



Introductory Chemistry Essentials

SIXTH EDITION in SI Units

Nivaldo J. Tro



Periodic Table of the Elements

	GROUP 1 1A									
1	1 H 1.01 hydrogen	2 2A				H—— 1.01— hydrogen		Atomic number Element symbol Atomic mass*		
2	3 Li 6.94 lithium	4 Be 9.01 beryllium						Element na	ame	
3	11 Na 22.99 sodium	Mg 24.31 magnesium	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	
PERIOD +	19 K 39.10 potassium	20 Ca 40.08 calcium	21 Sc 44.96 scandium	22 Ti 47.88 titanium	23 V 50.94 vanadium	24 Cr 52.00 chromium	25 Mn 54.94 manganese	26 Fe 55.85 iron	27 Co 58.93 cobalt	
5	37 Rb 85.47 rubidium	38 Sr 87.62 strontium	39 Y 88.91 yttrium	40 Zr 91.22 zirconium	41 Nb 92.91 niobium	42 Mo 95.95 molybdenum	43 Tc (99) technetium	44 Ru 101.07 ruthenium	45 Rh 102.91 rhodium	
6	55 Cs 132.91 cesium	56 Ba 137.33 barium	57 La 138.91 lanthanum	72 Hf 178.49 hafnium	73 Ta 180.95 tantalum	74 W 183.85 tungsten	75 Re 186.21 rhenium	76 Os 190.23 osmium	77 Ir 192.22 iridium	
7	87 Fr (223) francium	88 Ra (226) radium	89 Ac (227) actinium	104 Rf (261) rutherfordium	105 Db (262) dubnium	106 Sg (263) seaborgium	107 Bh (262) bohrium	108 Hs (265) hassium	109 Mt (266) meitnerium	
	132.91 cesium 87 Fr (223)	137.33 barium 88 Ra (226)	138.91 lanthanum 89 Ac (227)	178.49 hafnium 104 Rf (261)	180.95 tantalum 105 Db (262)	183.85 tungsten 106 Sg (263)	186.21 rhenium 107 Bh (262)	190.23 osmium 108 Hs (265)	192 iridi 10 M (26	

Lanthanide series

Actinide series

58	59	60	61	62	63
Ce	Pr	Nd	Pm	Sm	Eu
140.12	140.91	144.24	(147)	150.36	151.97
cerium	praseodymium	neodymium	promethium	samarium	europium
90	91	92	93	94	95
Th	Pa	U	Np	Pu	Am
(232)	(231)	(238)	(237)	(244)	(243)
thorium	protactinium	uranium	neptunium	plutonium	americium

^{*}The mass number of an important radioactive isotope—not the atomic mass—is shown in parentheses for those elements with no stable isotopes.

Introductory Chemistry Essentials in SI Units

Table of Contents

1	\sim	\sim	١,	_	r
١	ι,	u	v	\vdash	ı

Title Page

Copyright Page

Contents

Preface

- 1 The Chemical World
 - 1.1 Sand and Water
 - 1.2 Chemicals Compose Ordinary Things
 - 1.3 The Scientific Method: How Chemists Think

EVERYDAY CHEMISTRY: Combustion and the Scientific Method

1.4 Analyzing and Interpreting Data

Identifying Patterns in Data

Interpreting Graphs

1.5 A Beginning Chemist: How to Succeed

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

- 2 Measurement and Problem Solving
 - 2.1 The Metric Mix-up: A \$125 Million Unit Error
 - 2.2 Scientific Notation: Writing Large and Small Numbers
 - 2.3 Significant Figures: Writing Numbers to Reflect Precision

Counting Significant Figures

Exact Numbers

CHEMISTRY IN THE MEDIA: The COBE Satellite and Very Precise Measurements That Illuminate Our Cosmic Past

2.4 Significant Figures in Calculations

Multiplication and Division

Rounding



Addition and Subtraction

Calculations Involving Both Multiplication/Division and Addition/Subtraction

2.5 The Basic Units of Measurement

The Base Units

Prefix Multipliers

Derived Units

2.6 Problem Solving and Unit Conversion

Converting Between Units

General Problem-Solving Strategy

- 2.7 Solving Multistep Unit Conversion Problems
- 2.8 Unit Conversion in Both the Numerator and Denominator
- 2.9 Units Raised to a Power

