

TABLE OF CONTENTS

SECTION 1: BASIC CONSTANTS, UNITS, AND CONVERSION FACTORS

CODATA Recommended Values of the Fundamental Physical Constants: 2010	1-1
Standard Atomic Weights (2009)	1-11
Atomic Masses and Abundances	1-13
Electron Configuration and Ionization Energy of Neutral Atoms in the Ground State	1-17
International Temperature Scale of 1990 (ITS-90)	1-19
Conversion of Temperatures from the 1948 and 1968 Scales to ITS-90	1-20
International System of Units (SI)	1-22
Units for Magnetic Properties	1-26
Conversion Factors	1-27
Conversion of Temperatures	1-37
Conversion Factors for Energy Units	1-38
Conversion Factors for Pressure Units	1-39
Conversion Factors for Thermal Conductivity Units	1-40
Conversion Factors for Electrical Resistivity Units	1-41
Conversion Formulas for Concentration of Solutions	1-42
Conversion Factors for Chemical Kinetics	1-43
Conversion Factors for Ionizing Radiation	1-44
Values of the Gas Constant in Different Unit Systems	1-46

SECTION 2: SYMBOLS, TERMINOLOGY, AND NOMENCLATURE

Symbols and Terminology for Physical and Chemical Quantities	2-1
Expression of Uncertainty of Measurements	2-13
Nomenclature for Chemical Compounds	2-15
Nomenclature for Inorganic Ions and Ligands	2-16
Organic Substituent Groups and Ring Systems	2-23
Representation of Chemical Structures with the IUPAC International Chemical Identifier (InChI)	2-27
Scientific Abbreviations, Acronyms, and Symbols	2-29
Greek, Russian, and Hebrew Alphabets	2-43
Definitions of Scientific Terms	2-44
Thermodynamic Functions and Relations	2-69
Nobel Laureates in Chemistry and Physics	2-70

SECTION 3: PHYSICAL CONSTANTS OF ORGANIC COMPOUNDS

Physical Constants of Organic Compounds	3-1
Synonym Index of Organic Compounds	3-554
Diamagnetic Susceptibility of Selected Organic Compounds	3-576

SECTION 4: PROPERTIES OF THE ELEMENTS AND INORGANIC COMPOUNDS

The Elements	4-1
Physical Constants of Inorganic Compounds	4-43
Formula Index of Inorganic Compounds	4-102
Physical Properties of the Rare Earth Metals	4-115
Melting, Boiling, Triple, and Critical Points of the Elements	4-121
Heat Capacity of the Elements at 25 °C	4-124
Vapor Pressure of the Metallic Elements — Equations	4-125
Vapor Pressure of the Metallic Elements — Data	4-127
Density of Molten Elements and Representative Salts	4-128
Magnetic Susceptibility of the Elements and Inorganic Compounds	4-131
Index of Refraction of Inorganic Liquids	4-137
Physical and Optical Properties of Minerals	4-138
Crystallographic Data on Minerals	4-145

SECTION 5: THERMOCHEMISTRY, ELECTROCHEMISTRY, AND SOLUTION CHEMISTRY

CODATA Key Values for Thermodynamics	5-1
Standard Thermodynamic Properties of Chemical Substances	5-4
Thermodynamic Properties as a Function of Temperature	5-43
Thermodynamic Properties of Aqueous Ions	5-66

