- Know the difference between macroscopic and microscopic quantities.

- Understand that thermodynamics deals with macroscopic quantities.

- Be able to use the concept of equilibrium.

- Know and be able to use the ideal gas law: $\boldsymbol{PV = nRT}$.

- Know that the ideal gas temperature scale is the correct thermodynamic temperature scale.

- Know that temperature is a measure of thermal kinetic energy and that RT provides the scale for thermal energy.

- Understand what internal energy consists of and how heat, internal energy, and temperature differ from one another.

- Be able to state and apply the First Law of Thermodynamics in terms of heat and work: $\Delta U = q + w$.

- Know what is meant by a reversible process.

- Be familiar with the terms "system" and "surroundings".

- Understand the distinction between state functions and path functions. Know that only a small number of state functions are needed to fully specify the state of a system.

- Know and be able to use the definition of PV work.

- Know and be able to use the definition of enthalpy: $H \equiv U + PV$.

- Be able to calculate heat, work, ΔU, and ΔH for isothermal and constant pressure processes.

- Know that for an ideal gas, H and U depend on temperature alone; but this is not true for other substances.

- Know when ΔU or ΔH can be equated to q. Know the definitions of C_V and C_P in terms of U and H. Be able to use C_V and C_P in calculations involving the transfer of energy as heat.

- Understand the terms isothermal, adiabatic, and diathermic.

- Know the definition of entropy: $dS = dq_{rev} / T$. Be able to use it and the fact that entropy is a state function to calculate entropy changes.

- Be able to give Clausius's statement of the Second Law of Thermodynamics. Understand the significance of the entropy change of the universe as opposed to the entropy change of the system.

- Know that increases in T produce increases in U, H, and S; but U, H, and S can change with no change in T. Understand why this is so.

- Be able to predict the sign of the entropy change in phase transitions, heating and cooling, and processes involving the change in pressure or volume of gases.

- Know what is meant by cyclic, reversible, spontaneous, and isentropic processes and be able to calculate entropy changes in such processes.

- Understand that heat engines use the transfer of heat between two different temperatures to do work and that there is a fundamental limit to the efficiency of such engines.

- Know that it is impossible to devise a process that has the sole effect of turning heat into work.

- Understand that the quality of an energy source depends on the amount of entropy associated with a transfer of energy from the source.

- Be able to take partial derivatives of a function of several variables.

- Be able to write out the total differential of a function of several variables.

- Be able to use the definitions of H, A, and G. These will be provided on the test.

- Be able to write out the fundamental equation of thermodynamics ($dU = TdS - PdV$) in terms of U, H, A, and G for closed systems of fixed composition.

- Know which of T, S, P and V are the "natural variables" for each of U, H, A, and G.

- Be able to correctly carry out the basic partial derivative manipulations: Maxwell relations (equivalence of mixed second derivatives), inverses, chain rule, cyclic rule, and rearrangements of the fundamental equation.

- Be able to use numerical values of partial derivatives to estimate the change in one quantity from the change in another, such using C_v to estimate the change in U due to a change in T at constant V or using β to estimate the change in V when P changes at constant T.

- Know that Gibbs free energy gives the direction of spontaneous change for a process at constant temperature and pressure and understand why that is so.

- Know the definition of partial molar quantities. Know that they are equivalent to molar quantities for pure substances.

- Know that the Third Law of Thermodynamics postulates that the entropy of a perfect crystal is zero at the absolute zero of temperature. Understand that this can be used to compute absolute entropies.

- Understand that entropy increases with: increasing T, changing a low T phase to a higher T phase, increasing the molecular weight and/or complexity of molecules, and when a chemical reaction increases the number of moles of gas.

- Be able to define standard states and standard enthalpy and entropy changes; understand what is meant by reference states.

- Be able to calculate $\Delta S°_{rxn}$, $\Delta G°_{rxn}$, $\Delta C°_{P,rxn}$, and $\Delta H°_{rxn}$ from tabulated data.

- Understand how to use $\Delta C°_{P,rxn}$ to compute the temperature dependencies of $\Delta H°_{rxn}$ and $\Delta S°_{rxn}$.

- Know how to use $\Delta G = \Delta H - T\Delta S$ to estimate $\Delta G°_{rxn}$ at a temperature other than that for which the data are tabulated.

- Understand which tabulated thermodynamic quantities are for formation of the species (and be able to give the corresponding reaction) and which are absolute quantities.

