

## TABLE OF CONTENTS

### Front Matter

- TitlePage
- InfoPage

### Licensing

### Back Matter

- Index

## 1: Introduction - The Ambit of Chemistry

- 1.1: Prelude to Chemistry
- 1.2: What Chemists Do
- 1.3: Handling Large and Small Numbers
- 1.4: The International System of Units (SI)
- 1.5: SI Prefixes
- 1.6: Measurements, Quantities, and Unity Factors
  - 1.6.1: Measurements, Quantities, and Unity Factors Lecture Demonstrations
- 1.7: Errors in Measurement
  - 1.7.1: Errors in Measurement Lecture Demonstrations
- 1.8: Volume
- 1.9: Density
  - 1.9.1: Density Lecture Demonstrations
- 1.10: Conversion Factors and Functions

## 2: Atoms, Molecules, and Chemical Reactions

- 2.1: Prelude to Atoms and Reactions
- 2.2: Macroscopic Properties and Microscopic Models
- 2.3: The Atomic Theory
  - 2.3.1: Foods- Elemental Diets
- 2.4: Macroscopic and Microscopic Views of a Chemical Reaction
  - 2.4.1: Foods- The Mineral Nutrients Potassium and Iodine
- 2.5: Testing the Atomic Theory
  - 2.5.1: Biology- Water
- 2.6: Atomic Weights
- 2.7: The Amount of Substance- Moles
- 2.8: The Mole
- 2.9: The Amount of Substance
- 2.10: The Avogadro Constant
- 2.11: The Molar Mass
  - 2.11.1: Biology- Water
- 2.12: Formulas and Composition
  - 2.12.1: Biology- Formula and Composition of Water and Glucose
  - 2.12.2: Environment- Fertilizers, Formulas, and Ecological Stoichiometry
  - 2.12.3: Foods- Iron Supplements

- 2.12.4: Foods - Salt Additives
- 2.12.5: Lecture Demonstrations
- 2.13: Balancing Chemical Equations

## 3: Using Chemical Equations in Calculations

- 3.1: Prelude to Chemical Equations
- 3.2: Equations and Mass Relationships
  - 3.2.1: Cultural Connections- Berthollides- A Challenge to Chemical Stoichiometry
  - 3.2.2: Environment- Atom Efficiency and the 2006 Presidential Green Chemistry Award
  - 3.2.3: Everyday Life- Why Fats Don't Add Up on Food Nutrition Labels
  - 3.2.4: Food- Let's Cook!
  - 3.2.5: Foods- Metabolism of Dietary Sugar
  - 3.2.6: Lecture Demonstrations
  - 3.2.7: Sports, Physiology, and Health- Hydrogen Powered Bicycles "Run on Water"
- 3.3: The Limiting Reagent
  - 3.3.1: Cultural Connections- Anthropology and Protein Stoichiometry
  - 3.3.2: Environment- TSP, Ecological Stoichiometry, and Algal Blooms
  - 3.3.3: Everyday Life- Grilled Cheese Sandwiches and Omelets
  - 3.3.4: Everyday Life - Sodium Silicide Fueled Bicycles
  - 3.3.5: Foods- Protein Nutrition
  - 3.3.6: Forensics- Gunpowder Stoichiometry
  - 3.3.7: Geology- Using the Acid Test to Distinguish the Minerals in "Calomine"
  - 3.3.8: Lecture Demonstrations
  - 3.3.9: Physics- Rocket Propellants
  - 3.3.10: Sports, Physiology, and Health- Sodium Silicide Fueled Bicycles
- 3.4: Percent Yield
  - 3.4.1: Environment- Synthesis of Biodiesel Fuel
  - 3.4.2: Foods - Vegetable Oil Hydrogenation, Trans Fats, and Percent Yield
- 3.5: Analysis of Compounds
  - 3.5.1: Foods- Burning or Metabolizing Fats and Sugars
- 3.6: Thermochemistry
- 3.7: Energy
- 3.8: Thermochemical Equations
  - 3.8.1: Biology- Weight of Food and Energy Production
  - 3.8.2: Environment- Gas
  - 3.8.3: Foods- Energy from Fats and Sugars
  - 3.8.4: Geology- Heat Engine at Lost City
- 3.9: Hess' Law
  - 3.9.1: Biology- Anaerobic Fermentation in Beer and Lactic Acid in Muscles
  - 3.9.2: Environment- Heating Values of Various Fuels
  - 3.9.3: Foods- Fat vs. Sugar Metabolism
  - 3.9.4: Geology- Iron and its Ores
  - 3.9.5: Lecture Demonstration- Carbide Cannon
  - 3.9.6: Sports, Physiology, and Health- Aerobic vs Anaerobic Energy in Exercise
- 3.10: Standard Enthalpies of Formation
  - 3.10.1: Biology- Muscle Energy from ATP
  - 3.10.2: Foods- Energy in a Marshmallow
  - 3.10.3: Geology- Calculating the Heat Released by Serpentinization in the "Lost City"
  - 3.10.4: Sports, Physiology, and Health- Muscle Energy from ATP

