

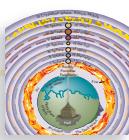
# Contents

Preface x

## 1 The Scientific Method 1

### How Scientists Study Nature 2

- 1.1 The Scientific Method 2
- 1.2 Why Science Is Successful 5



### The Solar System 8

- 1.3 A Survey of the Sky 8
- 1.4 The Ptolemaic System 10
- 1.5 The Copernican System 12
- 1.6 Kepler's Laws 14
- 1.7 Why Copernicus Was Right 16

### Universal Gravitation 18

- 1.8 What Is Gravity? 18
- 1.9 Why the Earth Is Round 20
- 1.10 The Tides 22
- 1.11 The Discovery of Neptune 23

### How Many of What 24

- 1.12 The SI System 25

Important Terms and Ideas 28

Multiple Choice 28

Exercises 29

## 2 Motion 31



### Describing Motion 32

- 2.1 Speed 32
- 2.2 Vectors 35
- 2.3 Acceleration 36
- 2.4 Distance, Time, and Acceleration 38

### Acceleration of Gravity 39

- 2.5 Free Fall 40
- 2.6 Air Resistance 44

### Force and Motion 46

- 2.7 First Law of Motion 46
- 2.8 Mass 47
- 2.9 Second Law of Motion 47

### 2.10 Mass and Weight 51

### 2.11 Third Law of Motion 52

## Gravitation 54

- 2.12 Circular Motion 54
- 2.13 Newton's Law of Gravity 57
- 2.14 Artificial Satellites 58

Important Terms and Ideas 62

Important Formulas 62

Multiple Choice 62

Exercises 65

## 3 Energy 71



### Work 72

- 3.1 The Meaning of Work 72
- 3.2 Power 74

## Energy 76

- 3.3 Kinetic Energy 76
- 3.4 Potential Energy 79
- 3.5 Energy Transformations 81
- 3.6 Conservation of Energy 83
- 3.7 The Nature of Heat 83

## Momentum 84

- 3.8 Linear Momentum 85
- 3.9 Rockets 88
- 3.10 Angular Momentum 88

## Relativity 90

- 3.11 Special Relativity 91
- 3.12 Rest Energy 93
- 3.13 General Relativity 95

Important Terms and Ideas 97

Important Formulas 98

Multiple Choice 98

Exercises 100

## 4 Energy and the Future 103



### The Energy Problem 104

- 4.1 Population and Prosperity 104

- 4.2** Energy Consumption 106  
**4.3** Global Warming 109  
**4.4** Carbon Dioxide and the Greenhouse Effect 111

### Fossil Fuels 116

- 4.5** Liquid Fuels 117  
**4.6** Natural Gas 120  
**4.7** Coal 121

### Alternative Sources 126

- 4.8** A Nuclear World? 126  
**4.9** Clean Energy I 130  
**4.10** Clean Energy II 132  
**4.11** Hydrogen and Fuel Cells 137  
**4.12** Biofuels 138

### Strategies for the Future 141

- 4.13** Conservation 142  
**4.14** What Governments Must Do 144

*Important Terms and Ideas* 147

*Multiple Choice* 147

*Exercises* 150

## 5 Matter and Heat 153



### Temperature and Heat 154

- 5.1** Temperature 154  
**5.2** Heat 157  
**5.3** Metabolic Energy 159

### Fluids 161

- 5.4** Density 161  
**5.5** Pressure 162  
**5.6** Buoyancy 166  
**5.7** The Gas Laws 168

### Kinetic Theory of Matter 172

- 5.8** Kinetic Theory of Gases 173  
**5.9** Molecular Motion and Temperature 174

### Changes of State 176

- 5.10** Liquids and Solids 176  
**5.11** Evaporation and Boiling 177  
**5.12** Melting 179

### Energy Transformations 182

- 5.13** Heat Engines 182  
**5.14** Thermodynamics 185  
**5.15** Fate of the Universe 186  
**5.16** Entropy 188

- Important Terms and Ideas* 189  
*Important Formulas* 190  
*Multiple Choice* 190  
*Exercises* 193

## 6 Electricity and Magnetism 199



### Electric Charge 200

- 6.1** Positive and Negative Charge 200  
**6.2** What Is Charge? 202  
**6.3** Coulomb's Law 204  
**6.4** Force on an Uncharged Object 206