- Understand that ΔS_{rxn} and ΔG_{rxn} are sensitive to pressure if gases are involved in the reaction.

- Be able to determine the number of phases and components from a description of a system.

- Know that the chemical potential is the partial molar Gibbs free energy.

- Know that at equilibrium the chemical potential of a substance must be the same in all phases.

- Know and be able to use the Gibbs phase rule: $f = 2 + c - p$.

- Know that higher temperature favors the higher entropy phase and higher pressure favors the higher density phase.

- Know what is meant by a metastable phase.

- Be able to sketch a single component phase diagram; be able to label the various regions, the triple point, and the critical point; and be able to describe what happens as a particular path is followed on the phase diagram.

- Be able to use the the Clapeyron equation and the equations for the temperature and pressure dependence of the chemical potential. These equations will be provided if needed:

$$\frac{dP}{dT} = \frac{\Delta H_{tr}}{T\Delta V_{tr}} \qquad \left(\frac{\partial \mu_i}{\partial T}\right)_P = -\bar{S}_i \qquad \left(\frac{\partial \mu_i}{\partial P}\right)_T = \bar{V}_i$$

- Know the Clausius-Clapeyron equation:
  Know when it is applicable and be able to use it.
  $$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

- Know the relation between chemical potential and activity: $\mu_i = \mu_i° + RT\ln a_i$.

- Know the common approximations for activity for solids, liquids, gases, and species in solution.

- Know the difference between ΔG_{rxn} and $\Delta G°_{rxn}$. Know what each is used for and know that $\Delta G_{rxn} = 0$ at equilibrium.

- Know and be able to use the Lewis equation together with the definitions of activity quotient and equilibrium constant: $\Delta G_{rxn} = \Delta G°_{rxn} + RT\ln Q$ and $\Delta G°_{rxn} = -RT\ln K_{eq}$.

- Understand why equilibrium might never be reached if there is only one degree of freedom.

- Know and be able to use the van't Hoff equation: $\ln\left(\dfrac{K_2}{K_1}\right) = \dfrac{\Delta H^\circ_{rxn}}{R}\left(\dfrac{1}{T_1} - \dfrac{1}{T_2}\right).$

- Understand and be able to use LeChatelier's principle.

- Know the properties of ideal solutions ($\Delta H_{mix} = 0$, $\Delta V_{mix} = 0$, Raoult's Law). Understand the physical reason for deviations from ideal solution behavior.

- Be able to calculate the Gibbs free energy of mixing, for ideal and non-ideal solutions, starting from pure substances: $\Delta G_{mix} = nRT\displaystyle\sum_i X_i \ln a_i.$

- Understand that for ideal systems the Gibbs free energy of mixing is entirely due to entropy.

- Be able to calculate the composition of the vapor phase in equilibrium with a solution. Know that for equilibrium with ideal solutions the vapor phase is always enriched in the more volatile component.

- Understand and be able to use Henry's Law in terms of both mole fraction and molality.

- Know how to convert between mole fraction and molality. Know that for aqueous solutions molar concentration is approximately equal to molality.

- Know and be able to use the definitions of activity and, when appropriate, activity coefficients for the various common standard states: pure solid, pure liquid, ideal gas, solvent, solute using the mole fraction scale, and solute using the molal scale.

- Understand that the Gibbs-Duhem equation may be used to calculate the activity of one component from the activities of other components.

- Understand that thermodynamic properties can not be determined for individual ions and that, by convention, ΔH°_f, ΔG°_f, and $\bar{S}^\circ$ are set to zero for the hydrogen ion.

- Know how to use the mean ionic activity coefficient in equilibrium expressions, how to calculate the ionic strength of an electrolyte solution, and how to use the Debye-Huckel equation to calculate mean ionic activity coefficients. If needed, the following equations will be provided:

$$a_\pm = \gamma_\pm m_\pm \qquad I = \frac{m}{2}\sum_i \nu_i Z_i^2 \qquad \ln\gamma_\pm = -\frac{1.173\,|Z_+ Z_-|\sqrt{I}}{1+\sqrt{I}}$$

- Know and be able to use the Nernst equation and the relationship between cell potential and free energy of reaction: $E = E^\circ - \dfrac{RT}{\nu F}\ln Q$ and $\Delta G^\circ_{rxn} = -\nu FE$. This includes knowing how to determine the number of moles of electrons transferred, ν.