- 3.11: Solution Concentrations
  - 3.11.1: Biology- Solution Concentrations and Cells
  - 3.11.2: Environment- Determining Safe Mercury Concentrations in Drinking Water
  - 3.11.3: Environment- Determining Water Purity via Biological Oxygen Demand
  - 3.11.4: Foods- Low Glycemic Index Foods and Blood Glucose Concentration
  - 3.11.5: Lecture Demonstration
- 3.12: Diluting and Mixing Solutions
- 3.13: Titrations

## 4: The Structure of Atoms

- 4.1: Prelude to Atomic Structure
- 4.2: Groups of Related Elements
- 4.3: The Periodic Table
- 4.4: Valence
- 4.5: Exceptions to the Periodic Law
- 4.6: Implications of Periodicity for Atomic Theory
- 4.7: The Nuclear Atom
- 4.8: Radiation
- 4.9: The Electron
  - 4.9.1: The Electron Lecture Demonstrations
- 4.10: The Nucleus
- 4.11: Atomic Structure and Isotopes
- 4.12: Isotopes
- 4.13: Transmutation and Radioactivity
  - 4.13.1: Lecture Demonstrations
- 4.14: Average Atomic Weights
  - 4.14.1: Lecture Demonstration- Model Mass Spectrometer
- 4.15: Measurement of Atomic Weights

## 5: The Electronic Structure of Atoms

- 5.1: Prelude to Electronic Structure
  - 5.1.1: Biology- Applications of Electronic Structure
  - 5.1.2: Lecture Demonstrations
- 5.2: Electrons and Valence
- 5.3: Lewis Diagrams
  - 5.3.1: Lewis Diagrams and Biological and Chemical Properties
- 5.4: The Wave Nature of the Electron
  - 5.4.1: Biology- The Wave Model for Light and Electrons
  - 5.4.2: Lecture Demonstrations
  - 5.4.3: Sports, Physiology, and Health- Sea Kayaking and Clapotis
- 5.5: Wave Mechanics
- 5.6: The Uncertainty Principle
- 5.7: Electron Waves in the Hydrogen Atom
- 5.8: Orbitals
  - 5.8.1: Cultural Connections- Tones on a Drum and Orbital Wave Functions
  - 5.8.2: Lecture Demonstrations
- 5.9: Quantum Numbers (Electronic)
- 5.11: Potential Energy

- 5.12: Electron Density and Potential Energy
- 5.13: Atoms Having More Than One Electron
- 5.14: Hydrogen, Helium, Lithium
- 5.15: Beryllium, Boron, Carbon
- 5.16: Electron Configurations
- 5.17: Electron Configurations and the Periodic Table