### Electricity and Matter 207

- 6.5** Matter in Bulk 207  
**6.6** Conductors and Insulators 208  
**6.7** Superconductivity 210

### Electric Current 211

- 6.8** The Ampere 211  
**6.9** Potential Difference 213  
**6.10** Ohm's Law 216  
**6.11** Electric Power 217

### Magnetism 220

- 6.12** Magnets 221  
**6.13** Magnetic Field 222  
**6.14** Oersted's Experiment 223  
**6.15** Electromagnets 226

### Using Magnetism 227

- 6.16** Magnetic Force on a Current 227  
**6.17** Electric Motors 229  
**6.18** Electromagnetic Induction 230  
**6.19** Transformers 233

*Important Terms and Ideas* 235

*Important Formulas* 236

*Multiple Choice* 236

*Exercises* 239

## 7 Waves 243



### Wave Motion 244

- 7.1** Water Waves 244  
**7.2** Transverse and Longitudinal Waves 245  
**7.3** Describing Waves 246  
**7.4** Standing Waves 249

**Sound Waves 250**

- 7.5** Sound 250  
**7.6** Doppler Effect 252  
**7.7** Musical Sounds 253

**Electromagnetic Waves 256**

- 7.8** Electromagnetic Waves 256  
**7.9** Types of EM Waves 258  
**7.10** Light “Rays” 261

**Wave Behavior 262**

- 7.11** Reflection 262  
**7.12** Refraction 263  
**7.13** Lenses 267  
**7.14** The Eye 271  
**7.15** Color 273  
**7.16** Interference 276  
**7.17** Diffraction 279

*Important Terms and Ideas* 282*Important Formulas* 282*Multiple Choice* 282*Exercises* 285**8 The Nucleus 289****Atom and Nucleus 290**

- 8.1** Rutherford Model of the Atom 290  
**8.2** Nuclear Structure 292

**Radioactivity 294**

- 8.3** Radioactive Decay 295  
**8.4** Half-Life 298  
**8.5** Radiation Hazards 299

**Nuclear Energy 301**

- 8.6** Units of Mass and Energy 301  
**8.7** Binding Energy 302  
**8.8** Binding Energy per Nucleon 303

**Fission and Fusion 305**

- 8.9** Nuclear Fission 305  
**8.10** How a Reactor Works 308  
**8.11** Plutonium 309  
**8.12** Nuclear Fusion 311

**Elementary Particles 314**

- 8.13** Antiparticles 314  
**8.14** Fundamental Interactions 317  
**8.15** Leptons and Hadrons 319

**A Physicist at Work: Michelangelo***D'Agostino* 321*Important Terms and Ideas* 322*Multiple Choice* 322*Exercises* 324**9 The Atom 327****Quantum Theory of Light 328**

- 9.1** Photoelectric Effect 328  
**9.2** Photons 329  
**9.3** What Is Light? 331  
**9.4** X-Rays 333

**Matter Waves 334**

- 9.5** De Broglie Waves 335  
**9.6** Waves of What? 337  
**9.7** Uncertainty Principle 338

**The Hydrogen Atom 339**

- 9.8** Atomic Spectra 340  
**9.9** The Bohr Model 341  
**9.10** Electron Waves and Orbitals 345  
**9.11** The Laser 346

**Quantum Theory of the Atom 349**

- 9.12** Quantum Mechanics 350  
**9.13** Quantum Numbers 351  
**9.14** Exclusion Principle 352

*Important Terms and Ideas* 353*Important Formulas* 354*Multiple Choice* 354*Exercises* 356**10 The Periodic Law 359****Elements and Compounds 360**

- 10.1** Chemical Change 360  
**10.2** Three Classes of Matter 361  
**10.3** The Atomic Theory 363

**The Periodic Law 366**

- 10.4** Metals and Nonmetals 366  
**10.5** Chemical Activity 367  
**10.6** Families of Elements 368  
**10.7** The Periodic Table 369  
**10.8** Groups and Periods 373

**Atomic Structure 374**

- 10.9** Shells and Subshells 375  
**10.10** Explaining the Periodic Table 375

**Chemical Bonds 379**

- 10.11** Types of Bond 379  
**10.12** Covalent Bonding 380  
**10.13** Ionic Bonding 381  
**10.14** Ionic Compounds 383  
**10.15** Atom Groups 384  
**10.16** Naming Compounds 385  
**10.17** Chemical Equations 385

*Important Terms and Ideas* 388*Multiple Choice* 388*Exercises* 390**11 Crystals, Ions, and Solutions 393****Solids 394**

- 11.1** Ionic and Covalent Crystals 395  
**11.2** The Metallic Bond 396  
**11.3** Molecular Crystals 399

**Solutions 402**

- 11.4** Solubility 402  
**11.5** Polar and Nonpolar Liquids 405  
**11.6** Ions in Solution 407  
**11.7** Evidence for Dissociation 409  
**11.8** Water 410  
**11.9** Water Pollution 414

**Acids and Bases 416**

- 11.10** Acids 416  
**11.11** Strong and Weak Acids 418  
**11.12** Bases 418  
**11.13** The pH Scale 420  
**11.14** Salts 421

*Important Terms and Ideas* 422*Multiple Choice* 423*Exercises* 425**12 Chemical Reactions 427****Quantitative Chemistry 428**

- 12.1** Phlogiston 428  
**12.2** Oxygen 431

- 12.3** The Mole 433

- 12.4** Formula Units 435

**Chemical Energy 436**

- 12.5** Exothermic and Endothermic Reactions 437  
**12.6** Chemical Energy and Stability 439  
**12.7** Activation Energy 441

**Reaction Rates 442**

- 12.8** Temperature and Reaction Rates 442  
**12.9** Other Factors 443

**A Chemist at Work: Judith M. Iriarte-Gross 444**

- 12.10** Chemical Equilibrium 445  
**12.11** Altering an Equilibrium 446

**Oxidation and Reduction 448**

- 12.12** Oxidation-Reduction Reactions 448  
**12.13** Electrochemical Cells 450

*Important Terms and Ideas* 453*Multiple Choice* 454*Exercises* 456**13 Organic Chemistry 459****Carbon Compounds 460**

- 13.1** Carbon Bonds 460  
**13.2** Alkanes 461  
**13.3** Petroleum Products 462

**Structures of Organic Molecules 466**

- 13.4** Structural Formulas 466  
**13.5** Isomers 467  
**13.6** Unsaturated Hydrocarbons 467  
**13.7** Benzene 470

**Organic Compounds 471**

- 13.8** Hydrocarbon Groups 472  
**13.9** Functional Groups 472  
**13.10** Polymers 476

**Chemistry of Life 481**

- 13.11** Carbohydrates 482  
**13.12** Photosynthesis 484  
**13.13** Lipids 485  
**13.14** Proteins 486  
**13.15** Soil Nitrogen 487  
**13.16** Nucleic Acids 489  
**13.17** Origin of Life 492

- Important Terms and Ideas* 494  
*Multiple Choice* 494  
*Exercises* 496

## 14 Atmosphere and Hydrosphere 499



### The Atmosphere 500

- 14.1** Regions of the Atmosphere 500  
**14.2** Atmospheric Moisture 504  
**14.3** Clouds 505

### Weather 509

- 14.4** Atmospheric Energy 509  
**14.5** The Seasons 512  
**14.6** Winds 513  
**14.7** General Circulation of the Atmosphere 516  
**14.8** Middle-Latitude Weather Systems 518

### Climate 524

- 14.9** Tropical Climates 526  
**14.10** Middle-Latitude Climates 527  
**14.11** Climate Change 527

### The Hydrosphere 530

- 14.12** Ocean Basins 531  
**14.13** Ocean Currents 533

*Important Terms and Ideas* 536

*Multiple Choice* 536

*Exercises* 538

## 15 The Rock Cycle 541



### Rocks 542

- 15.1** Composition of the Crust 542  
**15.2** Minerals 544  
**15.3** Igneous Rocks 546  
**15.4** Sedimentary Rocks 548  
**15.5** Metamorphic Rocks 550

### Within the Earth 551

- 15.6** Earthquakes 551  
**A Geophysicist at Work: Andrea Donnellan** 555  
**15.7** Structure of the Earth 556

- 15.8** The Earth's Interior 559  
**15.9** Geomagnetism 561

### Erosion 562

- 15.10** Weathering 563  
**15.11** Stream Erosion 565  
**15.12** Glaciers 567  
**15.13** Groundwater 568  
**15.14** Sedimentation 570

### Vulcanism 574

- 15.15** Volcanoes 574  
**15.16** Intrusive Rocks 578  
**15.17** The Rock Cycle 580

*Important Terms and Ideas* 581

*Multiple Choice* 582

*Exercises* 584

## 16 The Evolving Earth 587



### Tectonic Movement 588

- 16.1** Types of Deformation 588  
**16.2** Mountain Building 590  
**16.3** Continental Drift 591

### Plate Tectonics 595

- 16.4** Lithosphere and Asthenosphere 595  
**16.5** The Ocean Floors 596  
**16.6** Ocean-Floor Spreading 597  
**16.7** Plate Tectonics 599

### Methods of Historical Geology 608

- 16.8** Principle of Uniform Change 608  
**16.9** Rock Formations 611  
**16.10** Radiometric Dating 612  
**16.11** Fossils 614  
**16.12** Geologic Time 616

### Earth History 619

- 16.13** Precambrian Time 619  
**16.14** The Paleozoic Era 621  
**16.15** Coal and Petroleum 623  
**16.16** The Mesozoic Era 624  
**16.17** The Cenozoic Era 628  
**16.18** Human History 630

*Important Terms and Ideas* 632

*Multiple Choice* 633

*Exercises* 636

## 17 The Solar System 639



### The Family of the Sun 640

- 17.1** The Solar System 641
- 17.2** Comets 642
- 17.3** Meteors 645

### The Inner Planets 649

- 17.4** Mercury 649
- 17.5** Venus 650
- 17.6** Mars 653
- 17.7** Is There Life on Mars? 656
- 17.8** Asteroids 659

### The Outer Planets 663

- 17.9** Jupiter 663
- 17.10** Saturn 666
- 17.11** Uranus, Neptune, Pluto, and More 669

### The Moon 672

- 17.12** Phases of the Moon 673
- 17.13** Eclipses 674
- 17.14** The Lunar Surface 676
- 17.15** Evolution of the Lunar Landscape 680
- 17.16** Origin of the Moon 681

*Important Terms and Ideas* 682

*Multiple Choice* 683

*Exercises* 685

## 18 The Stars 687



### Tools of Astronomy 688

- 18.1** The Telescope 688
- 18.2** The Spectrometer 691
- 18.3** Spectrum Analysis 692

### The Sun 693

- 18.4** Properties of the Sun 694
- 18.5** The Aurora 696
- 18.6** Sunspots 697
- 18.7** Solar Energy 699

### The Stars 702

- 18.8** Stellar Distances 702
- 18.9** Variable Stars 703

- 18.10** Stellar Motions 705
- 18.11** Stellar Properties 705

### Life Histories of the Stars 706

- 18.12** H-R Diagram 707
- 18.13** Stellar Evolution 708
- 18.14** Supernovas 711
- 18.15** Pulsars 712
- 18.16** Black Holes 713

*Important Terms and Ideas* 716

*Multiple Choice* 717

*Exercises* 719

## 19 The Universe 721



### Galaxies 722

- 19.1** The Milky Way 722
- 19.2** Stellar Populations 725
- 19.3** Radio Astronomy 726
- 19.4** Galaxies 728
- 19.5** Cosmic Rays 731

### The Expanding Universe 732

- 19.6** Red Shifts 732
- 19.7** Quasars 735

### Evolution of the Universe 736

- 19.8** Dating the Universe 736

**An Astronomer at Work:** Wendy Freedman 738

- 19.9** After the Big Bang 739

- 19.10** Origin of the Solar System 743

### Extraterrestrial Life 745

- 19.11** Exoplanets 745
- 19.12** Interstellar Travel 747
- 19.13** Interstellar Communication 748

*Important Terms and Ideas* 750

*Multiple Choice* 751

*Exercises* 753

**Math Refresher** M-1

**The Elements** 000

**Answers to Odd-Numbered Exercises** A-1

**Glossary** G-1

**Photo Credits** 000

**Index** 000