

## Detailed Licensing

### Overview

**Title:** Thermodynamics and Chemical Equilibrium (Ellgen)

**Webpages:** 374

**Applicable Restrictions:** Noncommercial

**All licenses found:**

- [CC BY-SA 4.0](#): 96% (359 pages)
- [Undeclared](#): 3.7% (14 pages)
- [CC BY-NC-SA 4.0](#): 0.3% (1 page)

### By Page

- [Thermodynamics and Chemical Equilibrium \(Ellgen\) - CC BY-SA 4.0](#)
  - [Front Matter - Undeclared](#)
    - [TitlePage - Undeclared](#)
    - [InfoPage - Undeclared](#)
    - [Table of Contents - Undeclared](#)
    - [Licensing - Undeclared](#)
    - [About the Author - Undeclared](#)
  - [1: Introduction - Background and a Look Ahead - CC BY-SA 4.0](#)
    - [1.1: The Role of the Ideal Gas - CC BY-SA 4.0](#)
    - [1.2: Chemical Kinetics - CC BY-SA 4.0](#)
    - [1.3: Classical Thermodynamics - CC BY-SA 4.0](#)
    - [1.4: Statistical Thermodynamics - CC BY-SA 4.0](#)
    - [1.5: Heat Transfer in Practical Devices - CC BY-SA 4.0](#)
    - [1.6: The Concept of Equilibrium - CC BY-SA 4.0](#)
    - [1.7: Chemical Equilibrium and Predicting Chemical Change - CC BY-SA 4.0](#)
    - [1.8: Equilibrium and Classical Thermodynamics - CC BY-SA 4.0](#)
    - [1.9: A Few Ideas from the Philosophy of Science - CC BY-SA 4.0](#)
    - [1.10: A Few Ideas from Formal Logic - CC BY-SA 4.0](#)
    - [1.11: Problems - CC BY-SA 4.0](#)
  - [2: Gas Laws - CC BY-SA 4.0](#)
    - [2.1: Boyle's Law - CC BY-SA 4.0](#)
    - [2.2: Charles' Law - CC BY-SA 4.0](#)
    - [2.3: Avogadro's Hypothesis - CC BY-SA 4.0](#)
    - [2.4: Finding Avogadro's Number - CC BY-SA 4.0](#)
    - [2.5: The Kelvin Temperature Scale - CC BY-SA 4.0](#)
    - [2.6: Deriving the Ideal Gas Law from Boyle's and Charles' Laws - CC BY-SA 4.0](#)
    - [2.7: The Ideal Gas Constant and Boltzmann's Constant - CC BY-SA 4.0](#)
    - [2.8: Real Gases Versus Ideal Gases - CC BY-SA 4.0](#)
    - [2.9: Temperature and the Ideal Gas Thermometer - CC BY-SA 4.0](#)
    - [2.10: Deriving Boyle's Law from Newtonian Mechanics - CC BY-SA 4.0](#)
    - [2.11: The Barometric Formula - CC BY-SA 4.0](#)
    - [2.12: Van der Waals' Equation - CC BY-SA 4.0](#)
    - [2.13: Virial Equations - CC BY-SA 4.0](#)
    - [2.14: Gas Mixtures - Dalton's Law of Partial Pressures - CC BY-SA 4.0](#)
    - [2.15: Gas Mixtures - Amagat's Law of Partial Volumes - CC BY-SA 4.0](#)
    - [2.16: Problems - CC BY-SA 4.0](#)
  - [3: Distributions, Probability, and Expected Values - CC BY-SA 4.0](#)
    - [3.1: The Distribution Function as a Summary of Experimental Results - CC BY-SA 4.0](#)
    - [3.2: Outcomes, Events, and Probability - CC BY-SA 4.0](#)
    - [3.3: Some Important Properties of Events - CC BY-SA 4.0](#)
    - [3.4: Applying the Laws of Probability - CC BY-SA 4.0](#)
    - [3.5: Bar Graphs and Histograms - CC BY-SA 4.0](#)
    - [3.6: Continuous Distribution Functions - the Envelope Function is the Derivative of the Area - CC BY-SA 4.0](#)
    - [3.7: A Heuristic View of the Probability Density Function - CC BY-SA 4.0](#)
    - [3.8: A Heuristic View of the Cumulative Distribution Function - CC BY-SA 4.0](#)
    - [3.9: Random Variables, Expected Values, and Population Sets - CC BY-SA 4.0](#)
    - [3.10: Statistics - the Mean and the Variance of a Distribution - CC BY-SA 4.0](#)
    - [3.11: The Variance of the Average- The Central Limit Theorem - CC BY-SA 4.0](#)
    - [3.12: The Normal Distribution - CC BY-SA 4.0](#)