## 6: Chemical Bonding - Electron Pairs and Octets

- 6.1: Prelude to Chemical Bonding
- 6.2: Ionic Bonding
- 6.3: Energy and the Formation of Ions
- 6.4: The Ionic Crystal Lattice
- 6.5: Ions and Noble-Gas Electron Configurations
- 6.6: Ionization Energies
- 6.7: Ionization of Transition and Inner Transition Elements
- 6.8: Electron Affinities
- 6.9: Binary Ionic Compounds and Their Properties
- 6.10: The Octet Rule
- 6.11: Physical Properties
  - 6.11.1: Lecture Demonstrations
- 6.12: Chemical Properties
- 6.13: The Covalent Bond
- 6.14: Covalent Molecules and the Octet Rule
- 6.15: Writing Lewis Structures for Molecules
  - 6.15.1: An Excess of Bonds
  - 6.15.2: Deciding on a Skeleton Structure
  - 6.15.3: Multiple Bonds
- 6.16: Examples of Lewis Structures
- 6.17: Polyatomic Ions
- 6.18: Ionic Compounds Containing Polyatomic Ions
- 6.19: Atomic Sizes
- 6.20: Ionic Sizes
- 6.21: Periodic Variation of IE and EA
  - 6.21.1: Lecture Demonstrations

## 7: Further Aspects of Covalent Bonding

- 7.1: Prelude to Covalent Bonding
- 7.2: Exceptions to the Octet Rule
  - 7.2.1: Biology- Biologically Active Exceptions to the Octet Rule
- 7.3: The Shapes of Molecules
  - 7.3.1: Lecture Demonstrations
- 7.4: Molecules with Lone Pairs
  - 7.4.1: Lecture Demonstrations
- 7.5: Multiple Bonds and Molecular Shapes
- 7.6: Hybrid Orbitals
- 7.7: Orbital Descriptions of Multiple Bonds
- 7.8: Sigma and Pi Bonds
- 7.9: Polarizability
  - 7.9.1: Biology - Polarizability of Biologically Significant Atoms

- 7.10: Polar Covalent Bonds
  - 7.10.1: Biology- Nonpolar Iodine and Polar Hydrogen Iodide
  - 7.10.2: Lecture Demonstrations
- 7.11: Electronegativity
- 7.12: Polarity in Polyatomic Molecules
  - 7.12.1: Biology- The Hydrophobic Effect and Properties of Small Polyatomic Molecules
  - 7.12.2: Lecture Demonstrations
- 7.13: Formal Charge and Oxidation Numbers
- 7.14: Resonance

## 8: Properties of Organic Compounds

- 8.1: Prelude to Organic Compounds
  - 8.1.1: Astronomy- Mars Meteor and Extraterrestrial Life
  - 8.1.2: Geology- Earth's Oldest Fossils
- 8.2: Covalent Compounds and Intermolecular Forces
- 8.3: Dipole Forces
- 8.4: London Forces
  - 8.4.1: Chapter 8 page 3.jpg
  - 8.4.2: Atomic Radii
  - 8.4.3: Atomic sizes on periodic table.jpg
  - 8.4.4: Ionization Energies
    - 8.4.4.1: IonizationEnergyAtomicWeight.PNG
  - 8.4.5: Ionization Energies and Electron Affinities
    - 8.4.5.1: Electron Affinities
      - 8.4.5.1.1: Ionization Energies and Electron Affinities.jpg
  - 8.4.6: Polarizability on London Forces.jpg
- 8.5: Organic Compounds- Hydrocarbons
  - 8.5.1: Crude Oil Distillation.jpg
- 8.6: Alkanes
  - 8.6.1: Astronomy- Titan
  - 8.6.2: Boiling Points of Some Organic Compounds Whose Molecules Contain 32 or 34 Electrons
  - 8.6.3: Cultural Connections- Rockets
- 8.7: Cycloalkanes
- 8.8: Properties of Alkanes
  - 8.8.1: boiling points.jpg
  - 8.8.2: Table of Electronegativities
  - 8.8.3: Table of Straight Chain Alkanes
- 8.9: Aromatic Hydrocarbons
- 8.10: Unsaturated Hydrocarbons
  - 8.10.1: Chapter 7 page 19-2.jpg
- 8.11: Hydrogen Bonding- Water
  - 8.11.1: Atomic Radii and Ionic Radii
  - 8.11.2: H-Bonding Between 2 HF Molecules.jpg
  - 8.11.3: Nonmetal hydride bp.jpg
- 8.12: Ice and Water
  - 8.12.1: Ice; a hexagonal crystal.jpg
  - 8.12.2: Boiling Points of Hydrides

