Physics 3410
Exam 2 Outline
Spring 2016

Chapter 3

Thermal Equilibrium
- What are two conditions that determine if two systems are in thermal equilibrium with each other?
- What is the definition of temperature in terms of entropy?
- Understand the derivation we did with $\frac{\partial S}{\partial U}$, etc.
- In the expression $\left(\frac{\partial x}{\partial y}\right)_z$, what does the z signify?
- By looking at the entropy function of a system, how can we determine whether it satisfies the equipartition theorem, and determine its number of degrees of freedom?

Heat and Entropy
- What is the relationship between heat and entropy?
- What is the only way that the entropy of a system can decrease?
- If a system has constant heat capacity and changes temperature, what is the change in its entropy?
- What does the Third Law of Thermodynamics say?
- What does the Third Law imply about heat capacity? About the number of degress per freedom in a material?

Other Types of Equilibrium
- How do we define pressure in terms of entropy?
- Give the thermodynamic identity relating changes in U, S, V, and N.
- Use the thermodynamic identity to derive various partial derivatives.

Chemical Potential
- Define the chemical potential.
- During diffusive equilibrium, do particles flow to high or low μ?
- How much energy do I need to remove from a system if I add a particle and keep the entropy the same?

Negative Temperature
- What does it mean for a system to have negative temperature?
- What happens when a system with negative temperature is in contact with a system with positive temperature?
- Give an example of a system with negative temperature.
- What is necessary for a system to have negative temperature?
- What is β, and how does heat flow between systems with different β?

Negative Heat Capacity
- What does it mean for a system to have negative heat capacity (a "miserly" system)?
- By looking at an entropy-vs-energy graph, how can you identify such a system?
- What happens when energy flows into such a system? What happens if you place one next to a "normal" system at a lower temperature?
- Give an example of a system like this, and explain why it has negative heat capacity.

Chapter 4

PV Diagrams
- What do states and processes look like on a PV diagram?
- How can you calculate the work done by a process shown on a PV diagram?
- How can you determine the direction of work (in or out of the system)?
- How can you calculate the change in internal energy?
- How can you calculate the flow of heat into or out of a gas?

Isobaric processes
- What does isobaric mean?
- What does an isobaric process look like on a PV diagram?
- How would you implement an isobaric expansion in real life?

Constant-Volume Process
- How would you implement a constant-volume process physically?
- What would one look on a PV diagram?

Isothermal Process
- What does an isothermal process look like in a PV diagram?
- How would you implement it physically?
- What's the relationship between heat and work in an isothermal process?

Thermal Reservoir
- Define a thermal reservoir
- Give some examples of one
- What is the heat capacity of a thermal reservoir?

Adiabatic Process
- What does it mean for a process to be adiabatic?
- How would you implement an adiabatic process?
- Does insulation make a process more or less adiabatic?
- What is an isentropic process?
- What is the adiabatic exponent?
- What is the formula for an adiabatic process of an ideal gas on a PV diagram?

Heat Engines
- What is a heat engine? Some examples?
- A heat engine must operate in a cycle. What does this mean?
- Draw a diagram showing how energy flows in a heat engine.
- What is a perpetual motion machine of the 2nd kind? 1st kind?
- What is the efficiency of a heat engine in terms of the energy involved?
- What is the maximum efficiency of a heat engine, given the temperature extremes it operates between?
- On a PV diagram, what direction does a heat engine cycle run? (Clockwise or counterclockwise?) Why?

Carnot Cycle
- What is a Carnot cycle?
- How does it work?
- What is its efficiency?
- Why don't we use Carnot engines everywhere?

Refrigerator

- What is a refrigerator?
- What is a "perfect" refrigerator? Why doesn't it work?
- Draw a diagram showing how energy flows in a refrigerator.
- What is the coefficient of performance (C.O.P.) of a refrigerator?
- What is the maximum C.O.P.? What type of fridge reaches this C.O.P.?

Chapter 5

Enthalpy
- What two types of energy does enthalpy H take into account?
- What is the equation for H?
- At constant pressure, what does the change in enthalpy equal?
- What is the relationship between heat capacity and enthalpy?
- What is the enthalpy of formation?
- How can you use enthalpy to determine if a chemical reaction is exothermic or endothermic? (And what do those words mean, anyway?)

Free Energy
- Define free energy.
- What is the difference between Helmholtz and Gibbs free energy?
- If a system with free energy X (i.e. F or G) is created from scratch, what does X represent?
- If a system with free energy X is completely destroyed, what does X represent?
- At constant temperature, what does the change in Helmholtz free energy represent?
- At constant temperature and pressure, what does the change in Gibbs free energy represent?
- Understand how the four thermodynamic identities describe the different energy flows in a chemical process at constant temperature and pressure.

Thermodynamic Identities
- What are thermodynamic potentials?
- What are natural variables?
- What are the natural variables for each thermodynamic potential?
- Write the thermodynamic identity for each thermodynamic potential.
- What are conjugate variables? Name three pairs of conjugate variables.

Partial Derivatives
- Understand how to interpret and work with partial derivatives. For example, the coefficient of volume expansion or the coefficient of isothermal compressibility.
- Know how to derive partial derivatives involving the thermodynamic potentials, like $\left(\frac{\partial G}{\partial P}\right)_{T,N}$
- Know how to recognize and complete a Maxwell equation given one of the two derivatives.

Extensive and Intensive Variables
- What is an extensive quantity? Give some examples.
- What is an intensive quantity? Give some examples.
- What is a homogeneous function of 1st order? of 0th order? Give a thermodynamic example of each (besides U or T, we already did those).
- Why does $U = TS - PV + \mu N$? What are the related equations for F, G, and H?
- State the Gibbs-Duhem relation, and derive some derivatives from it.

Equilibrium and Free Energy
- What happens to the Helmholtz free energy at constant V, T, and N, as a system approaches equilibrium? Why?
- Under what conditions (i.e. what must be held constant) for the same thing to be true for the Gibbs free

energy?

Gibbs Free Energy and Phase Changes

- If I have a material with two or more different phases, how can I tell which one is more "stable" or prevalent?
- At STP, graphite is more stable than diamond. What must I do to make diamond the stable phase?
- Know how to calculate (or estimate) the phase transition temperature/pressure between two phases, given their Gibbs free energies, and their entropies and volumes per mole

Phase Diagram of Water

- Sketch the phase diagram of water on a PT graph.
- Where and what is the triple point of water?
- What is the critical point on the water phase diagram?
- How can I find the melting point and boiling point of water for a given atmospheric pressure?
- How can water exist as vapor in the air below 100°C?
- What determines the locations of the various phase boundary lines?

Clausius-Clapeyron Relation

- What determines the slope of a phase boundary line in a P–T graph?
- What is the formula for the Clausius Clapeyron relation?
- What does it tell us about phase boundaries?
- What happens to the entropy of a material as it goes from solid to liquid, or liquid to gas?
- What does the negative slope of the solid/liquid phase boundary of water tell us about the physical properties of water?
- Calculate the slope of a phase boundary, given the latent heat, transition temperature, and the densities of the two phases at that temperature.

van der Waals model

- What does the van der Waals model take into account that the ideal gas model does not?
- In the van der Waals equation, what do a and b signify?
- The van der Waals model is able to describe a liquid-gas phase transition. Explain how that works. On a graph of $P(V)$, identify the gas phase, the liquid phase, and the unstable region.
- What is a supercritical fluid? Where can it be found on a phase diagram? Where can it be found in nature?