- 3.13: The Expected Value of a Function of Several Variables and the Central Limit Theorem - CC BY-SA 4.0
- 3.14: Where Does the  $N - 1$  Come from? - CC BY-SA 4.0
- 3.15: Problems - CC BY-SA 4.0
- 4: The Distribution of Gas Velocities - CC BY-SA 4.0
  - 4.1: Distribution Functions for Gas-velocity Components - CC BY-SA 4.0
  - 4.2: Probability Density Functions for Velocity Components in Spherical Coordinates - CC BY-SA 4.0
  - 4.3: Maxwell's Derivation of the Gas-velocity Probability-density Function - CC BY-SA 4.0
  - 4.4: The Probability-density Function for Gas Velocities in One Dimension - CC BY-SA 4.0
  - 4.5: Combining the One-dimensional Probability Density Functions - CC BY-SA 4.0
  - 4.6: Boyle's Law from the Maxwell-Boltzmann Probability Density - CC BY-SA 4.0
  - 4.7: Experimental Test of the Maxwell-Boltzmann Probability Density - CC BY-SA 4.0
  - 4.8: Statistics for Molecular Speeds - CC BY-SA 4.0
  - 4.9: Pressure Variations for Macroscopic Samples - CC BY-SA 4.0
  - 4.10: Collisions between Gas Molecules Relative Velocity Coordinates - CC BY-SA 4.0
  - 4.11: The Probability Density Function for the Relative Velocity - CC BY-SA 4.0
  - 4.12: The Frequency of Collisions between Unlike Gas Molecules - CC BY-SA 4.0
  - 4.13: The Rate of Collisions between Unlike Gas Molecules - CC BY-SA 4.0
  - 4.14: Collisions between like Gas Molecules - CC BY-SA 4.0
  - 4.15: The Geometry of A Collision between Spherical Molecules - CC BY-SA 4.0
  - 4.16: The Energy of A Collision between Gas Molecules - CC BY-SA 4.0
  - 4.17: Problems - CC BY-SA 4.0
- 5: Chemical Kinetics, Reaction Mechanisms, and Chemical Equilibrium - CC BY-SA 4.0
  - 5.1: Chemical Kinetics - CC BY-SA 4.0
  - 5.2: Reaction Rates and Rate Laws - CC BY-SA 4.0
  - 5.3: Simultaneous Processes - CC BY-SA 4.0
  - 5.4: The Effect of Temperature on Reaction Rates - CC BY-SA 4.0
  - 5.5: Other Factors that Affect Reaction Rates - CC BY-SA 4.0
  - 5.6: Mechanisms and Elementary Processes - CC BY-SA 4.0
  - 5.7: Rate Laws for Elementary Processes - CC BY-SA 4.0
- 5.8: Experimental Determination of Rate Laws - CC BY-SA 4.0
- 5.9: First-order Rate Processes - CC BY-SA 4.0
- 5.10: Rate Laws by the Study of Initial Rates - CC BY-SA 4.0
- 5.11: Rate Laws from Experiments in a Continuous Stirred Tank Reactor - CC BY-SA 4.0
- 5.12: Predicting Rate Laws from Proposed Mechanisms - CC BY-SA 4.0
- 5.13: The Michaelis-Menten Mechanism for Enzyme-catalyzed Reactions - CC BY-SA 4.0
- 5.14: The Lindemann-Hinshelwood Mechanism for First-order Decay - CC BY-SA 4.0
- 5.15: Why Unimolecular Reactions are First Order - CC BY-SA 4.0
- 5.16: The Mechanism of the Base Hydrolysis of  $\text{Co}(\text{NH}_3)_5\text{X}^{n+}$  - CC BY-SA 4.0
- 5.17: Chemical Equilibrium as the Equality of Rates for Opposing Reactions - CC BY-SA 4.0
- 5.18: The Principle of Microscopic Reversibility - CC BY-SA 4.0
- 5.19: Microscopic Reversibility and the Second Law - CC BY-SA 4.0
- 5.20: Problems - CC BY-SA 4.0
- 6: Equilibrium States and Reversible Processes - CC BY-SA 4.0
  - 6.1: The Thermodynamic Perspective - CC BY-SA 4.0
  - 6.2: Thermodynamic Systems and Variables - CC BY-SA 4.0
  - 6.3: Equilibrium and Reversibility - Phase Equilibria - CC BY-SA 4.0
  - 6.4: Distribution Equilibria - CC BY-SA 4.0
  - 6.5: Equilibria in Chemical Reactions - CC BY-SA 4.0
  - 6.6: Le Chatelier's Principle - CC BY-SA 4.0
  - 6.7: The Number of Variables Required to Specify Some Familiar Systems - CC BY-SA 4.0
  - 6.8: Gibbs' Phase Rule - CC BY-SA 4.0
  - 6.9: Reversible vs. Irreversible Processes - CC BY-SA 4.0
  - 6.10: Duhem's Theorem - Specifying Reversible Change in A Closed System - CC BY-SA 4.0
  - 6.11: Reversible Motion of A Mass in A Constant Gravitational Field - CC BY-SA 4.0
  - 6.12: Equilibria and Reversible Processes - CC BY-SA 4.0
  - 6.13: The Laws of Thermodynamics - CC BY-SA 4.0
  - 6.14: Thermodynamic Criteria for Change - CC BY-SA 4.0
  - 6.15: State Functions in Systems Undergoing Spontaneous Change - CC BY-SA 4.0
  - 6.16: Problems - CC BY-SA 4.0
- 7: State Functions and The First Law - CC BY-SA 4.0