Heat of Combustion.....	5-68
Energy Content of Fuels.....	5-69
Ionization Constant of Water.....	5-70
Ionization Constant of Normal and Heavy Water.....	5-71
Electrical Conductivity of Water.....	5-72
Electrical Conductivity of Aqueous Solutions.....	5-73
Standard KCl Solutions for Calibrating Conductivity Cells.....	5-74
Molar Conductivity of Aqueous HF, HCl, HBr, and HI.....	5-75
Equivalent Conductivity of Electrolytes In Aqueous Solution.....	5-76
Ionic Conductivity and Diffusion at Infinite Dilution.....	5-77
Electrochemical Series.....	5-80
Reduction and Oxidation Potentials for Certain Ion Radicals.....	5-90
Dissociation Constants of Inorganic Acids and Bases.....	5-92
Dissociation Constants of Organic Acids and Bases.....	5-94
Activity Coefficients of Acids, Bases, and Salts.....	5-104
Mean Activity Coefficients of Electrolytes as a Function of Concentration.....	5-106
Enthalpy of Dilution of Acids.....	5-110
Enthalpy of Solution of Electrolytes.....	5-111
Enthalpy of Hydration of Gases.....	5-112
pH Scale for Aqueous Solutions.....	5-116
Practical pH Measurements on Natural Waters.....	5-120
Buffer Solutions Giving Round Values of pH at 25 °C.....	5-122
Concentrative Properties of Aqueous Solutions: Density, Refractive Index, Freezing Point Depression, and Viscosity.....	5-123
Solubility of Selected Gases in Water.....	5-149
Solubility of Carbon Dioxide in Water at Various Temperatures and Pressures.....	5-153
Aqueous Solubility and Henry's Law Constants of Organic Compounds.....	5-154
Aqueous Solubility of Inorganic Compounds at Various Temperatures.....	5-190
Solubility Product Constants.....	5-196
Solubility of Common Salts at Ambient Temperatures.....	5-199
Solubility of Hydrocarbons in Seawater.....	5-200
Solubility of Organic Compounds in Pressurized Hot Water.....	5-202
Solubility Chart.....	5-205

SECTION 6: FLUID PROPERTIES

Thermophysical Properties of Water and Steam.....	6-1
Vapor Pressure and Other Saturation Properties of Water.....	6-5
Standard Density of Water.....	6-7
Fixed-Point Properties of H ₂ O and D ₂ O.....	6-9
Properties of Saturated Liquid D ₂ O.....	6-10
Properties of Ice and Supercooled Water.....	6-12
Vapor Pressure of Ice.....	6-13
Melting Point of Ice as a Function of Pressure.....	6-13
Permittivity (Dielectric Constant) of Water at Various Frequencies.....	6-14
Thermophysical Properties of Air.....	6-15
Thermophysical Properties of Fluids.....	6-21
Thermophysical Properties of Selected Fluids at Saturation.....	6-38
Virial Coefficients of Selected Gases.....	6-47
Van der Waals Constants for Gases.....	6-56
Mean Free Path and Related Properties of Gases.....	6-57
Influence of Pressure on Freezing Points.....	6-58
Critical Constants of Organic Compounds.....	6-59
Critical Constants of Inorganic Compounds.....	6-83
Sublimation Pressure of Solids.....	6-86
Vapor Pressure.....	6-88
Vapor Pressure of Fluids at Temperatures Below 300 K.....	6-118
Vapor Pressure of Saturated Salt Solutions.....	6-126
Recommended Data for Vapor-Pressure Calibration.....	6-127
Enthalpy of Vaporization.....	6-128
Enthalpy of Fusion.....	6-146
Compressibility and Expansion Coefficients of Liquids.....	6-156
Temperature and Pressure Dependence of Liquid Density.....	6-158
Volumetric Properties of Aqueous Sodium Chloride Solutions.....	6-163