CHEMISTRY AND HEALTH: Drug Dosage

2.10 Density

Calculating Density

Density as a Conversion Factor

CHEMISTRY AND HEALTH: Density, Cholesterol, and Heart Disease

2.11 Numerical Problem-Solving Strategies and the Solution Map

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

3 Matter and Energy

- 3.1 In Your Room
- 3.2 What Is Matter?
- 3.3 Classifying Matter According to Its State: Solid, Liquid, and Gas
- 3.4 Classifying Matter According to Its Composition: Elements, Compounds, and Mixtures
- 3.5 Differences in Matter: Physical and Chemical Properties
- 3.6 Changes in Matter: Physical and Chemical Changes

Separating Mixtures Through Physical Changes

- 3.7 Conservation of Mass: There Is No New Matter
- 3.8 Energy



CHEMISTRY IN THE ENVIRONMENT: Getting Energy out of Nothing? Units of Energy

- 3.9 Energy and Chemical and Physical Change
- 3.10 Temperature: Random Motion of Molecules and Atoms
- 3.11 Temperature Changes: Heat Capacity

 EVERYDAY CHEMISTRY: Coolers, Camping, and the Heat Capacity of Water
- 3.12 Energy and Heat Capacity Calculations

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

4 Atoms and Elements

- 4.1 Experiencing Atoms at Tiburon
- 4.2 Indivisible: The Atomic Theory
- 4.3 The Nuclear Atom
- 4.4 The Properties of Protons, Neutrons, and Electrons EVERYDAY CHEMISTRY: Solid Matter?
- 4.5 Elements: Defined by Their Numbers of Protons
- 4.6 Looking for Patterns: The Periodic Law and the Periodic Table
- 4.7 Ions: Losing and Gaining Electrons
 lons and the Periodic Table
- 4.8 Isotopes: When the Number of Neutrons Varies
- 4.9 Atomic Mass: The Average Mass of an Elements Atoms
 CHEMISTRY IN THE ENVIRONMENT: Radioactive Isotopes at Hanford, Washington

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

5 Molecules and Compounds

- 5.1 Sugar and Salt
- 5.2 Compounds Display Constant Composition
- 5.3 Chemical Formulas: How to Represent Compounds



Polyatomic Ions in Chemical Formulas

Types of Chemical Formulas

5.4 A Molecular View of Elements and Compounds

Atomic Elements

Molecular Elements

Molecular Compounds

Ionic Compounds

5.5 Writing Formulas for Ionic Compounds

Writing Formulas for Ionic Compounds Containing Only Monoatomic Ions

Writing Formulas for Ionic Compounds Containing Polyatomic Ions

5.6 Nomenclature: Naming Compounds

5.7 Naming Ionic Compounds

Naming Binary Ionic Compounds Containing a Metal That Forms Only One Type of Cation

Naming Binary Ionic Compounds Containing a Metal That Forms More Than One Type of Cation

Naming Ionic Compounds Containing a Polyatomic Ion

EVERYDAY CHEMISTRY: Polyatomic Ions

5.8 Naming Molecular Compounds

5.9 Naming Acids

Naming Binary Acids

Naming Oxyacids

5.10 Nomenclature Summary

Ionic Compounds

Molecular Compounds

Acids

5.11 Formula Mass: The Mass of a Molecule or Formula Unit

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

6 Chemical Composition

- 6.1 How Much Sodium?
- 6.2 Counting Nails by the Kilogram
- 6.3 Counting Atoms by the Gram

Converting between Moles and Number of Atoms



Converting between Grams and Moles of an Element

Converting between Grams of an Element and Number of Atoms

6.4 Counting Molecules by the Gram

Converting between Grams and Moles of a Compound

Converting between Grams of a Compound and Number of Molecules

6.5 Chemical Formulas as Conversion Factors

Converting between Moles of a Compound and Moles of a Constituent Element

Converting between Grams of a Compound and Grams of a Constituent Element

- 6.6 Mass Percent Composition of Compounds
- 6.7 Mass Percent Composition from a Chemical Formula