- 7.1: Changes in a State Function are Independent of Path - CC BY-SA 4.0
- 7.2: The Total Differential - CC BY-SA 4.0
- 7.3: Line Integrals - CC BY-SA 4.0
- 7.4: Exact Differentials and State Functions - CC BY-SA 4.0
- 7.5: Determining Whether an Expression is an Exact Differential - CC BY-SA 4.0
- 7.6: The Chain Rule and the Divide-through Rule - CC BY-SA 4.0
- 7.7: Measuring Pressure-Volume Work - CC BY-SA 4.0
- 7.8: Measuring Work- Non-Pressure-Volume Work - CC BY-SA 4.0
- 7.9: Measuring Heat - CC BY-SA 4.0
- 7.10: The First Law of Thermodynamics - CC BY-SA 4.0
- 7.11: Other Statements of the First Law - CC BY-SA 4.0
- 7.12: Notation for Changes in Thermodynamic Quantities -  $E$  vs.  $\Delta E$  - CC BY-SA 4.0
- 7.13: Heat Capacities for Gases-  $C_v$ ,  $C_p$  - CC BY-SA 4.0
- 7.14: Heat Capacities of Solids- the Law of Dulong and Petit - CC BY-SA 4.0
- 7.15: Defining Enthalpy,  $H$  - CC BY-SA 4.0
- 7.16: Heat Transfer in Reversible Processes - CC BY-SA 4.0
- 7.17: Free Expansion of a Gas - CC BY-SA 4.0
- 7.18: Reversible vs. Irreversible Pressure-Volume Work - CC BY-SA 4.0
- 7.19: Isothermal Expansions of An Ideal Gas - CC BY-SA 4.0
- 7.20: Adiabatic Expansions of An Ideal Gas - CC BY-SA 4.0
- 7.21: Problems - CC BY-SA 4.0
- 8: Enthalpy and Thermochemical Cycles - CC BY-SA 4.0
  - 8.1: Enthalpy - CC BY-SA 4.0
  - 8.2: Using Thermochemical Cycles to Find Enthalpy Changes - CC BY-SA 4.0
  - 8.3: How Enthalpy Depends on Pressure - CC BY-SA 4.0
  - 8.4: Standard States and Enthalpies of Formation - CC BY-SA 4.0
  - 8.5: The Ideal Gas Standard State - CC BY-SA 4.0
  - 8.6: Standard Enthalpies of Reaction - CC BY-SA 4.0
  - 8.7: Standard State Heat Capacities - CC BY-SA 4.0
  - 8.8: How The Enthalpy Change for a Reaction Depends on Temperature - CC BY-SA 4.0
  - 8.9: Calorimetry - CC BY-SA 4.0
  - 8.10: Problems - CC BY-SA 4.0
- 9: The Second Law - Entropy and Spontaneous Change - CC BY-SA 4.0
  - 9.1: The Second Law of Thermodynamics - CC BY-SA 4.0
  - 9.2: The Carnot Cycle for an Ideal Gas and the Entropy Concept - CC BY-SA 4.0
  - 9.3: The Carnot Cycle for Any Reversible System - CC BY-SA 4.0
  - 9.4: The Entropy Change around Any Cycle for Any Reversible System - CC BY-SA 4.0
  - 9.5: The Tiling Theorem and the Paths of Cyclic Process in Other Spaces - CC BY-SA 4.0
  - 9.6: Entropy Changes for A Reversible Process - CC BY-SA 4.0
  - 9.7: Entropy Changes for A Spontaneous Process in An Isolated System - CC BY-SA 4.0
  - 9.8: The Entropy of the Universe - CC BY-SA 4.0
  - 9.9: The Significance of The Machine-based Statement of The Second Law - CC BY-SA 4.0
  - 9.10: A Slightly Philosophical Digression on Energy and Entropy - CC BY-SA 4.0
  - 9.11: A Third Statement of the Second Law - CC BY-SA 4.0
  - 9.12: Entropy and Predicting Change - CC BY-SA 4.0
  - 9.13: Defining the Helmholtz and Gibbs Free Energies - CC BY-SA 4.0
  - 9.14: The Fundamental Equation and Other Criteria for Reversible Change - CC BY-SA 4.0
  - 9.15: Entropy and Spontaneous Change - CC BY-SA 4.0
  - 9.16: Internal Entropy and the Second Law - CC BY-SA 4.0
  - 9.17: Notation and Terminology- Conventions for Spontaneous Processes - CC BY-SA 4.0
  - 9.18: The Heat Exchanged by A Spontaneous Process at Constant Entropy - CC BY-SA 4.0
  - 9.19: The Energy Change for A Spontaneous Process at Constant  $S$  and  $V$  - CC BY-SA 4.0
  - 9.20: The Enthalpy Change for A Spontaneous Process at Constant  $S$  and  $P$  - CC BY-SA 4.0
  - 9.21: The Entropy Change for A Spontaneous Process at Constant  $E$  and  $V$  - CC BY-SA 4.0
  - 9.22: The Entropy Change for A Spontaneous Process at Constant  $H$  and  $P$  - CC BY-SA 4.0
  - 9.23: The Reversible Work is the Minimum Work at Constant  $T$  - CC BY-SA 4.0
  - 9.24: The Free Energy Changes for A Spontaneous Process at Constant  $T$  - CC BY-SA 4.0
  - 9.25: Summary- Thermodynamic Functions as Criteria for Change - CC BY-SA 4.0
  - 9.26: Problems - CC BY-SA 4.0