- 8.13: Organic Compounds-Some Additional Classes
- 8.14: Alcohols
- 8.15: Ethers
- 8.16: Aldehydes and Ketones
  - 8.16.1: Biology- Ketosis
  - 8.16.2: Cultural Connections- The Cinnamon Trade
- 8.17: Carboxylic Acids
  - 8.17.1: Biology- Entomology
- 8.18: Esters
- 8.19: Organic Nitrogen Compounds
- 8.20: Macromolecular Substances
- 8.21: Diamond and Graphite
- 8.22: Silicon Dioxide
- 8.23: Synthetic Macromolecules- Some Applied Organic Chemistry
- 8.24: Addition Polymers
- 8.25: Condensation Polymers
- 8.26: Cross-Linking

## 9: Gases

- 9.1: Prelude to Gases
- 9.2: Property of Gases
- 9.3: Pressure
- 9.4: Measurement of Pressure
  - 9.4.1: Lecture Demonstrations
- 9.5: Gas Laws
- 9.6: Avogadro's Law
- 9.7: Boyle's Law
  - 9.7.1: Lecture Demonstrations
- 9.8: Charles's Law
  - 9.8.1: Lecture Demonstration
- 9.9: Gay-Lussac's Law
- 9.10: The Ideal Gas Equation
  - 9.10.1: Lecture Demonstration
- 9.11: The Law of Combining Volumes
- 9.12: Dalton's Law of Partial Pressures
  - 9.12.1: Lecture Demonstration
- 9.13: Kinetic Theory of Gases- Postulates of the Kinetic Theory
- 9.14: Kinetic Theory of Gases- The Total Molecular Kinetic Energy
- 9.15: Kinetic Theory of Gases- Molecular Speeds
- 9.16: Kinetic Theory of Gases - Graham's Law of Diffusion
  - 9.16.1: Lecture Demonstrations
- 9.17: Kinetic Theory of Gases- The Distribution of Molecular Speeds
- 9.18: Deviations from the Ideal Gas Law

## 10: Solids, Liquids and Solutions

- 10.1: Prelude to Solids, Liquids and Solutions
- 10.2: Solids
- 10.3: Lattices and Unit Cells

- 10.4: Crystal Systems
- 10.5: Closest-Packed Structures
- 10.6: Liquids
- 10.7: Viscosity
  - 10.7.1: Lecture Demonstration
- 10.8: Amorphous Materials- Glasses
- 10.9: Phase Transitions
- 10.10: Enthalpy of Fusion and Enthalpy of Vaporization
  - 10.10.1: Astronomy- Water on Mars
  - 10.10.2: Lecture Demonstrations
- 10.11: Vapor-Liquid Equilibrium
- 10.12: Boiling Point
- 10.13: Critical Temperature and Pressure
- 10.14: Phase Diagrams
- 10.15: Solutions
- 10.16: Saturated and Supersaturated Solutions
- 10.17: Miscibility
  - 10.17.1: Cultural Connections- Oil and Water
- 10.18: Measuring the Composition of a Solution
- 10.19: Solubility and Molecular Structure
- 10.21: The Separation of Mixtures
- 10.22: Distillation
- 10.23: Chromatography
- 10.24: Colligative Properties of Solutions
- 10.25: Boiling-Point Elevation and Freezing-Point Depression
- 10.26: Osmotic Pressure
- 10.27: Colloids

## 11: Reactions in Aqueous Solutions

- 11.1: Prelude to Aqueous Phase Reactions
- 11.2: Ions in Solution (Electrolytes)
- 11.3: Precipitation Reactions
- 11.4: Hydration of Ions
- 11.5: Hydrogen and Hydroxide Ions
- 11.6: Acid-Base Reactions
- 11.7: Acids
- 11.8: Bases
- 11.9: Strong Acids and Bases
- 11.10: Weak Acids
- 11.11: Weak Bases
- 11.12: Amphoteric Species
- 11.13: Conjugate Acid-Base Pairs
- 11.14: Lewis Acids and Bases
- 11.15: Redox Reactions
- 11.16: Oxidation Numbers and Redox Reactions
- 11.17: Balancing Redox Equations
- 11.18: Common Oxidizing Agents
- 11.19: Common Reducing Agents
- 11.20: Substances Which Are Both Oxidizing and Reducing Agents
- 11.21: Redox Couples

