# Study Guide Pchem Survey Class

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# BIOC 465-01\_(1473) - undergraduates BIOC 665-01 (1475) - graduate

# 1<sup>st</sup> class – introduction

- What is the definition of thermodynamics?
- What are the units of pressure?
- How is pressure defined in mechanics?
- What is an open and closed system?
- What is an extensive and intensive property?
- What is the most basic way to define temperature?
- What is the 0<sup>th</sup> law of thermodynamics?
- What is Boyles experiment?
- How to measure temperature?
- How does a gas thermometer look like?

# Class 2 – gas laws

- What is an open, closed, isolated system?
- Is North Dakota an open, closed, isolated system?
- Is pressure an extensive or intensive property?
- How is intensive/extensive defined in thermodynamics?
- What do you need to do to earn an "A" in this class?
- What experiment would proof Boyle's law?
- How is an ideal gas defined?
- Show that Boyle's low obeys the 0<sup>th</sup> law of thermodynamics.
- What gas law can you see when a hot air balloon is launched? <u>http://en.wikipedia.org/wiki/Hot\_air\_balloon</u> How does the thing work anyhow – hot air balloon?
- Rewrite the general ideal gas equation to identify Boyle's law, Charles law, and Gay-Lussac.
- What is Avogadro's law?
- An ideal gas obeys the general ideal gas equation for any pressure and any temperature. Correct?
- A none-ideal gas approximately obeys the general ideal gas equation for low/high (?) temperatures. Why?

# Class 3 – gas laws applications / gas mixtures / real gases

- Applications / examples of gas laws
- What is Dalton's law? Name an example of its application.

- What assumptions for ideal gases are not included in the van der Waals equation?
- Why are repulsive interactions ignored in the van der Waals equation?
- What are the improvements of the van der Waals equation as compared with the general ideal gas equation?
- Sketch the surface of allowed states for an ideal gas in a P,V, T diagram.
- What are isotherms?
- What are isobars?

#### Class 4 – phase diagrams, kinetic theory of gases - pressure

- How can you determine if a gas obeys the ideal gas equation?
- Look at Fig. 2.6 in your textbook (generic PV phase diagram). What happens if you go along the V axis through this diagram? Discuss the figure.
- What happens when you approach the critical point?
- The density of liquid and gaseous water could be the same. Correct? Wrong? Why?
- Combining thermodynamics and statistic results in what discipline?
- What are macroscopic and microscopic properties? Name examples.
- What is the main purpose of the kinetic theory of gases?
- When using a statistical model the pressure of an ideal gas is proportional to what?

#### Class 5 – kinetic theory of gases – temperature / distribution functions

- Ne, Ar, Xr at the same temperature have the same averaged kinetic energy? Correct? Wrong? Why?
- Boltzmann invented a special steel bolt used during World War II in submarines. Correct? Wrong?
- The averaged kinetic energy and temperature for an ideal gas are proportional. Correct? Wrong?
- Speed distributions are just some kind of hypothetical thing wired physical chemists use they don't really exist. Correct? Wrong?
- How can you measure the speed of gaseous species?
- What is the concept of distribution functions?
- Plot the one dimensional velocity distribution of a gas.
- Speed and velocity distributions look the same. Correct? Wrong?
- For a given gas, plot qualitatively the speed distribution as a function of temperature.
- For a given temperature, plot qualitatively the speed distribution as a function of molecular mass.
- The mean free path is the average time between collisions. Correct? Wrong?

#### **Class 6 – examples, summary**

- He released in a lab on earth disappears into deep space. Correct? Wrong? Why?
- What happens with the mean free path if the size of the scattered molecules increases?
- The mean free path can vary between micrometers and kilometers. Correct? Wrong? Why?
- He atoms are always faster than Ne atoms. Correct? Wrong? Why?
- I did write my own class summary. Correct? Wrong? Why?

## Class 7 – 1<sup>st</sup> law

- What is the most general form of the 1<sup>st</sup> law of thermodynamics?
- What is a more practical version of it?

- Explain what U, w, and q are.
- Work done by the system on the surroundings would be positive. Correct/wrong?
- Heat absorbed by the surrounding from the system would be negative. Correct/wrong?
- Define what a reversible and irreversible process is.
- Why does the product of pressure and volume or the integral over pressure and volume do not lead to the same result?
- Is heat a state function?
- What is a state function?
- What is pressure work?
- Calculate the maximum isothermal expansion work of an ideal gas.

# Class 8 – 1<sup>st</sup> law examples

- Go through your notes again and try to understand the examples.
- Consider a gas expansion/compression. When is the temperature change positive or negative?
- How the realize an isothermal expansion? What would be the condition required?
- How is enthalpy defined in thermodynamics?
- Calculate the heat at constant volume or constant pressure.
- What is a cyclic process?
- What is the difference between internal energy and enthalpy?
- dU and dH are always identically? Correct/wrong? Why?