- 10: Some Mathematical Consequences of the Fundamental Equation - CC BY-SA 4.0
  - 10.1: Thermodynamic Relationships from  $dE$ ,  $dH$ ,  $dA$  and  $dG$  - CC BY-SA 4.0
  - 10.2:  $dE = TdS - PdV$  and Internal consistency - CC BY-SA 4.0
  - 10.3: Expressing Thermodynamic Functions with Other Independent Variables - CC BY-SA 4.0
  - 10.4: Expressing Thermodynamic Functions with Independent Variables  $V$  and  $T$  - CC BY-SA 4.0
  - 10.5: Expressing Thermodynamic Functions with Independent Variables  $P$  and  $T$  - CC BY-SA 4.0
  - 10.6: The Transformation of Thermodynamic Variables in General - CC BY-SA 4.0
  - 10.7: Reversibility and Thermodynamic Variables in General - CC BY-SA 4.0
  - 10.8: Using the Pair  $(V, P)$  or the Pair  $(T, S)$  as Independent Variables - CC BY-SA 4.0
  - 10.9: The Relationship Between  $C_v$  and  $C_p$  for Any Substance - CC BY-SA 4.0
  - 10.10: The Dependence of  $C_v$  on Volume and of  $C_p$  on Pressure - CC BY-SA 4.0
  - 10.11: The Gibbs-Helmholtz Equation - CC BY-SA 4.0
  - 10.12: The Second Law and the Properties of Ideal Gases - CC BY-SA 4.0
  - 10.13: The second-dependence of the Energy and Enthalpy of A Real Gas - CC BY-SA 4.0
  - 10.14: The Joule-Thomson Effect - CC BY-SA 4.0
  - 10.15: Problems - CC BY-SA 4.0
- 11: The Third Law, Absolute Entropy, and the Gibbs Free Energy of Formation - CC BY-SA 4.0
  - 11.1: Heat Capacity as a Function of Temperature - CC BY-SA 4.0
  - 11.2: Enthalpy as a function of Temperature - CC BY-SA 4.0
  - 11.3: The Third Law - CC BY-SA 4.0
  - 11.4: Genesis of the Third Law - the Nernst Heat Theorem - CC BY-SA 4.0
  - 11.5: Absolute Entropy - CC BY-SA 4.0
  - 11.6: The Standard State for Third-law Entropies - CC BY-SA 4.0
  - 11.7: The Fugacity of a Gas - CC BY-SA 4.0
  - 11.8: A General Strategy for Expressing the Thermodynamic Properties of a Substance - CC BY-SA 4.0
  - 11.9: The Standard Entropy and the Gibbs Free Energy of Formation - CC BY-SA 4.0
  - 11.10: The Nature of Hypothetical States - CC BY-SA 4.0
  - 11.11: The Fugacity and Gibbs Free Energy of A Substance in Any System - CC BY-SA 4.0
