Part I – Fundamental Principles (Taught by Professor Blankschtein)

1. Scope, Basic Concepts, and Definitions (Chapters 1 and 2)
   - Postulatory vs. historical approach.
   - System specification.
   - Properties (intensive and extensive, primitive and derived, state and path functions).
   - Boundaries (adiabatic versus diathermal, rigid versus movable, permeable versus impermeable).
   - Simple and composite systems.
   - Temperature scales.
   - Postulates I and II.

2. Energy Balance and The First Law of Thermodynamics (Chapter 3)
   - Work interactions (P-V and generalized).
   - Adiabatic work interactions and Postulate III.
   - Heat interactions and Postulate IV.
   - Closed systems.
   - Open systems.
   - Evaluation of thermodynamic-property changes.
   - Approach to problem solving.

3. Reversibility and The Second Law of Thermodynamics (Chapter 4)
   - Reversible heat engines and the conversion of heat into work.
   - Carnot efficiency, reversible and irreversible processes.
   - Interpretation of entropy, entropy balance.
   - The combined First and Second Laws of Thermodynamics for closed and open simple systems.
   - Maximum work, availability and lost work concepts.
   - Flow work.
   - Analysis of thermodynamic feasibility and efficiency.

4. The Calculus of Thermodynamics (Chapter 5)
   - Fundamental Equation in Gibbs Coordinates.
   - Extensive and intensive properties (Euler’s theorem).
   - Legendre transformations.
   - Partial derivatives of Legendre transforms.
   - Single and multiple variable Legendre transforms.
   - Reordering variables and stepdown formulae.
Part II – Classical Thermodynamics of Pure Fluids and Mixtures
(Taught by Professor Blankschtein)

1. Properties of Pure Materials (Chapter 8)
   - Gibbs free energy representation of the Fundamental Equation.
   - Generalized charts and Theorem of Corresponding States:
     - Z-compressibility factors.
     - \( f/P \) fugacity.
     - Enthalpy and entropy.
   - Equations of state:
     - Cubic form (e.g., van der Waals, Redlich-Kwong, Martin, Peng-Robinson).
     - Virial form.
   - Departure functions (real-gas state to ideal-gas state).
   - Ideal-gas state heat capacities (\( C_p^o \), \( C_v^o \)).
   - Thermodynamic diagrams.
   - Calculation of thermodynamic derived properties using PVT departure functions and equations of state and \( C_p^o \) or \( C_v^o \) data.

2. Mixtures (Chapter 9)
   - Extensive and intensive differentials.
   - Partial molar properties.
   - Generalized Gibbs-Duhem relation.
   - \( P-V-T-N \) (e.g., Redlich-Kwong and Peng-Robinson) equations of state for mixtures.
   - Ideal-gas mixtures and ideal solutions (Lewis and Randall rule).
   - Regular and athermal solution behavior.
   - Mixing and excess functions.
   - Activity and fugacity coefficients and standard states.
   - Activity-coefficient models for liquid mixtures (e.g., Margules, van Laar, Wilson, NRTL, UNIQUAC, Flory-Huggins).

3. Equilibrium (Chapter 6)
   - Classification of equilibrium states.
   - Extrema principles.
   - Thermal, mechanical, and membrane equilibrium.

4. Stability (Chapter 7)
   - Criteria of stability.
   - Stability in one-component systems.
   - Stability in binary and multicomponent mixtures.
   - Critical phenomena.
Part III – Molecular Interpretation of Thermodynamic Properties Using Statistical Mechanics (Taught by Professor Trout)

1. **Introduction to Statistical Mechanics and Ideal gas models (Chapter 10, Course Reader, & Handouts)**
   - Probability distributions, in particular Boltzmann distribution.
   - Classical versus quantum statistical mechanics and phase space.
   - Postulates of statistical mechanics.
   - Ensembles and connection to Thermodynamics.
   - Partition functions and thermodynamic quantities for idea gases.
   - Computation of thermodynamic properties from energy levels.

2. **Ising Model and Molecular Understanding of Phase Equilibria (Course Reader, & Handouts)**
   - Ising model and lattice gas model.
   - Symmetry breaking.
   - Exact solutions and Mean field theory.
   - Beyond mean field theory.
   - Solutions via computer simulations.

3. **Simulations and Equations of State (Chapter 10, Course Reader, & Handouts)**
   - Monte Carlo simulations.
   - Intermolecular forces and potentials.
   - Configurational integral.
   - Microscopic derivation of equations of state, such as the one by van der Waals.
   - Radial distribution functions.
   - Molecular dynamics simulations.
Part IV – Applications in Phase and Chemical Equilibria
(Taught by Professor Trout)

1. **Phase Equilibrium (Chapter 15)**

   - Gibbs phase rule.
   - Differential and integral approaches.
   - Gibbs phase-rule applications.
   - Liquid-vapor and liquid-liquid equilibria.
   - Solubility of solids in fluids.
   - Pressure-temperature relations (Clausius-Clapeyron equation).
   - Phase diagrams.

2. **Chemical Equilibrium (Chapter 16)**

   - Conservation relationships.
   - Stoichiometric and non-stoichiometric formulations.
   - Equilibrium constants.
   - Standard states.
   - A statistical mechanical and quantum mechanical approach to chemical equilibria.
   - Gibbs phase rule for chemically-reacting systems.
   - Le Châtelier’s principle.