CHEMISTRY AND HEALTH: Fluoridation of Drinking Water

6.8 Calculating Empirical Formulas for Compounds

Calculating an Empirical Formula from Experimental Data

6.9 Calculating Molecular Formulas for Compounds

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

7 Chemical Reactions

- 7.1 Grade School Volcanoes, Automobiles, and Laundry Detergents
- 7.2 Evidence of a Chemical Reaction
- 7.3 The Chemical Equation
- 7.4 How to Write Balanced Chemical Equations
- 7.5 Aqueous Solutions and Solubility: Compounds Dissolved in Water

Aqueous Solutions

Solubility

- 7.6 Precipitation Reactions: Reactions in Aqueous Solution That Form a Solid
- 7.7 Writing Chemical Equations for Reactions in Solution: Molecular, Complete Ionic, and Net Ionic Equations
- 7.8 AcidBase and Gas Evolution Reactions

AcidBase (Neutralization) Reactions

Gas Evolution Reactions

CHEMISTRY AND HEALTH: Neutralizing Excess Stomach Acid

7.9 OxidationReduction Reactions



7.10 Classifying Chemical Reactions

Classifying Chemical Reactions by What Atoms Do

Classification Flowchart

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

8 Quantities in Chemical Reactions

8.1 Climate Change: Too Much Carbon Dioxide

8.2 Making Pancakes: Relationships between Ingredients

8.3 Making Molecules: Mole-to-Mole Conversions

8.4 Making Molecules: Mass-to-Mass Conversions

8.5 More Pancakes: Limiting Reactant, Theoretical Yield, and Percent Yield

8.6 Limiting Reactant, Theoretical Yield, and Percent Yield from Initial Masses of Reactants

8.7 Enthalpy: A Measure of the Heat Evolved or Absorbed in a Reaction

Sign of H(sub[rxn])

EVERYDAY CHEMISTRY: Bunsen Burners

Stoichiometry of H(sub[rxn])

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

9 Electrons in Atoms and the Periodic Table

- 9.1 Blimps, Balloons, and Models of the Atom
- 9.2 Light: Electromagnetic Radiation
- 9.3 The Electromagnetic Spectrum

CHEMISTRY AND HEALTH: Radiation Treatment for Cancer

- 9.4 The Bohr Model: Atoms with Orbits
- 9.5 The Quantum-Mechanical Model: Atoms with Orbitals

Baseball Paths and Electron Probability Maps

From Orbits to Orbitals



9.6 Quantum-Mechanical Orbitals and Electron Configurations

Quantum-Mechanical Orbitals

Electron Configurations: How Electrons Occupy Orbitals

- 9.7 Electron Configurations and the Periodic Table
- 9.8 The Explanatory Power of the Quantum-Mechanical Model
- 9.9 Periodic Trends: Atomic Size, Ionization Energy, and Metallic Character

Atomic Size

CHEMISTRY AND HEALTH: Pumping Ions: Atomic Size and Nerve Impulses

Ionization Energy

Metallic Character

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

10 Chemical Bonding

- 10.1 Bonding Models and AIDS Drugs
- 10.2 Representing Valence Electrons with Dots
- 10.3 Lewis Structures of Ionic Compounds: Electrons Transferred
- 10.4 Covalent Lewis Structures: Electrons Shared

Single Bonds

Double and Triple Bonds

10.5 Writing Lewis Structures for Covalent Compounds

Writing Lewis Structures for Polyatomic Ions

Exceptions to the Octet Rule

- 10.6 Resonance: Equivalent Lewis Structures for the Same Molecule
- 10.7 Predicting the Shapes of Molecules

Representing Molecular Geometries on Paper

CHEMISTRY AND HEALTH: Fooled by Molecular Shape

10.8 Electronegativity and Polarity: Why Oil and Water Dont Mix

Electronegativity

Polar Bonds and Polar Molecules

EVERYDAY CHEMISTRY: How Soap Works

Self-Assessment Quiz

Key Terms



Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

11 Gases

- 11.1 Extra-Long Straws
- 11.2 Kinetic Molecular Theory: A Model for Gases
- 11.3 Pressure: The Result of Constant Molecular Collisions