  - 11.12: Evaluating Entropy Changes Using Thermochemical Cycles - CC BY-SA 4.0
  - 11.13: Absolute Zero is Unattainable - CC BY-SA 4.0
  - 11.14: Problems - CC BY-SA 4.0
- 12: Applications of the Thermodynamic Criteria for Change - CC BY-SA 4.0
  - 12.1: Mechanical Processes - CC BY-SA 4.0
  - 12.2: The Direction of Spontaneous Heat Transfer - CC BY-SA 4.0
  - 12.3: Phase Changes - the Fusion of Ice - CC BY-SA 4.0
  - 12.4: Measuring the Entropy Change for Any Reversible Process - CC BY-SA 4.0
  - 12.5: Another Perspective on the Principle of Le Chatelier - CC BY-SA 4.0
  - 12.6: Phase Equilibria - Temperature Dependence of the Boiling Point - CC BY-SA 4.0
  - 12.7: Phase Equilibria - Temperature Dependence of the Melting Point - CC BY-SA 4.0
  - 12.8: The Clapeyron Equation - CC BY-SA 4.0
  - 12.9: The Clausius-Clapeyron Equation - CC BY-SA 4.0
  - 12.10: Problems - CC BY-SA 4.0
- 13: Equilibria in Reactions of Ideal Gases - CC BY-SA 4.0
  - 13.1: The Gibbs Free Energy of an Ideal Gas - CC BY-SA 4.0
  - 13.2: The Gibbs Free Energy Change for A Reaction of Ideal Gases - CC BY-SA 4.0
  - 13.3: The Thermodynamics of Mixing Ideal Gases - CC BY-SA 4.0
  - 13.4: The Gibbs Free Energy Change for Reaction at Constant Partial Pressures - CC BY-SA 4.0
  - 13.5:  $\Delta_r G$  is the rate at which the Gibbs Free Energy Changes with The Extent of Reaction - CC BY-SA 4.0
  - 13.6: The Standard Gibbs Free Energy Change and Equilibrium in Ideal Gas Reactions - CC BY-SA 4.0
  - 13.7: The Gibbs Free Energy of Formation and Equilibrium in Ideal Gas Reactions - CC BY-SA 4.0
  - 13.8: Equilibrium When A Component is Also Present as A Condensed Phase - CC BY-SA 4.0
  - 13.9: Equilibrium When An Ideal Gas Component is Also Present as A solute - CC BY-SA 4.0
  - 13.10: Problems - CC BY-SA 4.0
- 14: Chemical Potential - Extending the Scope of the Fundamental Equation - CC BY-SA 4.0
  - 14.1: Dependence of the Internal Energy on the Composition of the System - CC BY-SA 4.0
  - 14.2: Dependence of Other Thermodynamic Functions on the Composition - CC BY-SA 4.0
  - 14.3: Partial Molar Quantities - CC BY-SA 4.0