Properties of Cryogenic Fluids.....	6-164
Properties of Liquid Helium.....	6-165
Properties of Refrigerants.....	6-166
Properties of Gas Clathrate Hydrates.....	6-169
Ionic Liquids.....	6-174
Density and Specific Volume of Mercury.....	6-178
Thermal Properties of Mercury.....	6-179
Melting Curve of Mercury.....	6-180
Vapor Pressure of Mercury.....	6-181
Surface Tension of Common Liquids.....	6-182
Surface Tension of Aqueous Mixtures.....	6-186
Permittivity (Dielectric Constant) of Liquids.....	6-187
Permittivity (Dielectric Constant) of Gases.....	6-209
Azeotropic Data for Binary Mixtures.....	6-210
Viscosity of Gases.....	6-229
Viscosity of Liquids.....	6-231
Viscosity of Carbon Dioxide Along the Saturation Line.....	6-236
Viscosity and Density of Aqueous Hydroxide Solutions.....	6-237
Viscosity of Liquid Metals.....	6-238
Thermal Conductivity of Gases.....	6-240
Thermal Conductivity of Liquids.....	6-242
Diffusion in Gases.....	6-247
Diffusion of Gases in Water.....	6-249
Diffusion Coefficients in Liquids at Infinite Dilution.....	6-250

SECTION 7: BIOCHEMISTRY

Properties of Amino Acids.....	7-1
Structures of Common Amino Acids.....	7-3
Properties of Purine and Pyrimidine Bases.....	7-5
The Genetic Code.....	7-6
Properties of Fatty Acids and Their Methyl Esters.....	7-7
Composition and Properties of Common Oils And Fats.....	7-9
Carbohydrate Names and Symbols.....	7-14
Standard Transformed Gibbs Energies of Formation for Biochemical Reactants.....	7-16
Apparent Equilibrium Constants for Enzyme-Catalyzed Reactions.....	7-19
Thermodynamic Quantities for the Ionization Reactions of Buffers in Water.....	7-23
Biological Buffers.....	7-26
Typical pH Values of Biological Materials and Foods.....	7-27
Structure and Functions of Some Common Drugs.....	7-28
Chemical Constituents of Human Blood.....	7-45
Chemical Composition of the Human Body.....	7-48
Nutrient Values of Foods.....	7-49

SECTION 8: ANALYTICAL CHEMISTRY

Introduction.....	8-1
Abbreviations and Symbols Used in Analytical Chemistry.....	8-2
Basic Instrumental Techniques of Analytical Chemistry.....	8-6
Analytical Standardization and Calibration.....	8-9
Mass- and Volume-Based Concentration Units.....	8-14
Detection of Outliers in Measurements.....	8-15
Properties of Carrier Gases for Gas Chromatography.....	8-17
Properties of Common Cross-Linked Silicone Stationary Phases.....	8-18
Detectors for Gas Chromatography.....	8-19
Solid-Phase Microextraction Sorbents.....	8-21
Eluotropic Values of Solvents on Octadecylsilane and Octylsilane.....	8-23
Solvents for Ultraviolet Spectrophotometry.....	8-24
Correlation Table for Ultraviolet Active Functionalities.....	8-25
Wavelength-Wavenumber Conversion Table.....	8-28
Middle-Range Infrared Absorption Correlation Charts.....	8-31
Common Spurious Infrared Absorption Bands.....	8-37
Nuclear Spins, Moments, and Other Data Related to NMR Spectroscopy.....	8-38
Properties of Important NMR Nuclei.....	8-41

Proton NMR Absorption of Major Chemical Families.....	8-42
Proton NMR Correlation Chart for Major Organic Functional Groups.....	8-48
Proton NMR Shifts of Common Organic Solvents.....	8-49
¹³ C-NMR Absorptions of Major Functional Groups.....	8-56
¹³ C NMR Chemical Shifts of Common Organic Solvents.....	8-57
¹⁵ N-NMR Chemical Shifts of Major Chemical Families.....	8-58
Natural Abundance of Important Isotopes.....	8-60
Common Mass Spectral Fragmentation Patterns of Organic Compound Families.....	8-61
Common Mass Spectral Fragments Lost.....	8-63
Major Reference Masses in the Spectrum of Heptacosafuorotributylamine (Perfluorotributylamine).....	8-64
Mass Spectral Peaks of Common Organic Solvents.....	8-65
Common Spurious Signals Observed in Mass Spectrometers.....	8-72
Reduction of Weighings in Air to Vacuo.....	8-73
Standards for Laboratory Weights.....	8-74
Indicators for Acids and Bases.....	8-76
Preparation of Special Analytical Reagents.....	8-77
Organic Analytical Reagents for the Determination of Inorganic Cations.....	8-82

SECTION 9: MOLECULAR STRUCTURE AND SPECTROSCOPY

Bond Lengths in Crystalline Organic Compounds.....	9-1
Bond Lengths in Organometallic Compounds.....	9-17
Structure of Free Molecules in the Gas Phase.....	9-19
Characteristic Bond Lengths in Free Molecules.....	9-48
Atomic Radii of the Elements.....	9-49
Dipole Moments.....	9-51
Hindered Internal Rotation.....	9-60
Bond Dissociation Energies.....	9-65
Electronegativity.....	9-97
Force Constants for Bond Stretching.....	9-98
Fundamental Vibrational Frequencies of Small Molecules.....	9-99
Spectroscopic Constants of Diatomic Molecules.....	9-102

SECTION 10: ATOMIC, MOLECULAR, AND OPTICAL PHYSICS

Line Spectra of the Elements.....	10-1
Atomic Transition Probabilities.....	10-93
Electron Affinities.....	10-147
Proton Affinities.....	10-168
Atomic and Molecular Polarizabilities.....	10-187
Ionization Energies of Atoms and Atomic Ions.....	10-197
Ionization Energies of Gas-Phase Molecules.....	10-200
X-Ray Atomic Energy Levels.....	10-218
Electron Binding Energies of the Elements.....	10-222
Natural Width of X-Ray Lines.....	10-228
Photon Attenuation Coefficients.....	10-229
Classification of Electromagnetic Radiation.....	10-234
Sensitivity of the Human Eye to Light of Different Wavelengths.....	10-236
Blackbody Radiation.....	10-237
Characteristics of Infrared Detectors.....	10-239
Index of Refraction of Inorganic Crystals.....	10-240
Refractive Index and Transmittance of Representative Glasses.....	10-244
Index of Refraction of Water.....	10-245
Index of Refraction of Liquids for Calibration Purposes.....	10-246
Index of Refraction of Air.....	10-247
Index of Refraction of Gases.....	10-248
Characteristics of Laser Sources.....	10-249
Infrared Laser Frequencies.....	10-255
Infrared and Far-Infrared Absorption Frequency Standards.....	10-262

SECTION 11: NUCLEAR AND PARTICLE PHYSICS

Summary Tables of Particle Properties.....	11-1
Table of the Isotopes.....	11-2
Neutron Scattering and Absorption Properties.....	11-175
Cosmic Radiation.....	11-188

SECTION 12: PROPERTIES OF SOLIDS

Techniques for Materials Characterization: Experimental Techniques Used to Determine the Composition, Structure, and Energy States of Solids and Liquids.....	12-1
Symmetry of Crystals.....	12-5
Ionic Radii in Crystals.....	12-11
Polarizabilities of Atoms and Ions in Solids.....	12-13
Crystal Structures and Lattice Parameters of Allotropes of the Elements.....	12-15
Phase Transitions in the Solid Elements at Atmospheric Pressure.....	12-19
Lattice Energies.....	12-21
The Madelung Constant and Crystal Lattice Energy.....	12-34
Elastic Constants of Single Crystals.....	12-35
Electrical Resistivity of Pure Metals.....	12-41
Electrical Resistivity of Selected Alloys.....	12-43
Electrical Resistivity of Graphite Materials.....	12-46
Permittivity (Dielectric Constant) of Inorganic Solids.....	12-47
Curie Temperature of Selected Ferroelectric Crystals.....	12-56
Properties of Antiferroelectric Crystals.....	12-57
Dielectric Constants of Glasses.....	12-58
Properties of Superconductors.....	12-59
High-Temperature Superconductors.....	12-75
Organic Superconductors.....	12-77
Properties of Semiconductors.....	12-80
Selected Properties of Semiconductor Solid Solutions.....	12-94
Properties of Organic Semiconductors.....	12-96
Diffusion Data for Semiconductors.....	12-100
Properties of Magnetic Materials.....	12-108
Organic Magnets.....	12-117
Electron Inelastic Mean Free Paths.....	12-120
Electron Stopping Powers.....	12-122
Electron Work Function of the Elements.....	12-124
Secondary Electron Emission.....	12-125
Optical Properties of Selected Elements.....	12-126
Optical Properties of Selected Inorganic and Organic Solids.....	12-151
Elasto-Optic, Electro-Optic, and Magneto-Optic Constants.....	12-170
Nonlinear Optical Constants.....	12-184
Phase Diagrams.....	12-187
Heat Capacity of Selected Solids.....	12-205
Thermal and Physical Properties of Pure Metals.....	12-206
Thermophysical Properties of Stainless Steel 310.....	12-208
Thermal Conductivity of Metals and Semiconductors as a Function of Temperature.....	12-209
Thermal Conductivity of Alloys as a Function of Temperature.....	12-211
Thermal Conductivity of Crystalline Dielectrics.....	12-212
Thermal Conductivity of Ceramics and Other Insulating Materials.....	12-214
Thermal Conductivity of Glasses.....	12-216
Thermoelectric Properties of Metals and Semiconductors.....	12-220
Fermi Energy and Related Properties of Metals.....	12-222
Properties of Commercial Metals and Alloys.....	12-224
Hardness of Minerals and Ceramics.....	12-225

SECTION 13: POLYMER PROPERTIES

Abbreviations Used in Polymer Science and Technology.....	13-1
Physical Properties of Selected Polymers.....	13-3
Nomenclature for Organic Polymers.....	13-5
Solvents for Common Polymers.....	13-9
Glass Transition Temperature for Selected Polymers.....	13-10
Dielectric Constant of Selected Polymers.....	13-17
Second Virial Coefficients of Polymer Solutions.....	13-18
Pressure–Volume–Temperature Relationships for Polymer Melts.....	13-21
Upper Critical (UCST) and Lower Critical (LCST) Solution Temperatures of Binary Polymer Solutions.....	13-26
Vapor Pressures (Solvent Activities) for Binary Polymer Solutions.....	13-40
Specific Enthalpies of Solution of Polymers and Copolymers.....	13-45
Solubility Parameters of Selected Polymers.....	13-73

SECTION 14: GEOPHYSICS, ASTRONOMY, AND ACOUSTICS

Astronomical Constants.....	14-1
Properties of the Solar System.....	14-2
Satellites of the Planets.....	14-4
Interstellar Molecules.....	14-7
Mass, Dimensions, and Other Parameters of the Earth.....	14-10
Geological Time Scale.....	14-12
Acceleration Due to Gravity.....	14-13
Density, Pressure, and Gravity as a Function of Depth within the Earth.....	14-14
Ocean Pressure as a Function of Depth and Latitude.....	14-15
Properties of Seawater.....	14-16
Abundance of Elements in the Earth's Crust and in the Sea.....	14-18
Solar Irradiance at the Earth.....	14-19
U.S. Standard Atmosphere (1976).....	14-20
Geographical and Seasonal Variations in Solar Radiation.....	14-26
Major World Earthquakes.....	14-27
Weather-Related Scales.....	14-31
Infrared Absorption by the Earth's Atmosphere.....	14-33
Atmospheric Concentration of Carbon Dioxide, 1958–2008.....	14-34
Global Temperature Trend, 1880–2011.....	14-36
Global Warming Potential of Greenhouse Gases.....	14-37
Atmospheric Electricity.....	14-39
Speed of Sound in Various Media.....	14-46
Attenuation and Speed of Sound in Air as a Function of Humidity and Frequency.....	14-48
Speed of Sound in Dry Air.....	14-49
Musical Scales.....	14-50
Characteristics of Human Hearing.....	14-51

SECTION 15: PRACTICAL LABORATORY DATA

Standard ITS-90 Thermocouple Tables.....	15-1
Secondary Reference Points on the ITS-90 Temperature Scale.....	15-10
Relative Sensitivity of Bayard-Alpert Ionization Gauges to Various Gases.....	15-12
Laboratory Solvents and Other Liquid Reagents.....	15-13
Miscibility of Organic Solvents.....	15-23
Density of Solvents as a Function of Temperature.....	15-25
Dependence of Boiling Point on Pressure.....	15-26
Ebullioscopic Constants for Calculation of Boiling Point Elevation.....	15-27
Cryoscopic Constants for Calculation of Freezing Point Depression.....	15-28
Freezing Point Lowering by Electrolytes in Aqueous Solution.....	15-29
Correction of Barometer Readings to 0 °C Temperature.....	15-30
Determination of Relative Humidity from Dew Point.....	15-31
Determination of Relative Humidity from Wet and Dry Bulb Temperatures.....	15-32
Constant Humidity Solutions.....	15-33
Standard Salt Solutions for Humidity Calibration.....	15-34
Low-Temperature Baths for Maintaining Constant Temperature.....	15-35
Metals and Alloys with Low Melting Temperature.....	15-36
Wire Tables.....	15-37
Characteristics of Particles and Particle Dispersoids.....	15-38
Density of Various Solids.....	15-39
Density of Sulfuric Acid.....	15-40
Density of Ethanol–Water Mixtures.....	15-42
Dielectric Strength of Insulating Materials.....	15-43
Coefficient of Friction.....	15-48
Flame Temperatures.....	15-50
Allocation of Frequencies in the Radio Spectrum.....	15-51

SECTION 16: HEALTH AND SAFETY INFORMATION

Handling and Disposal of Chemicals in Laboratories.....	16-1
Flammability of Chemical Substances.....	16-13
Threshold Limits for Airborne Contaminants.....	16-29
Octanol–Water Partition Coefficients.....	16-42
Protection against Ionizing Radiation.....	16-47

Annual Limits on Intakes of Radionuclides	16-48
Chemical Carcinogens	16-52

Section I
Basic Constants, Units, and Conversion Factors

APPENDIX A: MATHEMATICAL TABLES

Miscellaneous Mathematical Constants	A-1
Decimal Equivalents of Common Fractions	A-2
Quadratic Formula	A-2
Exponential and Hyperbolic Functions and Their Common Logarithms	A-3
Natural Trigonometric Functions to Four Places	A-6
Relation of Angular Functions in Terms of One Another	A-8
Derivatives	A-9
Integration	A-11
Integrals	A-15
Differential Equations	A-46
Fourier Series	A-57
Fourier Expansions for Basic Periodic Functions	A-59
The Fourier Transforms	A-61
Series Expansion	A-65
Vector Analysis	A-68
Orthogonal Curvilinear Coordinates	A-75
Transformation of Integrals	A-77
Bessel Functions	A-78
The Factorial Function	A-80
The Gamma Function	A-81
The Beta Function	A-82
The Error Function	A-83
Orthogonal Polynomials	A-83
Tables of Orthogonal Polynomials	A-86
Clebsch-Gordan Coefficients	A-87
Normal Probability Function	A-88
Percentage Points, Student's <i>t</i> -Distribution	A-91
Percentage Points, Chi-Square Distribution	A-91
Percentage Points, <i>F</i> -Distribution	A-93
Moment of Inertia for Various Bodies of Mass	A-97

APPENDIX B: SOURCES OF PHYSICAL AND CHEMICAL DATA	B-1
--	-----

INDEX	I-1
--------------------	-----