Pressure Units

Pressure Unit Conversion

11.4 Boyles Law: Pressure and Volume

EVERYDAY CHEMISTRY: Airplane Cabin Pressurization

EVERYDAY CHEMISTRY: Extra-long Snorkels

- 11.5 Charless Law: Volume and Temperature
- 11.6 The Combined Gas Law: Pressure, Volume, and Temperature
- 11.7 Avogadros Law: Volume and Moles
- 11.8 The Ideal Gas Law: Pressure, Volume, Temperature, and Moles

Determining Molar Mass of a Gas from the Ideal Gas Law

Ideal and Nonideal Gas Behavior

11.9 Mixtures of Gases

Partial Pressure and Physiology

Collecting Gases over Water

11.10 Gases in Chemical Reactions

Molar Volume at Standard Temperature and Pressure

CHEMISTRY IN THE ENVIRONMENT: Air Pollution

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

- 12 Liquids, Solids, and Intermolecular Forces
 - 12.1 Spherical Water
 - 12.2 Properties of Liquids and Solids
 - 12.3 Intermolecular Forces in Action: Surface Tension and Viscosity
 Surface Tension



Viscosity

12.4 Evaporation and Condensation

Boiling

Energetics of Evaporation and Condensation

Heat of Vaporization

12.5 Melting, Freezing, and Sublimation

Energetics of Melting and Freezing

Heat of Fusion

Sublimation

12.6 Types of Intermolecular Forces: Dispersion, DipoleDipole, Hydrogen Bonding, and IonDipole

Dispersion Force

DipoleDipole Force

Hydrogen Bonding

IonDipole Force

CHEMISTRY AND HEALTH: Hydrogen Bonding in DNA

12.7 Types of Crystalline Solids: Molecular, Ionic, and Atomic

Molecular Solids

Ionic Solids

Atomic Solids

12.8 Water: A Remarkable Molecule

CHEMISTRY IN THE ENVIRONMENT: Water Pollution and the Flint River Water Crisis

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

13 Solutions

- 13.1 Tragedy in Cameroon
- 13.2 Solutions: Homogeneous Mixtures
- 13.3 Solutions of Solids Dissolved in Water: How to Make Rock Candy

Solubility and Saturation

Electrolyte Solutions: Dissolved Ionic Solids

How Solubility Varies with Temperature

13.4 Solutions of Gases in Water: How Soda Pop Gets Its Fizz



13.5 Specifying Solution Concentration: Mass Percent

Mass Percent

Using Mass Percent in Calculations

13.6 Specifying Solution Concentration: Molarity

Using Molarity in Calculations

Ion Concentrations

13.7 Solution Dilution

13.8 Solution Stoichiometry

13.9 Freezing Point Depression and Boiling Point Elevation: Making Water Freeze Colder and Boil Hotter

Freezing Point Depression

EVERYDAY CHEMISTRY: Antifreeze in Frogs

Boiling Point Elevation

13.10 Osmosis: Why Drinking Saltwater Causes Dehydration

CHEMISTRY AND HEALTH: Solutions in Medicine

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

14 Acids and Bases

14.1 Sour Patch Kids and International Spy Movies

14.2 Acids: Properties and Examples

14.3 Bases: Properties and Examples

14.4 Molecular Definitions of Acids and Bases

The Arrhenius Definition

The BrønstedLowry Definition

14.5 Reactions of Acids and Bases

Neutralization Reactions

Acid Reactions

EVERYDAY CHEMISTRY: What Is in My Antacid?