- 14.4: Chemical Potentials and Stoichiometry - CC BY-SA 4.0
- 14.5:  $\sum \mu_j dn_j = 0$  and Primitive Vs. Gibbsian Equilibrium - CC BY-SA 4.0
- 14.6: The Change Criteria in A System Composed of Subsystems - CC BY-SA 4.0
- 14.7: At Constant P and T,  $\Delta_r G$  is the Change in Gibbs Free Energy - CC BY-SA 4.0
- 14.8: Gibbs-Duhem Equation - CC BY-SA 4.0
- 14.9: The Dependence of Chemical Potential on Other Variables - CC BY-SA 4.0
- 14.10: Chemical Activity - CC BY-SA 4.0
- 14.11: Back to the Fugacity- the Fugacity of A Component of A Gas Mixture - CC BY-SA 4.0
- 14.12: Relating Fugacity and Chemical Activity - CC BY-SA 4.0
- 14.13: Relating the Differentials of Chemical Potential and Activity - CC BY-SA 4.0
- 14.14: Dependence of Activity on Temperature- Relative Partial Molar Enthalpies - CC BY-SA 4.0
- 14.15: Problems - CC BY-SA 4.0
- 15: Chemical Potential, Fugacity, Activity, and Equilibrium - CC BY-SA 4.0
  - 15.1: The Chemical Potential and Fugacity of a Gas - CC BY-SA 4.0
  - 15.2: The Chemical Potential and Activity of a Gas - CC BY-SA 4.0
  - 15.3: The Pressure-dependence of the Fugacity and Activity of a Condensed Phase - CC BY-SA 4.0
  - 15.4: Standard States for the Fugacity and Activity of a Pure Solid - CC BY-SA 4.0
  - 15.5: The Chemical Potential, Fugacity, and Activity of a Pure Solid - CC BY-SA 4.0
  - 15.6: Chemical Potential, Fugacity, and Equilibrium - CC BY-SA 4.0
  - 15.7: Chemical Potential, Activity, and Equilibrium - CC BY-SA 4.0
  - 15.8: The Rate of Gibbs Free Energy Change with Extent of Reaction - CC BY-SA 4.0
  - 15.9: Problems - CC BY-SA 4.0
- 16: The Chemical Activity of the Components of a Solution - CC BY-SA 4.0
  - 16.1: Solutions Whose Components are in Equilibrium with Their Own Gases - CC BY-SA 4.0
  - 16.2: Raoult's Law and Ideal Solutions - CC BY-SA 4.0
  - 16.3: Expressing the Activity Coefficient as a Deviation from Raoult's Law - CC BY-SA 4.0
  - 16.4: Henry's Law and the Fugacity and Activity of A Solution Component - CC BY-SA 4.0
  - 16.5: Expressing the Activity Coefficient as A Deviation from Henry's Law - CC BY-SA 4.0
  - 16.6: Henry's Law and the Hypothetical One-molal Standard State - CC BY-SA 4.0
  - 16.7: Finding the Activity of a Solute from the Activity of the Solvent - CC BY-SA 4.0
  - 16.8: When the Solute Obeys Henry's Law, the Solvent Obeys Raoult's Law - CC BY-SA 4.0
  - 16.9: Properties of Ideal Solutions - CC BY-SA 4.0
  - 16.10: Colligative Properties - Boiling-point Elevation - CC BY-SA 4.0
  - 16.11: Colligative Properties - Freezing-point Depression - CC BY-SA 4.0
  - 16.12: Colligative Properties - Osmotic Pressure - CC BY-SA 4.0
  - 16.13: Colligative Properties - Solubility of a Solute in an Ideal Solution - CC BY-SA 4.0
  - 16.14: Colligative Properties - Solubility of a Gas - CC BY-SA 4.0
  - 16.15: Solvent Activity Coefficients from Freezing-point Depression Measurements - CC BY-SA 4.0
  - 16.16: Electrolytic Solutions - CC BY-SA 4.0
  - 16.17: Activities of Electrolytes - The Mean Activity Coefficient - CC BY-SA 4.0
  - 16.18: Activities of Electrolytes - The Debye-Hückel Theory - CC BY-SA 4.0
  - 16.19: Finding Solute Activity Using the Hypothetical One-molal Standard State - CC BY-SA 4.0
  - 16.20: Problems - CC BY-SA 4.0
- 17: Electrochemistry - CC BY-SA 4.0
  - 17.1: Oxidation-reduction Reactions - CC BY-SA 4.0
  - 17.2: Electrochemical Cells - CC BY-SA 4.0
  - 17.3: Defining Oxidation States - CC BY-SA 4.0
  - 17.4: Balancing Oxidation-reduction Reactions - CC BY-SA 4.0
  - 17.5: Electrical Potential - CC BY-SA 4.0
  - 17.6: Electrochemical Cells as Circuit Elements - CC BY-SA 4.0
  - 17.7: The Direction of Electron Flow and its Implications - CC BY-SA 4.0
  - 17.8: Electrolysis and the Faraday - CC BY-SA 4.0
  - 17.9: Electrochemistry and Conductivity - CC BY-SA 4.0
  - 17.10: The Standard Hydrogen Electrode (S.H.E) - CC BY-SA 4.0
  - 17.11: Half-reactions and Half-cells - CC BY-SA 4.0
  - 17.12: Standard Electrode Potentials - CC BY-SA 4.0
  - 17.13: Predicting the Direction of Spontaneous Change - CC BY-SA 4.0
  - 17.14: Cell Potentials and the Gibbs Free Energy - CC BY-SA 4.0
  - 17.15: The Nernst Equation - CC BY-SA 4.0