## 12: Chemistry of the Representative Elements

- 12.1: Prelude to Descriptive Chemistry
- 12.2: Group IA - Alkali Metals
- 12.3: Group II- Alkaline Earths
- 12.4: Group IIIA
- 12.5: Group IVA
- 12.6: Group VA Elements
- 12.7: Group VIA- Chalcogens
  - 12.7.1: Cultural Connections- Sulfur
- 12.8: Group VIIA- Halogens
- 12.9: Group VIIIA- Noble Gases

## 13: Chemical Equilibrium

- 13.1: Prelude to Equilibria
- 13.2: The Equilibrium State
- 13.3: The Equilibrium Constant
- 13.4: The Law of Chemical Equilibrium
- 13.5: The Equilibrium Constant in Terms of Pressure
- 13.6: Calculating the Extent of a Reaction
- 13.7: Successive Approximation
- 13.8: Predicting the Direction of a Reaction
- 13.9: Le Chatelier's Principle
- 13.10: The Effect of a Change in Pressure
- 13.11: The Effect of a Change in Temperature
- 13.12: Effect of Adding a Reactant or Product
- 13.13: The Molecular View of Equilibrium

## 14: Ionic Equilibria in Aqueous Solutions

- 14.1: Prelude to Ionization of Water
- 14.2: Ionization of Water
- 14.3: pH and pOH
- 14.4: The pH of Solutions of Weak Acids
- 14.5: The pH of Solutions of Weak Bases
- 14.6: Polyprotic Acids and Bases
- 14.7: Conjugate Acid-Base Pairs and pH
  - 14.7.1: Foods- From Cleaning and Disinfection to Microbial Nutrition and Protein Modification
- 14.8: Buffer Solutions
  - 14.8.1: Foods- Food Additives
  - 14.8.2: Foods- Production of Food Ingredients
  - 14.8.3: Foods- The Effect of Polyols
- 14.9: Indicators
- 14.10: Titration Curves
  - 14.10.1: Foods- Acid Value and the Quality of Fats and Oils
- 14.11: The Solubility Product
- 14.12: The Common-Ion Effect
  - 14.12.1: Foods- Calcium Tartrate and Treatment of Wine Waster-Waters
- 14.13: The Solubilities of Salts of Weak Acids



## 15: Thermodynamics- Atoms, Molecules and Energy

- 15.1: Prelude to Thermodynamics
- 15.2: Heat Capacities
  - 15.2.1: Lecture Demonstrations
- 15.3: Heat Capacity and Microscopic Changes
- 15.4: Internal Energy
- 15.5: Thermodynamic Terms and Conventions
- 15.6: Enthalpy
- 15.7: Measuring the Enthalpy Change
  - 15.7.1: Lecture Demonstrations
- 15.8: State Functions
- 15.9: Standard Pressure
- 15.10: Bond Enthalpies
- 15.11: Bond Enthalpies and Exothermic or Endothermic Reactions
- 15.12: Fossil Fuels and the Energy Crisis
- 15.13: Photosynthesis

## 16: Entropy and Spontaneous Reactions

- 16.1: Prelude to Spontaneity
- 16.2: Spontaneous Processes and Molecular Probability
- 16.3: Atoms, Molecules, and Probability
- 16.4: Rates of Spontaneous Processes
- 16.5: Thermodynamic Probability  $W$  and Entropy
- 16.6: Getting Acquainted with Entropy
- 16.7: Standard Molar Entropies
- 16.8: Dependence of  $S$  on Molecular Structure
- 16.9: Some Trends In Entropy Values
- 16.10: Entropy Changes in Gaseous Reactions
- 16.11: Entropy, Randomness, and Disorder
- 16.12: Measuring the Entropy
- 16.13: Including the Surroundings
- 16.14: The Free Energy
- 16.15: Maximum Useful Work
- 16.16: Equilibrium Constants Revisited