Base Reactions

14.6 AcidBase Titration: A Way to Quantify the Amount of Acid or Base in a Solution

14.7 Strong and Weak Acids and Bases

Strong Acids



Weak Acids

Strong Bases

Weak Bases

14.8 Water: Acid and Base in One

14.9 The pH and pOH Scales: Ways to Express Acidity and Basicity

Calculating pH from [H(sub[3])O(sup[+])]

Calculating [H(sub[3])O(sup[+])] from pH

The pOH Scale

14.10 Buffers: Solutions That Resist pH Change

CHEMISTRY AND HEALTH: Alkaloids

CHEMISTRY AND HEALTH: The Danger of Antifreeze

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

15 Chemical Equilibrium

15.1 Life: Controlled Disequilibrium

15.2 The Rate of a Chemical Reaction

Collision Theory

How Concentration Affects the Rate of a Reaction

How Temperature Affects the Rate of a Reaction

- 15.3 The Idea of Dynamic Chemical Equilibrium
- 15.4 The Equilibrium Constant: A Measure of How Far a Reaction Goes

Writing Equilibrium Constant Expressions for Chemical Reactions

The Significance of the Equilibrium Constant

15.5 Heterogeneous Equilibria: The Equilibrium Expression for Reactions Involving a Solid or a Liquid

15.6 Calculating and Using Equilibrium Constants

Calculating Equilibrium Constants

Using Equilibrium Constants in Calculations

- 15.7 Disturbing a Reaction at Equilibrium: Le Châteliers Principle
- 15.8 The Effect of a Concentration Change on Equilibrium
- 15.9 The Effect of a Volume Change on Equilibrium

CHEMISTRY AND HEALTH: How a Developing Fetus Gets Oxygen from Its Mother



15.10 The Effect of a Temperature Change on Equilibrium

15.11 The Solubility-Product Constant

Using Ksp to Determine Molar Solubility

15.12 The Path of a Reaction and the Effect of a Catalyst

How Activation Energies Affect Reaction Rates

Catalysts Lower the Activation Energy

Enzymes: Biological Catalysts

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

16 Oxidation and Reduction

16.1 The End of the Internal Combustion Engine?

16.2 Oxidation and Reduction: Some Definitions

16.3 Oxidation States: Electron Bookkeeping

EVERYDAY CHEMISTRY: The Bleaching of Hair

16.4 Balancing Redox Equations

CHEMISTRY IN THE ENVIRONMENT: Photosynthesis and Respiration: Energy for Life

16.5 The Activity Series: Predicting Spontaneous Redox Reactions

The Activity Series of Metals

Predicting Whether a Metal Will Dissolve in Acid

16.6 Batteries: Using Chemistry to Generate Electricity

Dry-Cell Batteries

Lead-Acid Storage Batteries

Fuel Cells

16.7 Electrolysis: Using Electricity to Do Chemistry

16.8 Corrosion: Undesirable Redox Reactions

EVERYDAY CHEMISTRY: The Fuel-Cell Breathalyzer

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

17 Radioactivity and Nuclear Chemistry



- 17.1 Diagnosing Appendicitis
- 17.2 The Discovery of Radioactivity
- 17.3 Types of Radioactivity: Alpha, Beta, and Gamma Decay

Alpha () Radiation

Beta () Radiation

Gamma () Radiation

Positron Emission

- 17.4 Detecting Radioactivity
- 17.5 Natural Radioactivity and Half-Life

Half-Life

CHEMISTRY AND HEALTH: Environmental Radon

A Natural Radioactive Decay Series

17.6 Radiocarbon Dating: Using Radioactivity to Measure the Age of Fossils and Other Artifacts

CHEMISTRY IN THE MEDIA: The Shroud of Turin

- 17.7 The Discovery of Fission and the Atomic Bomb
- 17.8 Nuclear Power: Using Fission to Generate Electricity
- 17.9 Nuclear Fusion: The Power of the Sun
- 17.10 The Effects of Radiation on Life

Acute Radiation Damage

Increased Cancer Risk

Genetic Defects

Measuring Radiation Exposure

17.11 Radioactivity in Medicine

Isotope Scanning

Radiotherapy

Self-Assessment Quiz

Key Terms

Exercises

Answers to Skillbuilder Exercises

Answers to Conceptual Checkpoints

Appendix: Mathematics Review

Answers to Odd-Numbered Exercises

Glossary

Α



В

С

D

Ε

F

G

Н

I

Κ

L

М

N O

Р

Q

R

S

T U

٧

W

Χ

Credits

Index