- 17.16: The Nernst Equation for Half-cells - CC BY-SA 4.0
- 17.17: Combining two Half-cell Equations to Obtain a new Half-cell Equation - CC BY-SA 4.0
- 17.18: The Nernst Equation and the Criterion for Equilibrium - CC BY-SA 4.0
- 17.19: Problems - CC BY-SA 4.0
- 18: Quantum Mechanics and Molecular Energy Levels - CC BY-SA 4.0
  - 18.1: Energy Distributions and Energy Levels - CC BY-SA 4.0
  - 18.2: Quantized Energy - De Broglie's Hypothesis and the Schroedinger Equation - CC BY-SA 4.0
  - 18.3: The Schrödinger Equation for A Particle in A Box - CC BY-SA 4.0
  - 18.4: The Schrödinger Equation for a Molecule - CC BY-SA 4.0
  - 18.5: Solutions to Schroedinger Equations for Harmonic Oscillators and Rigid Rotors - CC BY-SA 4.0
  - 18.6: Wave Functions, Quantum States, Energy Levels, and Degeneracies - CC BY-SA 4.0
  - 18.7: Particle Spins and Statistics- Bose-Einstein and Fermi-Dirac Statistics - CC BY-SA 4.0
- 19: The Distribution of Outcomes for Multiple Trials - CC BY-SA 4.0
  - 19.1: Distribution of Results for Multiple Trials with Two Possible Outcomes - CC BY-SA 4.0
  - 19.2: Distribution of Results for Multiple Trials with Three Possible Outcomes - CC BY-SA 4.0
  - 19.3: Distribution of Results for Multiple Trials with Many Possible Outcomes - CC BY-SA 4.0
  - 19.4: Stirling's Approximation - CC BY-SA 4.0
  - 19.5: Problems - CC BY-SA 4.0
- 20: Boltzmann Statistics - CC BY-SA 4.0
  - 20.1: The Independent-Molecule Approximation - CC BY-SA 4.0
  - 20.2: The Probability of An Energy Level at Constant N, V, and T - CC BY-SA 4.0
  - 20.3: The Population Sets of a System at Equilibrium at Constant N, V, and T - CC BY-SA 4.0
  - 20.4: How can Infinitely Many Probabilities Sum to Unity? - CC BY-SA 4.0
  - 20.5: The Total Probability Sum at Constant N, V, and T - CC BY-SA 4.0
  - 20.6: The Most Probable Population Set at Constant N, V, and T - CC BY-SA 4.0
  - 20.7: The Microstates of a Given Population Set - CC BY-SA 4.0
  - 20.8: The Probabilities of Microstates that Have the Same Energy - CC BY-SA 4.0
  - 20.9: The Probabilities of the Population Sets of an Isolated System - CC BY-SA 4.0
  - 20.10: Entropy and Equilibrium in an Isolated System - CC BY-SA 4.0
  - 20.11: Thermodynamic Probability and Equilibrium in an Isomerization Reaction - CC BY-SA 4.0
  - 20.12: The Degeneracy of an Isolated System and Its Entropy - CC BY-SA 4.0
  - 20.13: The Degeneracy of an Isolated System and its Entropy - CC BY-SA 4.0
  - 20.14: Effective Equivalence of the Isothermal and Constant-energy Conditions - CC BY-SA 4.0
  - 20.15: Problems - CC BY-SA 4.0
- 21: The Boltzmann Distribution Function - CC BY-SA 4.0
  - 21.1: Finding the Boltzmann Equation - CC BY-SA 4.0
  - 21.2: Lagrange's Method of Undetermined Multipliers - CC BY-SA 4.0
  - 21.3: Deriving the Boltzmann Equation I - CC BY-SA 4.0
  - 21.4: Deriving the Boltzmann Equation II - CC BY-SA 4.0
  - 21.5: Partition Functions and Equilibrium - Isomeric Molecules - CC BY-SA 4.0
  - 21.6: Finding  $\beta$  and the Thermodynamic Functions for Distinguishable Molecules - CC BY-SA 4.0
  - 21.7: The Microscopic Model for Reversible Change - CC BY-SA 4.0
  - 21.8: The Third Law of Thermodynamics - CC BY-SA 4.0
  - 21.9: The Partition Function for a System of N Molecules - CC BY-SA 4.0
  - 21.10: Problems - CC BY-SA 4.0
- 22: Some Basic Applications of Statistical Thermodynamics - CC BY-SA 4.0
  - 22.1: Interpreting the Partition Function - CC BY-SA 4.0
  - 22.2: Conditions under which Integrals Approximate Partition Functions - CC BY-SA 4.0
  - 22.3: Probability Density Functions from the Energies of Classical-mechanical Models - CC BY-SA 4.0
  - 22.4: Partition Functions and Average Energies at High Temperatures - CC BY-SA 4.0
  - 22.5: Energy Levels for a Three-dimensional Harmonic Oscillator - CC BY-SA 4.0
  - 22.6: Energy and Heat Capacity of the "Einstein Crystal" - CC BY-SA 4.0
  - 22.7: Applications of Other Entropy Relationships - CC BY-SA 4.0
  - 22.8: Problems - CC BY-SA 4.0
- 23: The Ensemble Treatment - CC BY-SA 4.0