## **Class 9 – heat capacities**

- What is the definition of a heat capacity?
- What is the heat at constant volume?
- What is the heat at constant pressure?
- dU=?
- C<sub>p</sub>dT=?
- What is U+PV?
- PV is also called what?
- How to measure heat capacities?
- $C_p > C_v$ ? Correct? Wrong? Why?
- What is gamma in thermodynamics?
- Name a few energy storage mechanisms? How does a molecule store energy?
- Is the Boltzmann distribution good for something?
- What has a larger heat capacity He or butane?
- Would you put an ice cube in tea or soup? Why?

## Class 10 – adiabatic vs. isothermal gas expansions

- How large is the internal energy change for an adiabatic expansion?
- What is an adiabatic equation?
- Why may you see fog formation when opening a Champagne bottle?
- Name applications of adiabatic gas expansions.
- Why is the work smaller in an adiabatic expansion than in an isothermal expansion?
- What do you need to do in an expansion to keep the temperature constant?

Typically I skip this for exams:

- What is the standard molar enthalpy of formation?
- What is the standard enthalpy of reaction?
- Hess was one of these nasty German Nazis. Correct? Wrong?
- Another Hess came up with a well-known law in thermodynamics. For what is that one used?

#### **Class 11 – temperature dependence of enthalpies**

- What is an enthalpy again?
- How to describe the temperature dependence of enthalpies?
- Who was Gustav Kirchhoff? What did he come up with?

#### **Class 12 – start with Entropy**

- Who is Mr. Entropy?
- What are the 0<sup>th</sup> and 1<sup>st</sup> laws of thermodynamics?
- Would a water drop in your hands spontaneously forming an ice cube violate the 1<sup>st</sup> law?
- What definition of the entropy do you know?
- What is a micro state?
- What is a thermodynamic probability?
- What is Boltzmann's formula?
- Calculate the entropy change for an isothermal expansion of an ideal gas.
- How large is the probability for a spontaneous reversal of the gas expansion?
- Is S a state function?
- What is a state function?
- Is S extensive or intensive?

## **Class 13/14 – thermodynamic definition of the Entropy**

- What is the more practical or thermodynamic definition of the entropy?
- Why is a reversible pathway required to calculate the entropy?
- Provide at least one version of the 2<sup>nd</sup> law of thermodynamics?
- Calculate the entropy for a reversible or irreversible process.
- Prove that heat cannot flow from a colder to a hotter body.
- What is the efficiency of a Carnot engine?
- What is the temperature dependence of the entropy?

# Class 15 – 3<sup>rd</sup> law of thermodynamics

- State the 3<sup>rd</sup> law of thermodynamics.
- What is the entropy at zero Kelvin?
- How many laws of thermodynamics do we have?
- Is an entropy change associated with a phase change? If yes, how to calculate it?
- List the properties of the entropy.
- Write a list of all laws in thermodynamics that fits on the backside of a business card.
- There are at least 4 common versions of the 2<sup>nd</sup> law. How do these look like?
- What is the reference point of the entropy at zero Kelvin?
- Why can we measure absolute entropies but not absolute enthalpies?
- Familiarize yourself with the properties of the entropy. The power point includes a list.

• Why can one not reach exactly zero Kelvin?

## Class 16 – Gibbs energy

- What is the definition of the Gibbs energy?
- What is the Gibbs energy change for a spontaneous process?
- What is the equilibrium condition when considering the Gibbs energy?
- What is the difference between the Gibbs energy and the Helmholtz energy?
- What is sometimes called the "free energy"?
- Can you synthesize diamonds from graphite at room temperature and ambient pressure? Yes/No? Why?
- Calculate G for the reaction A  $\rightarrow$  B + C.
- Name examples or applications where you would need to consider the Gibbs or Helmholtz energy?
- What is the definition of the Helmholtz energy?
- Entropy change for a spontaneous process is positive. Yes/No? Why?
- If this is correct why is the Gibbs energy change for a spontaneous process negative?
- What is the maximum non-expansion work? How to calculate it?
- Just increase the temperature and you can synthesize diamonds. Yes/No? Why?

# Class 17-19 – Phase equilibria, chemical potential

- What is the definition of the chemical potential?
- How would you explain to your younger cousin what the chemical potential is?
- What is the chemical potential for a pure one component system?
- What is the rule for a stable phase using the chemical potential?
- Recall that Gibbs energy follows for 2<sup>nd</sup> law and the chemical potential is closely related to Gibbs energy. What are the connections here?
- How is the thermal, mechanical, and material equilibrium defined? In other words, what is the condition for a materials equilibrium?
- What is the analogy between a mechanical system and thermodynamics in regard of the chemical potential?
- Where is the rule "the stable phase has the smallest chemical potential" coming from?
- Comment on "the chemical potential is a partial molar quantity". What is the concept/idea?
- What is the functional form of the chemical potential for a gas mixture?
- