AT A GLANCE *Intermolecular Forces in Liquids* 201**CHEMICAL CONNECTIONS**

- 7-A *The Importance of Gas Densities* 178
- 7-B *Blood Pressure and the Sodium Ion/Potassium Ion Ratio* 193
- 7-C *Hydrogen Bonding and the Density of Water* 199

8 Solutions 203

- 8-1 Characteristics of Solutions 203
- 8-2 Solubility 205
- 8-3 Solution Formation 208
- 8-4 Solubility Rules 209
- 8-5 Percent Concentration Units 212
- 8-6 Molarity Concentration Unit 218

CHEMISTRY AT A GLANCE *Specifying Solution Concentrations* 221

- 8-7 Dilution 222
- 8-8 Colloidal Dispersions and Suspensions 223
- 8-9 Colligative Properties of Solutions 224
- 8-10 Osmosis and Osmotic Pressure 228

CHEMISTRY AT A GLANCE *Summary of Colligative Property Terminology* 233**CHEMICAL CONNECTIONS**

- 8-A *Factors Affecting Gas Solubility* 206
- 8-B *Solubility of Vitamins* 211
- 8-C *Controlled-Release Drugs: Regulating Concentration, Rate, and Location of Release* 220

9 Chemical Reactions 235

- 9-1 Types of Chemical Reactions 235
- CHEMISTRY AT A GLANCE** *Types of Chemical Reactions* 240
- 9-2 Redox and Nonredox Chemical Reactions 240
- 9-3 Terminology Associated with Redox Processes 243
- 9-4 Collision Theory and Chemical Reactions 245
- 9-5 Exothermic and Endothermic Chemical Reactions 247
- 9-6 Factors That Influence Chemical Reaction Rates 249
- CHEMISTRY AT A GLANCE** *Factors That Increase Chemical Reaction Rates* 253
- 9-7 Chemical Equilibrium 253
- 9-8 Equilibrium Constants 255
- 9-9 Altering Equilibrium Conditions: Le Châtelier's Principle 259
- CHEMISTRY AT A GLANCE** *Le Châtelier's Principle and Altered Equilibrium Conditions* 263
- CHEMICAL CONNECTIONS**
- 9-A *Combustion Reactions, Carbon Dioxide, and Global Warming* 238
- 9-B *Changes in Human Body Temperature and Chemical Reaction Rates* 252
- 9-C *Stratospheric Ozone: An Equilibrium Situation* 256

10 Acids, Bases, and Salts 265

- 10-1 Arrhenius Acid–Base Theory 265
- 10-2 Brønsted–Lowry Acid–Base Theory 267
- CHEMISTRY AT A GLANCE** *Acid–Base Definitions* 271
- 10-3 Mono-, Di-, and Triprotic Acids 271
- 10-4 Strengths of Acids and Bases 273
- 10-5 Ionization Constants for Acids and Bases 274
- 10-6 Salts 276
- 10-7 Acid–Base Neutralization Chemical Reactions 277
- 10-8 Self-Ionization of Water 280
- 10-9 The pH Concept 282
- CHEMISTRY AT A GLANCE** *Acids and Acidic Solutions* 287
- 10-10 The pK_a Method for Expressing Acid Strength 288
- 10-11 The pH of Aqueous Salt Solutions 289
- 10-12 Buffers 291
- CHEMISTRY AT A GLANCE** *Buffer Systems* 295
- 10-13 The Henderson–Hasselbalch Equation 297
- 10-14 Electrolytes 298
- 10-15 Equivalents and Milliequivalents of Electrolytes 299
- 10-16 Acid–Base Titrations 303
- CHEMICAL CONNECTIONS**
- 10-A *Excessive Acidity Within the Stomach: Antacids and Acid Inhibitors* 279
- 10-B *pH Values for Acid Rain* 286
- 10-C *Composition and Characteristics of Blood Plasma* 292
- 10-D *Acidosis and Alkalosis* 296
- 10-E *Electrolytes and Body Fluids* 302

11 Nuclear Chemistry 306

- 11-1 Stable and Unstable Nuclides 306
- 11-2 The Nature of Radioactive Emissions 308
- 11-3 Equations for Radioactive Decay 310
- 11-4 Rate of Radioactive Decay 313
- CHEMISTRY AT A GLANCE** *Radioactive Decay* 314
- 11-5 Transmutation and Bombardment Reactions 316
- 11-6 Radioactive Decay Series 318
- 11-7 Detection of Radiation 319
- 11-8 Chemical Effects of Radiation 320
- 11-9 Biochemical Effects of Radiation 323
- 11-10 Sources of Radiation Exposure 326
- 11-11 Nuclear Medicine 329
- 11-12 Nuclear Fission and Nuclear Fusion 333
- CHEMISTRY AT A GLANCE** *Characteristics of Nuclear Reactions* 336
- 11-13 Nuclear and Chemical Reactions Compared 337
- CHEMICAL CONNECTIONS**
- 11-A *Preserving Food Through Food Irradiation* 324
- 11-B *The Indoor Radon-222 Problem* 327
- 11-C *Technetium-99m: The “Workhorse” of Nuclear Medicine* 331

PART II ORGANIC CHEMISTRY**12 Saturated Hydrocarbons 339**

- 12-1 Organic and Inorganic Compounds 339
- 12-2 Bonding Characteristics of the Carbon Atom 340
- 12-3 Hydrocarbons and Hydrocarbon Derivatives 341
- 12-4 Alkanes: Acyclic Saturated Hydrocarbons 342
- 12-5 Structural Formulas 345
- 12-6 Alkane Isomerism 346
- 12-7 Conformations of Alkanes 348
- 12-8 IUPAC Nomenclature for Alkanes 350
- 12-9 Line-Angle Structural Formulas for Alkanes 357
- CHEMISTRY AT A GLANCE** *Structural Representations for Alkane Molecules* 358
- 12-10 Classification of Carbon Atoms 359
- 12-11 Branched-Chain Alkyl Groups 361

12-12	Cycloalkanes	363
12-13	IUPAC Nomenclature for Cycloalkanes	365
12-14	Isomerism in Cycloalkanes	366
12-15	Sources of Alkanes and Cycloalkanes	368
12-16	Physical Properties of Alkanes and Cycloalkanes	369
12-17	Chemical Properties of Alkanes and Cycloalkanes	371
CHEMISTRY AT A GLANCE <i>Properties of Alkanes and Cycloalkanes</i> 374		
12-18	Halogenated Alkanes and Cycloalkanes	375
CHEMICAL CONNECTIONS		
12-A	<i>The Occurrence of Methane</i>	344
12-B	<i>The Physiological Effects of Alkanes</i>	372
12-C	<i>Chlorofluorocarbons and the Ozone Layer</i>	378
13	Unsaturated Hydrocarbons	380
13-1	Unsaturated Hydrocarbons	380
13-2	Characteristics of Alkenes and Cycloalkenes	381
13-3	Nomenclature for Alkenes and Cycloalkenes	383
13-4	Line-Angle Structural Formulas for Alkenes	387
13-5	Constitutional Isomerism in Alkenes	387
13-6	Cis-Trans Isomerism in Alkenes	390
13-7	Naturally Occurring Alkenes	393
13-8	Physical Properties of Alkenes and Cycloalkenes	396
13-9	Preparation of Alkenes	397
13-10	Chemical Reactions of Alkenes	397
13-11	Polymerization of Alkenes: Addition Polymers	403
CHEMISTRY AT A GLANCE <i>Chemical Reactions of Alkenes</i> 407		
13-12	Alkynes	407
CHEMISTRY AT A GLANCE <i>IUPAC Nomenclature for Alkanes, Alkenes, and Alkynes</i> 409		
13-13	Aromatic Hydrocarbons	410
13-14	Nomenclature for Aromatic Hydrocarbons	412
13-15	Properties of and Sources for Aromatic Hydrocarbons	415
13-16	Fused-Ring Aromatic Hydrocarbons	417
CHEMISTRY AT A GLANCE <i>Types of Unsaturated Hydrocarbons</i> 417		
CHEMICAL CONNECTIONS		
13-A	<i>Ethene: A Plant Hormone and High-Volume Industrial Chemical</i>	386
13-B	<i>Cis-Trans Isomerism and Vision</i>	392
13-C	<i>Carotenoids: A Source of Color</i>	395
14	Alcohols, Phenols, and Ethers	419
14-1	Bonding Characteristics of Oxygen Atoms in Organic Compounds	419
14-2	Structural Characteristics of Alcohols	420
14-3	Nomenclature for Alcohols	421
14-4	Isomerism for Alcohols	424
14-5	Important Commonly Encountered Alcohols	425
14-6	Physical Properties of Alcohols	430
14-7	Preparation of Alcohols	432
14-8	Classification of Alcohols	433
14-9	Chemical Reactions of Alcohols	435
CHEMISTRY AT A GLANCE <i>Summary of Chemical Reactions Involving Alcohols</i> 443		
14-10	Structural Characteristics of Phenols	444
14-11	Nomenclature for Phenols	444
14-12	Physical and Chemical Properties of Phenols	446
14-13	Occurrence of and Uses for Phenols	447
14-14	Structural Characteristics of Ethers	450
14-15	Nomenclature for Ethers	451
14-16	Occurrence of and Uses for Ethers	453
14-17	Isomerism for Ethers	454
14-18	Physical and Chemical Properties of Ethers	457
14-19	Cyclic Ethers	458
14-20	Thiols: Sulfur Analogs of Alcohols	459
14-21	Thioethers: Sulfur Analogs of Ethers	462
CHEMISTRY AT A GLANCE <i>Alcohols, Thiols, Ethers, and Thioethers</i> 464		
CHEMICAL CONNECTIONS		
14-A	<i>Menthol: A Useful Naturally Occurring Terpene Alcohol</i>	435
14-B	<i>Red Wine and Resveratrol</i>	450
14-C	<i>Ethers as General Anesthetics</i>	455
14-D	<i>Garlic and Onions: Odiferous Medicinal Plants</i>	463
15	Aldehydes and Ketones	466
15-1	The Carbonyl Group	466
15-2	Compounds Containing a Carbonyl Group	467
15-3	The Aldehyde and Ketone Functional Groups	469
15-4	Nomenclature for Aldehydes	470
15-5	Nomenclature for Ketones	472
15-6	Isomerism for Aldehydes and Ketones	474
15-7	Selected Common Aldehydes and Ketones	475
15-8	Physical Properties of Aldehydes and Ketones	479
15-9	Preparation of Aldehydes and Ketones	480
15-10	Oxidation and Reduction of Aldehydes and Ketones	482
15-11	Reaction of Aldehydes and Ketones with Alcohols	486
CHEMISTRY AT A GLANCE <i>Summary of Chemical Reactions Involving Aldehydes and Ketones</i> 491		
15-12	Sulfur-Containing Carbonyl Groups	491
CHEMICAL CONNECTIONS		
15-A	<i>Melanin: A Hair and Skin Pigment</i>	478
15-B	<i>Diabetes, Aldehyde Oxidation, and Glucose Testing</i>	484
15-C	<i>Lachrymatory Aldehydes and Ketones</i>	493
16	Carboxylic Acids, Esters, and Other Acid Derivatives	495
16-1	Structure of Carboxylic Acids and Their Derivatives	495
16-2	IUPAC Nomenclature for Carboxylic Acids	498
16-3	Common Names for Carboxylic Acids	501
16-4	Polyfunctional Carboxylic Acids	504

- 16-5 Physical Properties of Carboxylic Acids 507
- 16-6 Preparation of Carboxylic Acids 508
- 16-7 Acidity of Carboxylic Acids 509
- 16-8 Carboxylic Acid Salts 510
- 16-9 Carboxylic Acid Decarboxylation Reactions 513
- 16-10 Structure of Esters 513
- 16-11 Preparation of Esters 514

CHEMISTRY AT A GLANCE Summary of the “H Versus R” Relationship for Pairs of Hydrocarbon Derivatives 515

- 16-12 Nomenclature for Esters 517
- 16-13 Selected Common Esters 519
- 16-14 Isomerism for Carboxylic Acids and Esters 522
- 16-15 Physical Properties of Esters 523
- 16-16 Chemical Reactions of Esters 524

CHEMISTRY AT A GLANCE Summary of Chemical Reactions Involving Carboxylic Acids and Esters 526

- 16-17 Sulfur Analogs of Esters 527
- 16-18 Polyesters 528
- 16-19 Acid Chlorides and Acid Anhydrides 530
- 16-20 Esters and Anhydrides of Inorganic Acids 533

CHEMICAL CONNECTIONS

- 16-A Nonprescription Pain Relievers Derived from Propanoic Acid 505
- 16-B Carboxylic Acids and Skin Care 506
- 16-C Aspirin 521
- 16-D Nitroglycerin: An Inorganic Triester 535

17 Amines and Amides 539

- 17-1 Bonding Characteristics of Nitrogen Atoms in Organic Compounds 539
- 17-2 Structure and Classification of Amines 540
- 17-3 Nomenclature for Amines 542
- 17-4 Isomerism for Amines 544
- 17-5 Physical Properties of Amines 545
- 17-6 Basicity of Amines 546
- 17-7 Reaction of Amines with Acids 548
- 17-8 Alkylation of Ammonia and Amines 551
- 17-9 Heterocyclic Amines 552
- 17-10 Selected Biochemically Important Amines 556
- 17-11 Alkaloids 559
- 17-12 Structure and Classification of Amides 563
- 17-13 Nomenclature for Amides 565
- 17-14 Selected Amides and Their Uses 567
- 17-15 Basicity of Amides 569
- 17-16 Physical Properties of Amides 570
- 17-17 Preparation of Amides 571
- 17-18 Hydrolysis of Amides 574

CHEMISTRY AT A GLANCE Summary of Chemical Reactions Involving Amines and Amides 575

- 17-19 Polyamides and Polyurethanes 576

CHEMICAL CONNECTIONS

- 17-A Caffeine: The Most Widely Used Central Nervous System Stimulant 554
- 17-B Nicotine Addiction: A Widespread Example of Drug Dependence 555

- 17-C Alkaloids Present in Chocolate 560
- 17-D Acetaminophen: A Substituted Amide 568

PART III BIOLOGICAL CHEMISTRY



18 Carbohydrates 580

- 18-1 Biochemistry—An Overview 581
- 18-2 Occurrence and Functions of Carbohydrates 582
- 18-3 Classification of Carbohydrates 582
- 18-4 Chirality: Handedness in Molecules 584
- 18-5 Stereoisomerism: Enantiomers and Diastereomers 589
- 18-6 Designating Handedness Using Fischer Projection Formulas 590

CHEMISTRY AT A GLANCE Constitutional Isomers and Stereoisomers 595

- 18-7 Properties of Enantiomers 596
- 18-8 Classification of Monosaccharides 598
- 18-9 Biochemically Important Monosaccharides 601
- 18-10 Cyclic Forms of Monosaccharides 604
- 18-11 Haworth Projection Formulas 608
- 18-12 Reactions of Monosaccharides 611

CHEMISTRY AT A GLANCE “Sugar Terminology” Associated with Monosaccharides and Their Derivatives 615

- 18-13 Disaccharides 615
- 18-14 Oligosaccharides 625
- 18-15 General Characteristics of Polysaccharides 628
- 18-16 Storage Polysaccharides 630
- 18-17 Structural Polysaccharides 632

CHEMISTRY AT A GLANCE Types of Glycosidic Linkages for Common Glucose-Containing Di- and Polysaccharides 634

- 18-18 Acidic Polysaccharides 636
- 18-19 Dietary Considerations and Carbohydrates 638
- 18-20 Glycolipids and Glycoproteins: Cell Recognition 638

CHEMICAL CONNECTIONS

- 18-A Lactose Intolerance or Lactase Persistence 619
- 18-B Changing Sugar Patterns: Decreased Sucrose, Increased Fructose 621
- 18-C Sugar Substitutes 622

18-D Blood Types and Oligosaccharides 627

18-E Edible Fibers and Health 635

19 Lipids 641

19-1 Structure and Classification of Lipids 641

19-2 Types of Fatty Acids 643

19-3 Physical Properties of Fatty Acids 647

19-4 Energy-Storage Lipids: Triacylglycerols 649

19-5 Dietary Considerations and Triacylglycerols 653

19-6 Chemical Reactions of Triacylglycerols 657

CHEMISTRY AT A GLANCE Classification Schemes for Fatty Acid Residues Present in Triacylglycerols 665

19-7 Membrane Lipids: Phospholipids 666

19-8 Membrane Lipids: Sphingoglycolipids 671

CHEMISTRY AT A GLANCE Terminology for and Structural Relationships Among Various Types of Fatty-Acid-Containing Lipids 672

19-9 Membrane Lipids: Cholesterol 673

19-10 Cell Membranes 675

19-11 Emulsification Lipids: Bile Acids 679

19-12 Messenger Lipids: Steroid Hormones 681

19-13 Messenger Lipids: Eicosanoids 685

19-14 Protective-Coating Lipids: Biological Waxes 688

CHEMISTRY AT A GLANCE Types of Lipids in Terms of How They Function 690

19-15 Saponifiable and Nonsaponifiable Lipids 691

CHEMICAL CONNECTIONS

19-A The Fat Content of Tree Nuts and Peanuts 655

19-B Fat Substitutes 658

19-C The Cleansing Action of Soap and Detergents 661

19-D Trans Fatty Acid Content of Foods 663

19-E Anabolic Steroid Use in Competitive Sports 684

19-F The Mode of Action for Anti-Inflammatory Drugs 687

20 Proteins 694

20-1 Characteristics of Proteins 694

20-2 Amino Acids: The Building Blocks for Proteins 695

20-3 Essential Amino Acids 698

20-4 Chirality and Amino Acids 699

20-5 Acid-Base Properties of Amino Acids 700

20-6 Cysteine: A Chemically Unique Amino Acid 703

20-7 Peptides 703

20-8 Biochemically Important Small Peptides 707

20-9 General Structural Characteristics of Proteins 709

20-10 Primary Structure of Proteins 710

20-11 Secondary Structure of Proteins 714

20-12 Tertiary Structure of Proteins 717

20-13 Quaternary Structure of Proteins 721

CHEMISTRY AT A GLANCE Protein Structure 722

20-14 Protein Hydrolysis 723

20-15 Protein Denaturation 723

20-16 Protein Classification Based on Shape 726

20-17 Protein Classification Based on Function 731

20-18 Glycoproteins 733

20-19 Lipoproteins 736

CHEMICAL CONNECTIONS

20-A "Substitutes" for Human Insulin 712

20-B Denaturation and Human Hair 725

20-C Protein Structure and the Color of Meat 730

20-D Cyclosporine: An Antirejection Drug 735

20-E Colostrum: Immunoglobulins and Much More 737

20-F Lipoproteins and Heart Disease Risk 739

21 Enzymes and Vitamins 742

21-1 General Characteristics of Enzymes 742

21-2 Enzyme Structure 743

21-3 Nomenclature and Classification of Enzymes 745

21-4 Models of Enzyme Action 750

21-5 Enzyme Specificity 752

21-6 Factors That Affect Enzyme Activity 752

CHEMISTRY AT A GLANCE Enzyme Activity 756

21-7 Extremozymes 757

21-8 Enzyme Inhibition 758

CHEMISTRY AT A GLANCE Enzyme Inhibition 760

21-9 Regulation of Enzyme Activity 761

21-10 Prescription Drugs That Inhibit Enzyme Activity 764

21-11 Medical Uses of Enzymes 768

21-12 General Characteristics of Vitamins 770

21-13 Water-Soluble Vitamins: Vitamin C 772

21-14 Water-Soluble Vitamins: The B Vitamins 774

21-15 Fat-Soluble Vitamins 781

CHEMICAL CONNECTIONS

21-A Enzymatic Browning: Discoloration of Fruits and Vegetables 749

21-B *H. pylori* and Stomach Ulcers 754

21-C Enzymes, Prescription Medications, and the "Grapefruit Effect" 769

22 Nucleic Acids 787

22-1 Types of Nucleic Acids 787

22-2 Nucleotides: Structural Building Blocks For Nucleic Acids 788

22-3 Nucleotide Formation 790

22-4 Primary Nucleic Acid Structure 793

CHEMISTRY AT A GLANCE Nucleic Acid Structure 796

22-5 The DNA Double Helix 797

22-6 Replication of DNA Molecules 801

CHEMISTRY AT A GLANCE DNA Replication 804

22-7 Overview of Protein Synthesis 806

22-8 Ribonucleic Acids 807

22-9 Transcription: RNA Synthesis 809

22-10 The Genetic Code 815

22-11 Anticodons and tRNA Molecules 818

22-12 Translation: Protein Synthesis 822

CHEMISTRY AT A GLANCE Protein Synthesis: Transcription and Translation 827

22-13 Mutations 829

- 22-14 Nucleic Acids and Viruses 831
- 22-15 Recombinant DNA and Genetic Engineering 833
- 22-16 The Polymerase Chain Reaction 838

CHEMICAL CONNECTIONS

- 22-A Antimetabolites: Anticancer Drugs That Inhibit DNA Synthesis 805
- 22-B The Circadian Clock and Clock Genes 814
- 22-C Antibiotic Protein Synthesis Inhibitors 828
- 22-D Erythropoietin (EPO): Red Blood Cells, Mutations, and Athletic Performance 832

23 Biochemical Energy Production 841

- 23-1 Metabolism 841
- 23-2 Metabolism and Cell Structure 843
- 23-3 Important Nucleotide-Containing Compounds in Metabolic Pathways 845
- 23-4 Important Carboxylate Ions in Metabolic Pathways 853
- 23-5 High-Energy Phosphate Compounds 855
- 23-6 An Overview of Biochemical Energy Production 858

CHEMISTRY AT A GLANCE *Simplified Summary of the Four Stages of Biochemical Energy Production* 859

- 23-7 The Citric Acid Cycle 860
- CHEMISTRY AT A GLANCE** *Summary of the Reactions of the Citric Acid Cycle* 865
- 23-8 The Electron Transport Chain 866

CHEMISTRY AT A GLANCE *Summary of the Flow of Electrons Through the Four Complexes of the Electron Transport Chain* 871

- 23-9 Oxidative Phosphorylation 872
- CHEMISTRY AT A GLANCE** *Summary of the Common Metabolic Pathway* 875
- 23-10 ATP Production for the Common Metabolic Pathway 877
- 23-11 Non-ETC Oxygen-Consuming Reactions 878
- 23-12 B Vitamins and the Common Metabolic Pathway 881

CHEMICAL CONNECTIONS

- 23-A Adenosine Phosphates and Muscle Relaxation/Contraction 848
- 23-B Brown Fat, Newborn Babies, and Hibernating Animals 875
- 23-C Cyanide Poisoning 876
- 23-D Phytochemicals: Compounds with Color and Antioxidant Functions 880

24 Carbohydrate Metabolism 883

- 24-1 Digestion and Absorption of Carbohydrates 883
- 24-2 Glycolysis 886
- 24-3 Fates of Pyruvate 895
- 24-4 ATP Production from the Complete Oxidation of Glucose 901
- 24-5 Glycogen Synthesis and Degradation 903
- 24-6 Gluconeogenesis 906
- 24-7 Terminology for Glucose Metabolic Pathways 909
- 24-8 The Pentose Phosphate Pathway 911

- CHEMISTRY AT A GLANCE** *Glucose Metabolism* 912
- 24-9 Hormonal Control of Carbohydrate Metabolism 913
- 24-10 B Vitamins and Carbohydrate Metabolism 915

CHEMICAL CONNECTIONS

- 24-A Lactate Accumulation 899
- 24-B Diabetes Mellitus 914

25 Lipid Metabolism 917

- 25-1 Digestion and Absorption of Lipids 917
- 25-2 Triacylglycerol Storage and Mobilization 920
- 25-3 Glycerol Metabolism 922
- 25-4 Oxidation of Fatty Acids 923
- 25-5 ATP Production from Fatty Acid Oxidation 928
- 25-6 Ketone Bodies and Ketogenesis 931
- 25-7 Biosynthesis of Fatty Acids: Lipogenesis 936
- 25-8 Relationships Between Lipogenesis and Citric Acid Cycle Intermediates 942
- 25-9 Fate of Fatty-Acid-Generated Acetyl CoA 944

CHEMISTRY AT A GLANCE *Interrelationships Between Carbohydrate and Lipid Metabolism* 946

- 25-10 Relationships Between Lipid and Carbohydrate Metabolism 947
- 25-11 B Vitamins and Lipid Metabolism 948

CHEMICAL CONNECTIONS

- 25-A High-Intensity Versus Low-Intensity Workouts 931
- 25-B Statins: Drugs That Lower Plasma Levels of Cholesterol 945

26 Protein Metabolism 950

- 26-1 Protein Digestion and Absorption 950
- 26-2 Amino Acid Utilization 952
- 26-3 Transamination and Oxidative Deamination 955
- 26-4 The Urea Cycle 961

CHEMISTRY AT A GLANCE *Metabolic Reactions That Involve Nitrogen-Containing Compounds* 967

- 26-5 Amino Acid Carbon Skeletons 969
- 26-6 Amino Acid Biosynthesis 971
- 26-7 Hemoglobin Catabolism 973
- 26-8 Proteins and the Element Sulfur 976
- 26-9 Interrelationships Among Metabolic Pathways 980

CHEMISTRY AT A GLANCE *Interrelationships Among Carbohydrate, Lipid, and Protein Metabolism* 980

- 26-10 B Vitamins and Protein Metabolism 982

CHEMICAL CONNECTIONS

- 26-A The Chemical Composition of Urine 966
- 26-B Arginine, Citrulline, and the Chemical Messenger Nitric Oxide 968

Answers to Selected Exercises A-1

Index/Glossary I-1

Preface

The positive responses of instructors and students who used the previous six editions of this text have been gratifying—and have led to the new seventh edition that you hold in your hands. This new edition represents a renewed commitment to the goals I initially set when writing the first edition. These goals have not changed with the passage of time. My initial and still ongoing goals are to write a text in which:

- The needs are simultaneously met for the many students in the fields of nursing, allied health, biological sciences, agricultural sciences, food sciences, and public health who are required to take such a course.
- The development of chemical topics always starts out at ground level. The students who will use this text often have little or no background in chemistry and hence approach the course with a good deal of trepidation. This “ground level” approach addresses this situation.
- The amount and level of mathematics is purposefully restricted. Clearly, some chemical principles cannot be divorced entirely from mathematics and, when this is the case, appropriate mathematical coverage is included.
- The early chapters focus on fundamental chemical principles, and the later chapters—built on these principles—develop the concepts and applications central to the fields of organic chemistry and biochemistry.

New Features Added to the Seventh Edition

Two new features are present in this seventh edition of the text. They are: (1) Section Quick Quizzes, and (2) Section Learning Focus Statements.

Section Quick Quizzes: Each section in each chapter of the text now ends with a “Section Quick Quiz.” Depending on the section length and the number of concepts covered, the quick quiz consists of two to six multiple choice questions which highlight the key terms and concepts covered in the section that a student should be aware of after the initial reading of the text section. Answers to the quick quiz questions are given immediately following the set of questions. The word “quick” in the phrase “quick quiz” is significant. The questions are designed to generate immediate answers. In most cases a time of no more than a minute is sufficient to complete the quiz.

Two important purposes for this new quick quiz feature are: (1) to serve as a guide to the most important terms and concepts found in the section under study, and (2) to serve as an important review system for a student when he or she is studying for an upcoming class exam on the subject matter under study.

Learning Focus Statements: Learning focus statements are now found at the beginning of each section in each chapter of the text. These statements provide the student with insights into the focus of the section in terms of topics covered and the needed learning outcomes associated with these topics.

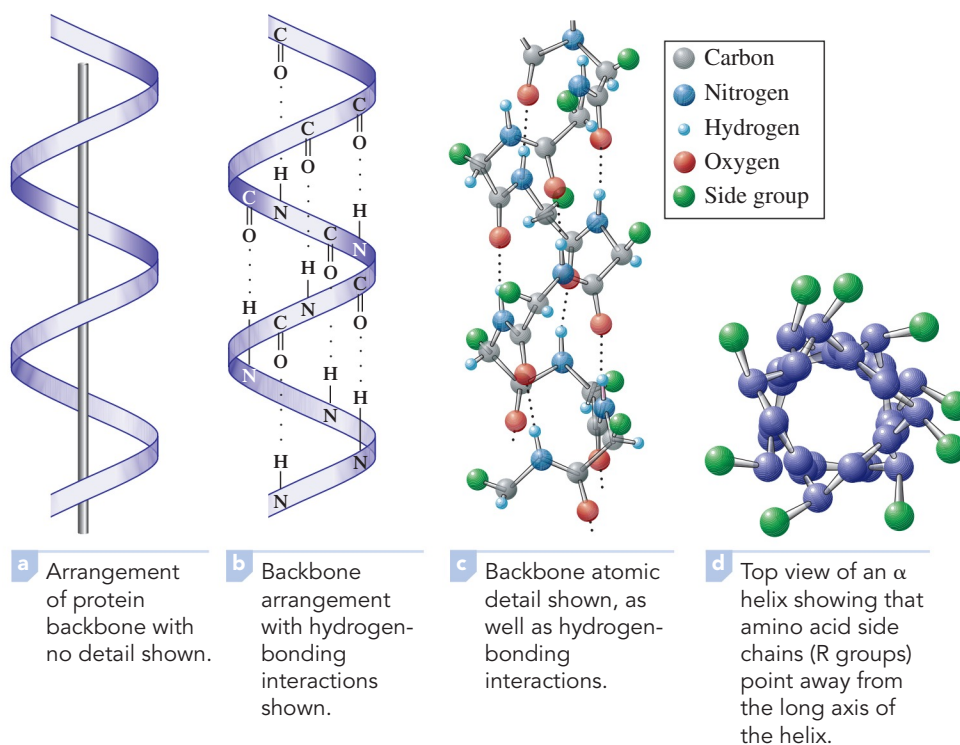
Important Continuing Features in the Seventh Edition

Focus on Biochemistry Most students taking this course have a greater interest in the biochemistry portion of the course than the preceding two parts. But biochemistry, of course, cannot be understood without a knowledge of the fundamentals of

organic chemistry, and understanding organic chemistry in turn depends on knowing the key concepts of general chemistry. Thus, in writing this text, I essentially started from the back and worked forward. I began by determining what topics would be considered in the biochemistry chapters and then tailored the organic and then general sections to support that presentation. Users of the previous editions confirm that this approach ensures an efficient but thorough coverage of the principles needed to understand biochemistry.

Art Program See the story of general, organic, and biological chemistry come alive on each page! In addition to the narrative, the art and photography program helps tell a very important story—the story of ourselves and the world around us. Chemistry is everywhere! An integrated talking label system in the art and photography program gives key figures a “voice” and helps students learn more effectively.

Emphasis on Visual Support I believe strongly in visual reinforcement of key concepts in a textbook; thus this book uses art and photos wherever possible to teach key concepts. Artwork is used to make connections and highlight what is important for the student to know. Reaction equations use color to emphasize the portions of a molecule that undergo change. Colors are likewise assigned to things like valence shells and classes of compounds to help students follow trends. Computer-generated, three-dimensional molecular models accompany many discussions in the organic and biochemistry sections of the text. Color photographs show applications of chemistry to help make concepts real and more readily remembered. The following example is representative of the art program.



Chemistry at a Glance Visual summaries called *Chemistry at a Glance* pull together material from several sections of a chapter to help students see the larger picture. Representative of such features are those entitled

- Relationships involving the Mole Concept (Section 6-7)
- Factors that increase Chemical Reaction Rates (Section 9-6)
- Properties of Alkanes and Cycloalkanes (Section 12-17)

- Types of Glycosidic Linkages for Disaccharides and Polysaccharides (Section 18-17)
- Types of Lipids in Terms of How They Function (Section 19-14)
- Summary of the Reactions of the Citric Acid Cycle (Section 23-7)

Given the popularity of the *Chemistry at a Glance* summaries in the previous editions, several new ones have been added and several existing ones have been revised. New and revised *Chemistry at a Glance* topics include:

- Types of Unsaturated Hydrocarbon (Section 13-16)
- Summary of Chemical Reactions Involving Alcohols (Section 14-9)
- Summary of Chemical Reactions Involving Carboxylic Acids (Section 16-7)
- Constitution Isomers and Stereoisomers (Section 18-6)
- Interrelationships Among Carbohydrate, Lipid, and Protein Metabolism (Section 26-8)

Chemical Connections In every chapter *Chemical Connection* boxes emphasize the relevancy of chemical topics under consideration. They focus on issues relevant to a student's own life in terms of health issues, societal issues, and environmental issues. Representative of issues selected for *Chemical Connection* coverage are the following:

- Fresh Water, Seawater, Hard Water, and Soft Water (Section 4-8)
- The Chemical Sense of Smell (Section 5-8)
- Stratospheric Ozone: An Equilibrium Situation (Section 9-8)
- Red Wine and Resveratrol (Section 14-14)
- The Fatty Content of Tree Nuts and Peanuts (Section 19-4)

New topics selected for *Chemical Connection* emphasis in this edition are:

- Electrons in Excited States (Section 3-7)
- Edible Fiber and Health (Section 18-17)
- The Circadian Clock: Clock Genes (Section 22-9)
- EPO: Red Blood Cells, Mutations, and Athletic Performance (Section 22-13)
- Adenosine Phosphates and Muscle Relaxation/Contraction (Section 23-3)
- Phytochemicals: Compounds with Color and Antioxidant Properties (Section 23-11)

Updated *Chemical Connection* boxes include

- Elemental Composition of the Human Body (Section 1-7)
- Combustion Reactions: Carbon Dioxide and Global Warming (Section 9-1)
- Human Body Temperature and Chemical Reaction Rates (Section 9-6)
- Electrolytes and Body Fluids (Section 10-15)
- Caffeine: A Widely Used Central Nervous System Stimulant (Section 17-9)
- Lactose Intolerance or Lactase Persistence (Section 18-13)
- Trans Fatty Acid Content of Foods (Section 19-6)
- Enzymes, Prescription Medications and the "Grapefruit Effect" (Section 21-11)

Commitment to Student Learning In addition to the study help *Chemistry at a Glance* offers, the text is built on a strong foundation of learning aids designed to help students master the course material.

- **Problem-solving pedagogy.** Because problem solving is often difficult for students in this course to master, I have taken special care to provide support to help students build their skills. Within the chapters, worked-out *Examples* follow the explanation of many concepts. These examples walk students through the thought processes involved in problem solving, carefully outlining all of the steps involved.

Diversity of Worked-out Examples *Worked-out examples* are a standard feature in the general chemistry portion of all textbooks for this market. This relates primarily to the mathematical nature of many general chemistry topics. In most texts, fewer worked-out examples appear in the organic chemistry chapters, and still fewer (almost none) are found in the biochemistry portion due to decreased dependence of the topical matter on mathematical concepts. Such is not the case in this textbook. All chapters in the latter portions of the text contain numerous worked-out examples. Several additional worked-out examples have been added to this new edition. Newly added worked-out examples include the following topics:

- Classifying Matter as a Pure Substance or a Mixture (Section 1-3)
- Classifying Substances as Elements or Compounds (Section 1-7)
- Distinguishing Between Chemical Symbols and Chemical Formulas (Section 1-8)
- Diagramming Coordinate Covalent Bond Formation Using Lewis Structures (Section 5-2)
- Using Delta Notation to Specify the Direction of Bond Polarity (Section 5-6)
- Using Electronegativity Difference to Predict Chemical Bond Type (Section 5-7)
- Using Clinical Laboratory Concentration Units (Section 8-7)
- Converting an Ion Concentration from moles/L to mEq/L (Section 10-13)
- Identifying Components of a Nucleotide (Section 22-1)
- **Margin notes.** Liberally distributed throughout the text, *margin notes* provide tips for remembering and distinguishing between concepts, highlight links across chapters, and describe interesting historical background information.
- **Defined terms.** All definitions are highlighted in the text when they are first presented, using boldface and italic type. Each defined term appears as a complete sentence; students are never forced to deduce a definition from context. In addition, the definitions of all terms appear in the combined *Index/Glossary* found at the end of the text. A major emphasis in this new edition has been “refinements” of the defined terms. All defined terms were reexamined to see if they could be stated with greater clarity. The result was a “rewording” of many defined terms.
- **Concepts to Remember review.** A concise review of key concepts presented in each chapter appears at the end of the chapter, placed just before the end-of-chapter problems. This is a helpful aid for students as they prepare for exams.
- **End-of-chapter problems.** An extensive set of end-of-chapter problems complements the worked-out examples within the chapters. These end-of-chapter problems are organized by topic and paired, with each pair testing similar material. The answer to the odd-numbered member of the pair is given at the back of the book are two problem-set features:

Problems denoted with a ▲ involve concepts found not only in the section under consideration but also concepts found in one or more earlier sections of the chapter.

Over 1000 of the 3284 total end-of-chapter problems are new to this edition of the text. This total number of end-of-chapter problems significantly exceeds that of most other texts.

Content Changes Coverage of a number of topics has been expanded in this edition. The two driving forces in expanded coverage considerations were (1) the requests of users and reviewers of the previous editions and (2) my desire to incorporate new research findings, particularly in the area of biochemistry, into the text. Topics with expanded coverage include:

- Clinical Laboratory Concentration Units (Section 8-5)
- Concentration Units for Isotopic Solutions (Section 8-10)
- Equivalents and Milliequivalents of Electrolytes (Section 10-15)
- Charge Balance in Electrolytic Solutions (Section 10-15)

- Preparation of Alkenes (Section 13-9)
- Functional Group Isomerism (Section 14-7)
- Alcohol Condensation Reactions (Section 14-9)
- Carboxylic Acid Decarboxylation Reactions (Section 16-9)
- OxyContin Formulations (Section 17-12)
- Medical Uses of Enzymes (Section 21-11)
- Fat-Soluble Vitamins (Section 21-15)
- The Human Transcriptome (Section 22-9)
- Mutations (Section 22-13)
- Transamination Reactions (Section 26-3)
- Proteins and the Element Sulfur (Section 26-8)

Supporting Materials

Please visit <http://www.cengage.com/chemistry/stoker/gob7E> for information about the student and instructor resources for this text.

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Basic Concepts About Matter

1

Chapter Outline

- 1-1** Chemistry: The Study of Matter 1
- 1-2** Physical States of Matter 2
- 1-3** Properties of Matter 3
- 1-4** Changes in Matter 6
- 1-5** Pure Substances and Mixtures 7
- 1-6** Elements and Compounds 10
- 1-7** Discovery and Abundance of the Elements 13
- 1-8** Names and Chemical Symbols of the Elements 15
- 1-9** Atoms and Molecules 18
- 1-10** Chemical Formulas 20



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Numerous physical and chemical changes in matter occur during a volcanic eruption.

In this chapter, the question “What exactly is chemistry about?” is addressed. In addition, common terminology associated with the field of chemistry is considered. Much of this terminology is introduced in the context of the ways in which matter is classified. Like all other sciences, chemistry has its own specific language. It is necessary to restrict the meanings of some words so that all chemists (and those who study chemistry) can understand a given description of a chemical phenomenon in the same way.

1-1 Chemistry: The Study of Matter

LEARNING FOCUS

Define the term *matter*; indicate whether or not various entities are considered to be matter.

Chemistry is the field of study concerned with the characteristics, composition, and transformations of matter. What is matter? **Matter** is anything that has mass and occupies space. The term *mass* refers to the amount of matter present in a sample. ◀

Matter includes all naturally occurring things—both living and nonliving—that can be seen (such as plants, soil, and rocks), as well as things

▶ The mass of a sample of matter is a measure of the amount of matter present in the sample.

that cannot be seen (such as air and bacteria). Matter also includes materials that do not occur naturally, that is, synthetic materials that are produced in a laboratory or industrial setting using, directly or indirectly, naturally occurring starting materials. Various forms of energy such as heat, light, and electricity are not considered to be matter. However, chemists must be concerned with energy as well as with matter because nearly all changes that matter undergoes involve the release or absorption of energy. ◀

▶ *The universe is composed entirely of matter and energy.*

The scope of chemistry is extremely broad, and it touches every aspect of our lives. An iron gate rusting, a chocolate cake baking, the production in a laboratory of an antibiotic or a plastic composite, the diagnosis and treatment of a heart attack, the propulsion of a jet airliner, and the digesting of food all fall within the realm of chemistry. The key to understanding such diverse processes is understanding the fundamental nature of matter, which is what is now considered.

Section 1-1 Quick Quiz

- Which of the following is a characteristic of all types of matter?
 - naturally occurring
 - visible to the naked eye
 - has mass
 - no correct response
- Which of the following is classified as matter?
 - heat energy
 - a scientific theory
 - chocolate milk
 - no correct response
- Which of the following processes does not fall within the realm of chemistry?
 - detonation of an explosive
 - cooking of a hamburger patty
 - production of a blood pressure medication
 - no correct response

Answers: 1. c; 2. c; 3. d

1-2 Physical States of Matter

LEARNING FOCUS

Characterize each of the three states of matter in terms of the definiteness or indefiniteness of its shape and volume.

Three physical states exist for matter: solid, liquid, and gas. The classification of a given matter sample in terms of physical state is based on whether its shape and volume are definite or indefinite. ◀

Solid is the physical state characterized by a definite shape and a definite volume. A dollar coin has the same shape and volume whether it is placed in a large container or on a table top (Figure 1-1a). For solids in powdered or granulated forms, such as sugar or salt, a quantity of the solid takes the shape of the portion of the container it occupies, but each individual particle has a definite shape and definite volume. **Liquid** is the physical state characterized by an indefinite shape and a definite volume. A liquid always takes the shape of its container to the extent that it fills the container (Figure 1-1b). **Gas** is the physical state characterized by an indefinite shape and an indefinite volume. A gas always completely fills its container, adopting both the container's volume and its shape (Figure 1-1c).

The state of matter observed for a particular substance depends on its temperature, the surrounding pressure, and the strength of the forces holding its structural particles together. At the temperatures and pressures normally encountered on Earth, water is one of the few substances found in all three physical states: solid ice, liquid

▶ *The volume of a sample of matter is a measure of the amount of space occupied by the sample.*

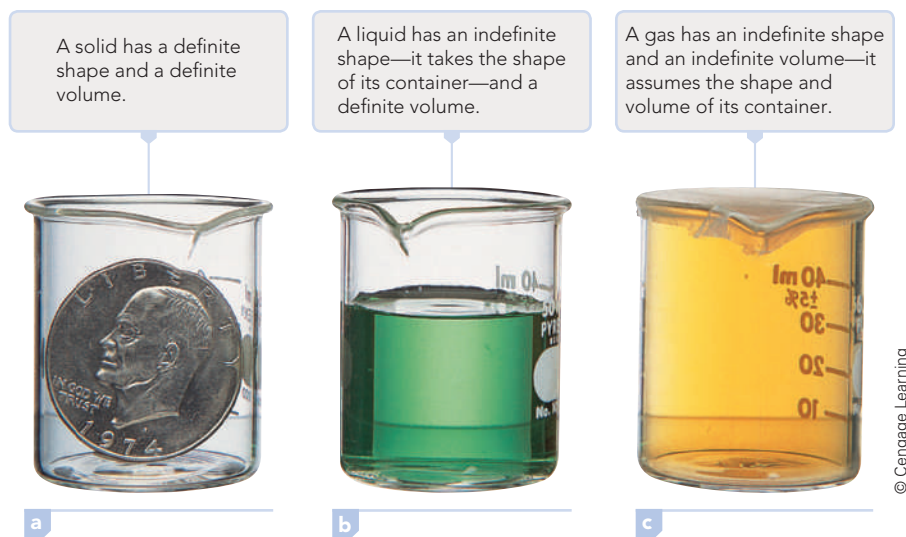


Figure 1-1 A comparison of the volume and shape characteristics of solids, liquids, and gases.

water, and gaseous steam (Figure 1-2). Under laboratory conditions, states other than those commonly observed can be attained for almost all substances. Oxygen, which is nearly always thought of as a gas, becomes a liquid at -183°C and a solid at -218°C . The metal iron is a gas at extremely high temperatures (above 3000°C).

Section 1-2 Quick Quiz

- Which of the following is a characteristic of both liquids and gases?
 - definite shape
 - definite volume
 - indefinite shape
 - no correct response
- The characterization “completely fills its container” describes the
 - solid state
 - liquid state
 - gaseous state
 - no correct response
- The characterization “indefinite shape, definite volume” applies to
 - a solid
 - a liquid
 - both a solid and a liquid
 - no correct response

Answers: 1. c; 2. c; 3. b

1-3 Properties of Matter

LEARNING FOCUS

Classify a given property of a substance as a *physical property* or a *chemical property*.

Various kinds of matter are distinguished from each other by their properties. A **property** is a distinguishing characteristic of a substance that is used in its identification and description. Each substance has a unique set of properties that distinguishes it from all other substances. Properties of matter are of two general types: physical and chemical.

A **physical property** is a characteristic of a substance that can be observed without changing the basic identity of the substance. Common physical properties include color, physical state (solid, liquid, or gas), melting point, boiling point, and hardness. ◀

▶ *Physical properties are properties associated with a substance's physical existence. They can be determined without reference to any other substance, and determining them causes no change in the identity of the substance.*

Figure 1-2 Water can be found in the solid, liquid, and vapor (gaseous) forms simultaneously, as shown here at Yellowstone National Park.



FRILET Patrick / Hemis / Alamy



Andy Levin/Science Source

Figure 1-3 The green color of the Statue of Liberty results from the reaction of the copper skin of the statue with the components of air. That copper will react with the components of air is a chemical property of copper.

► *Chemical properties describe the ability of a substance to form new substances, either by reaction with other substances or by decomposition.*

During the process of determining a physical property, the physical appearance of a substance may change, but the substance's identity does not. For example, it is impossible to measure the melting point of a solid without changing the solid into a liquid. Although the liquid's appearance is much different from that of the solid, the substance is still the same; its chemical identity has not changed. Hence, melting point is a physical property.

A **chemical property** is a characteristic of a substance that describes the way the substance undergoes or resists change to form a new substance. For example, copper objects turn green when exposed to moist air for long periods of time (Figure 1-3); this is a chemical property of copper. The green coating formed on the copper is a new substance that results from the copper's reaction with oxygen, carbon dioxide, and water present in air. The properties of this new substance (the green coating) are very different from those of metallic copper. On the other hand, gold objects resist change when exposed to air for long periods of time. The lack of reactivity of gold with air is a chemical property of gold.

Most often, the changes associated with chemical properties result from the interaction (reaction) of a substance with one or more other substances. However, the presence of a second substance is not an absolute requirement. Sometimes the presence of energy (usually heat or light) can trigger the change known as *decomposition*. That hydrogen peroxide, in the presence of either heat or light, decomposes into the substances water and oxygen is a chemical property of hydrogen peroxide. ◀

When chemical properties are specified, conditions such as temperature and pressure are usually given because they influence the interactions between substances. For example, the gases oxygen and hydrogen do not react with each other at room temperature, but they react explosively at a temperature of several hundred degrees.

EXAMPLE 1-1

Classifying Properties as Physical or Chemical

Classify each of the following properties of selected metals as a *physical* property or a *chemical* property.

- Iron metal rusts in an atmosphere of moist air.
- Mercury metal is a liquid at room temperature.
- Nickel metal dissolves in acid to produce a light green solution.
- Potassium metal has a melting point of 63°C .

Solution

- Chemical property.* The interaction of iron metal with moist air produces a new substance (rust).
- Physical property.* Visually determining the physical state of a substance does not produce a new substance.
- Chemical property.* A change in color indicates the formation of a new substance.
- Physical property.* Measuring the melting point of a substance does not change the substance's composition.

The focus on relevancy feature Chemical Connections 1-A—Carbon Monoxide: A Substance with Both “Good” and “Bad” Properties—discusses the important concept that a decision about the significance or usefulness of a substance should not be made solely on the basis of just one or two of its many chemical or physical properties. The discussion there focuses on both the “bad” and “good” properties possessed by the gas carbon monoxide.

CHEMICAL CONNECTIONS 1-A**Carbon Monoxide: A Substance with Both “Good” and “Bad” Properties**

Possession of a “bad” property, such as toxicity or a strong noxious odor, does not mean that a chemical substance has nothing to contribute to the betterment of human society. The gas carbon monoxide is an important example of this concept.

It is common knowledge that carbon monoxide is toxic to humans and at higher concentrations can cause death. This gas, which can be present in significant concentrations in both automobile exhaust and cigarette smoke, impairs human health by reducing the oxygen-carrying capacity of the blood. It does this by interacting with the hemoglobin in red blood cells in a way that prevents the hemoglobin from distributing oxygen throughout the body. Someone who dies from carbon monoxide poisoning actually dies from lack of oxygen. (Additional information about the human health effects of the air pollutant carbon monoxide is found in Chemical Connections 6-A) Because of its toxicity, many people automatically label carbon monoxide a “bad substance,” a substance that is not wanted and not needed.

The fact that carbon monoxide is colorless, odorless, and tasteless is very significant. Because of these properties, carbon monoxide gives no warning of its initial presence. Several other common air pollutants are more toxic than carbon monoxide. However, they have properties that warn of their presence and hence are not considered as “dangerous” as carbon monoxide.

Despite its toxicity, carbon monoxide plays an important role in the maintenance of the high standard of living we now enjoy. Its contribution lies in the field of iron metallurgy and the production of steel. The isolation of iron from iron ores, necessary for the production of steel, involves a series of high-temperature reactions, carried out in a blast furnace, in which the iron content of molten iron ores reacts with carbon monoxide. These reactions release the iron from its ores. The carbon monoxide needed in steel-making is obtained by reacting coke (a product derived by heating coal to a high temperature without air being present) with oxygen.

The industrial consumption of the metal iron, both in the United States and worldwide, is approximately 10 times greater than that of all other metals combined. Steel production accounts for nearly all of this demand for iron. Without steel, our standard of living would drop dramatically, and carbon monoxide is necessary for the production of steel.



Carbon monoxide is needed to produce molten iron from iron ore in a blast furnace.

Is carbon monoxide a “good” or a “bad” chemical substance? The answer to this question depends on the context in which the carbon monoxide is encountered. In terms of air pollution, it is a “bad” substance. In terms of steel-making, it is a “good” substance. A similar “good–bad” dichotomy exists for almost every chemical substance.

Section 1-3 Quick Quiz

- Which of the following statements about various substances describes a *physical* property of the substance?
 - Copper metal can be drawn into thin wires.
 - Gold metal does not tarnish in air.
 - Hydrogen peroxide decomposes in the presence of light.
 - no correct response
- Which of the following statement about various substances describes a *chemical* property of the substance?
 - Silver metal will not dissolve in hydrochloric acid.
 - Beryllium metal has a silvery-gray color.
 - Water (ice) melts at 32°F.
 - no correct response
- In which of the following pairs of properties are both *physical* properties?
 - low density, flammable
 - reacts with oxygen, does not react with iodine
 - very brittle, very toxic
 - no correct response

Answers: 1. a; 2. a; 3. d

1-4 Changes in Matter

LEARNING FOCUS

Classify a given change that occurs in matter as a *physical change* or a *chemical change*.

Changes in matter are common and familiar occurrences. Changes take place when food is digested, paper is burned, and a pencil is sharpened. Like properties of matter, changes in matter are classified into two categories: physical and chemical.

A **physical change** is a process in which a substance changes its physical appearance but not its chemical composition. A new substance is never formed as a result of a physical change. ◀

A change in physical state is the most common type of physical change. Melting, freezing, evaporation, and condensation are all changes of state. In any of these processes, the composition of the substance undergoing change remains the same even though its physical state and appearance change. The melting of ice does not produce a new substance; the substance is water both before and after the change. Similarly, the steam produced from boiling water is still water.

A **chemical change** is a process in which a substance undergoes a change in chemical composition. Chemical changes always involve conversion of the material or materials under consideration into one or more new substances, each of which has properties and a composition distinctly different from those of the original materials. Consider, for example, the rusting of iron objects left exposed to moist air (Figure 1-4). The reddish-brown substance (the rust) that forms is a new substance with chemical properties that are obviously different from those of the original iron.

► *Physical changes need not involve a change of state. Pulverizing an aspirin tablet into a powder and cutting a piece of adhesive tape into small pieces are physical changes that involve only the solid state.*



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Figure 1-4 As a result of chemical change, bright steel girders become rusty when exposed to moist air.

EXAMPLE 1-2

Correct Use of the Terms *Physical* and *Chemical* in Describing Changes

Complete each of the following statements about changes in matter by placing the word *physical* or *chemical* in the blank.

- The fashioning of a piece of wood into a round table leg involves a _____ change.
- The vigorous reaction of potassium metal with water to produce hydrogen gas is a _____ change.
- Straightening a bent piece of iron with a hammer is an example of a _____ change.
- The ignition and burning of a match involve a _____ change.

Solution

- a. *Physical*. The table leg is still wood. No new substances have been formed.
- b. *Chemical*. A new substance, hydrogen, is produced.
- c. *Physical*. The piece of iron is still a piece of iron.
- d. *Chemical*. New gaseous substances, as well as heat and light, are produced as the match burns.

Chemists study the nature of changes in matter to learn how to bring about favorable changes and prevent undesirable ones. The control of chemical change has been a major factor in attaining the modern standard of living now enjoyed by most people in the developed world. The many plastics, synthetic fibers, and prescription drugs now in common use are produced using controlled chemical change.

Chemistry at a Glance—Use of the Terms *Physical* and *Chemical*—reviews the ways in which the terms *physical* and *chemical* are used to describe the properties of substances and the changes that substances undergo. Note that the term *physical*, used as a modifier, always conveys the idea that the composition (chemical identity) of a substance did not change, and that the term *chemical*, used as a modifier, always conveys the idea that the composition of a substance did change.

Section 1-4 Quick Quiz

1. Which of the following processes is not a *physical* change?
 - a. crushing ice cubes to make ice chips
 - b. melting ice cubes to produce liquid water
 - c. freezing liquid water to produce ice cubes
 - d. no correct response
2. Which of the following processes is an example of *chemical* change?
 - a. grating a piece of cheese
 - b. burning a piece of wood
 - c. pulverizing a hard sugar cube
 - d. no correct response
3. Which of the following is always a characteristic of *chemical* change?
 - a. heat is produced
 - b. light is emitted
 - c. one or more new substances are produced
 - d. no correct answer

Answers: 1. d; 2. b; 3. c

1-5 Pure Substances and Mixtures**LEARNING FOCUS**

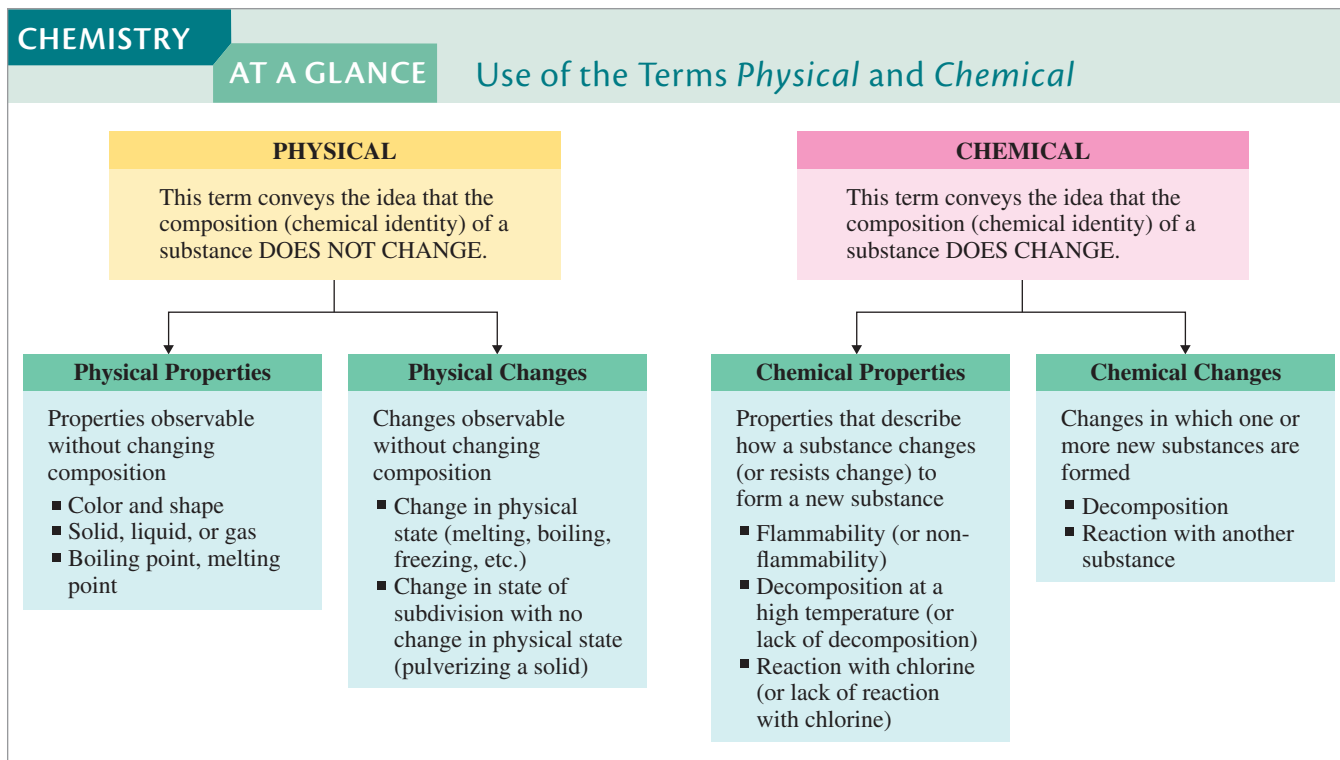
Know the major differences among the matter classifications *pure substance*, *heterogeneous mixture*, and *homogeneous mixture*.

In addition to its classification by physical state (Section 1-2), matter can also be classified in terms of its chemical composition as a pure substance or as a mixture. A **pure substance** is a single kind of matter that cannot be separated into other kinds of matter by any physical means. All samples of a pure substance contain only that substance and nothing else. Pure water is water and nothing else. Pure sucrose (table sugar) contains only that substance and nothing else. ◀

A pure substance always has a definite and constant composition. This invariant composition dictates that the properties of a pure substance are always the same under a given set of conditions. Collectively, these definite and constant physical and chemical properties constitute the means by which we identify the pure substance.

A **mixture** is a physical combination of two or more pure substances in which each substance retains its own chemical identity. Components of a mixture retain their

► Substance is a general term used to denote any variety of matter. Pure substance is a specific term that is applied to matter that contains only a single substance. All samples of a pure substance, no matter what their source, have the same properties under the same conditions.



► *Most naturally occurring samples of matter are mixtures. Gold and diamond are two of the few naturally occurring pure substances. Despite their scarcity in nature, numerous pure substances exist. They are obtained from natural mixtures by using various types of separation techniques or are synthesized in the laboratory from naturally occurring materials.*

Figure 1-5 Physical separation of the two components of a mixture using the magnetic properties of one of the mixture components.

identity because they are physically mixed rather than chemically combined. Consider a mixture of small rock salt crystals and ordinary sand. Mixing these two substances changes neither the salt nor the sand in any way. The larger, colorless salt particles are easily distinguished from the smaller, light-gray sand granules.

One characteristic of any mixture is that its components can be separated by using physical means. In our salt–sand mixture, the larger salt crystals could be—though very tediously—“picked out” from the sand. A somewhat easier separation method would be to dissolve the salt in water, which would leave the undissolved sand behind. The salt could then be recovered by evaporation of the water. Figure 1-5a shows a mixture of potassium dichromate (orange crystals) and iron filings. A magnet can be used to separate the components of this mixture (Figure 1-5b).

Another characteristic of a mixture is variable composition. Numerous different salt–sand mixtures, with compositions ranging from a slightly salty sand mixture to a slightly sandy salt mixture, could be made by varying the amounts of the two components. ◀



Mixtures are subclassified as heterogeneous or homogeneous. This subclassification is based on visual recognition of the mixture's components. A **heterogeneous mixture** is a mixture that contains visibly different phases (parts), each of which has different properties. A nonuniform appearance is a characteristic of all heterogeneous mixtures. Examples include chocolate chip cookies and blueberry muffins. Naturally occurring heterogeneous mixtures include rocks, soils, and wood.

A **homogeneous mixture** is a mixture that contains only one visibly distinct phase (part), which has uniform properties throughout. The components present in a homogeneous mixture cannot be visually distinguished. A sugar–water mixture in which all of the sugar has dissolved has an appearance similar to that of pure water. Air is a homogeneous mixture of gases; motor oil and gasoline are multicomponent homogeneous mixtures of liquids; and metal alloys such as 14-karat gold (a mixture of copper and gold) are examples of homogeneous mixtures of solids. The homogeneity present in solid-state metallic alloys is achieved by mixing the metals while they are in the molten state. ◀

Figure 1-6 summarizes key concepts presented in this section about various classifications of matter.

▶ All human body fluids, such as urine, blood, or sweat are mixtures of many substances. Since their components cannot be visually distinguished from each other, they are homogeneous mixtures.

EXAMPLE 1-3

Classifying Matter as a Pure Substance or a Mixture

Classify each of the following as a *heterogeneous mixture*, a *homogeneous mixture*, or a *pure substance*. Assume that each sample has been well stirred.

- a “pinch” of table salt, one quart of water
- a “pinch” of ground black pepper, one quart of water
- one substance present, one phase present
- two substances present, same properties throughout

Solution

- Two substances present means *mixture*; since table salt is soluble in water only one phase is present, a characteristic of a *homogeneous mixture*.
- Two substances present means *mixture*; since black pepper is insoluble in water two phases are present (solid and liquid), a characteristic of a *heterogeneous mixture*.
- One substance present means *pure substance* rather than mixture; a mixture requires the presence of two substances. The presence of two phases does not cause the classification to change from pure substance to mixture. An example of a “one substance, two phase” situation is ice cubes in water. Water (a pure substance) is present in two states (solid and liquid).
- This *mixture* (two substances present) is a *homogeneous mixture* as the same properties throughout denotes homogeneity.

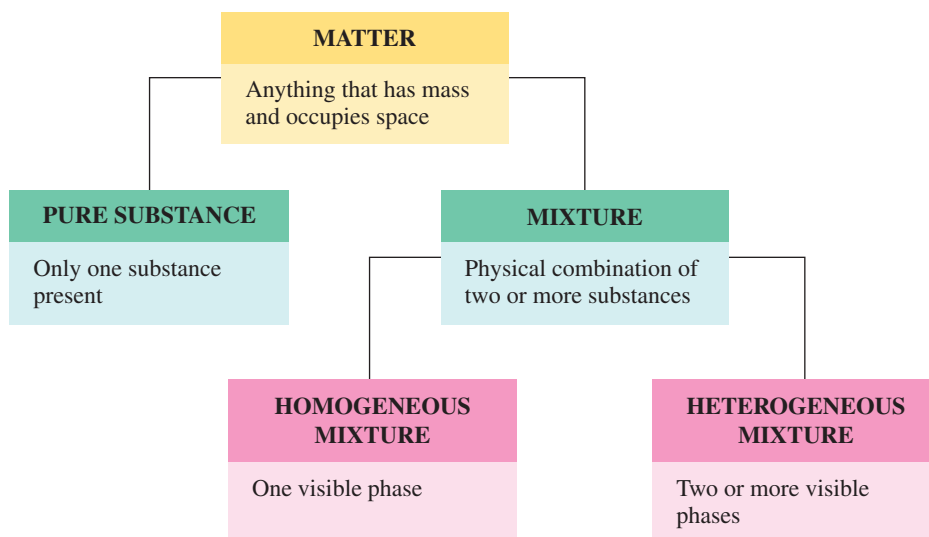


Figure 1-6 Matter falls into two basic classes: pure substances and mixtures. Mixtures, in turn, may be homogeneous or heterogeneous.