- 23.1: Ensembles of N-molecule Systems - *CC BY-SA 4.0*
- 23.2: The Ensemble Entropy and the Value of  $\beta$  - *CC BY-SA 4.0*
- 23.3: The Thermodynamic Functions of the N-molecule System - *CC BY-SA 4.0*
- 24: Indistinguishable Molecules - Statistical Thermodynamics of Ideal Gases - *CC BY-SA 4.0*
  - 24.1: The Partition Function for N Distinguishable, Non-interacting Molecules - *CC BY-SA 4.0*
  - 24.2: The Partition Function for N Indistinguishable, Non-interacting Molecules - *CC BY-SA 4.0*
  - 24.3: Occupancy Probabilities for Translational Energy Levels - *CC BY-SA 4.0*
  - 24.4: The Separable-modes molecular Model - *CC BY-SA 4.0*
  - 24.5: The Partition Function for A Gas of Indistinguishable, Non-interacting, Separable-modes Molecules - *CC BY-SA 4.0*
  - 24.6: The Translational Partition Function of An Ideal Gas - *CC BY-SA 4.0*
  - 24.7: The Electronic Partition Function of an Ideal Gas - *CC BY-SA 4.0*
  - 24.8: The Vibrational Partition Function of A Diatomic Ideal Gas - *CC BY-SA 4.0*
  - 24.9: The Rotational Partition Function of A Diatomic Ideal Gas - *CC BY-SA 4.0*
  - 24.10: The Gibbs Free Energy for One Mole of An Ideal Gas - *CC BY-SA 4.0*
  - 24.11: The Standard Gibbs Free Energy for  $\text{H}_2(\text{g})$ ,  $\text{I}_2(\text{g})$ , and  $\text{HI}(\text{g})$  - *CC BY-SA 4.0*
  - 24.12: The Gibbs Free Energy Change for Forming  $\text{HI}(\text{g})$  from  $\text{H}_2(\text{g})$  and  $\text{I}_2(\text{g})$  - *CC BY-SA 4.0*
  - 24.13: The Reference State for Molecular Partition Functions - *CC BY-SA 4.0*
  - 24.14: Problems - *CC BY-SA 4.0*
- 25: Bose-Einstein and Fermi-Dirac Statistics - *CC BY-SA 4.0*
  - 25.1: Quantum Statistics - *CC BY-SA 4.0*
  - 25.2: Fermi-Dirac Statistics and the Fermi-Dirac Distribution Function - *CC BY-SA 4.0*
  - 25.3: Bose-Einstein Statistics and the Bose-Einstein Distribution Function - *CC BY-SA 4.0*
- 26: Appendices - *CC BY-NC-SA 4.0*
  - 26.1: Appendix A. Standard Atomic Weights 1999† - *CC BY-SA 4.0*
  - 26.2: Appendix B. - *CC BY-SA 4.0*
  - 26.3: Appendix B. Fundamental Constants† - *Undeclared*
  - 26.4: Appendix C. - *CC BY-SA 4.0*
  - 26.5: Units and Conversion Factors - *Undeclared*
  - 26.6: Appendix D. - *CC BY-SA 4.0*
  - 26.7: Appendix D. Some Important Definite Integrals - *Undeclared*
- Back Matter - *Undeclared*
  - Index - *Undeclared*
  - Index - *Undeclared*
  - Glossary - *Undeclared*
  - Detailed Licensing - *Undeclared*