## 17: Electrochemical Cells

- 17.1: Prelude to Electrochemistry
- 17.2: Electrolysis
- 17.3: Electrolysis of Brine
- 17.4: Aluminum Production
- 17.5: Refining of Copper
- 17.6: Electroplating
- 17.7: Quantitative Aspects of Electrolysis
- 17.8: Galvanic Cells
- 17.9: Cell Notation and Conventions
- 17.10: Electromotive Force of Galvanic Cells
- 17.11: Storage Batteries
- 17.12: Fuel Cells
- 17.13: Galvanic Cells and Free Energy
- 17.14: Cells at Non-Standard Conditions

## 18: Chemical Kinetics

- 18.1: Prelude to Kinetics
- 18.2: The Rate of Reaction
- 18.3: The Rate Equation
- 18.4: Microscopic View of Chemical Reactions
- 18.5: Unimolecular Processes
- 18.6: Bimolecular Processes
- 18.7: Termolecular Processes
- 18.8: 18.7-Reaction Mechanisms
- 18.9: 18.8-Increasing the Rate of a Reaction
- 18.10: The Effect of Temperature
- 18.11: Catalysis
- 18.12: Heterogeneous Catalysis

## 19: Nuclear Chemistry

- 19.1: Prelude to Nuclear Chemistry
- 19.2: Naturally Occurring Radioactivity
- 19.3: Radioactive Series
- 19.4: Artificially Induced Nuclear Reactions
- 19.5: Bombardment with Positive Ions
- 19.6: Neutron Bombardment
- 19.7: Further Modes of Decay - Positron Emission and Electron Capture
- 19.8: Nuclear Stability
- 19.9: The Rate of Radioactive Decay
- 19.10: Instruments for Radiation Detection
- 19.11: Units of Radiation Dose
- 19.12: Uses of Artificial Isotopes
- 19.13: Mass-Energy Relationships
  - 19.13.1: Lecture Demonstrations on Mass Energy Relationships
- 19.14: Nuclear Fission
  - 19.14.1: Nuclear Fission and WWII
- 19.15: Nuclear Power Plants
- 19.16: Breeder Reactors
- 19.17: Nuclear Fusion

## 20: Molecules in Living Systems

- 20.1: Prelude to Biochemistry
- 20.2: The Elements of Life
- 20.3: The Building Blocks of Biochemistry
- 20.4: Fats and Lipids
- 20.5: Nonpolar Lipids
- 20.6: Polar Lipids
- 20.7: Carbohydrates
- 20.8: Simple Sugars
- 20.9: Disaccharides
- 20.10: Polysaccharides
- 20.11: Proteins
- 20.12: Polypeptide Chains
- 20.13: The Amino Acids
- 20.14: Primary Protein Structure

- 20.15: Secondary Protein Structure
- 20.16: Higher-Order Structure
- 20.17: Nucleic Acids
- 20.18: Nucleic Acid Structure
- 20.19: Information Storage
- 20.20: The Double Helix
- 20.21: DNA Replication
- 20.22: Transcription and Translation

## 21: Spectra and Structure of Atoms and Molecules

- 21.1: Prelude to Spectroscopy
- 21.2: The Nature of Electromagnetic Radiation
- 21.3: Atomic Spectra and the Bohr Theory
- 21.4: Bohr Theory of the Atom
- 21.5: The Spectra of Molecules- Infrared
- 21.6: The Visible and Ultraviolet Spectra of Molecules- Molecular Orbitals
- 21.7: Molecular Orbitals
- 21.8: Delocalized Electrons
- 21.9: Conjugated Systems

## 22: Metals

- 22.1: Prelude to Metals
- 22.2: Metallic Bonding
- 22.3: Metallurgy
- 22.4: Beneficiation
- 22.5: Reduction of Metals
- 22.6: Refining of Metals
- 22.7: Corrosion
- 22.8: Coordination Compounds
- 22.9: Geometry of Complexes
- 22.10: Chelating Agents
- 22.11: Transitional Metal Ions in Aqueous Solutions

[Index](#)

[Index](#)

[Glossary](#)

[Detailed Licensing](#)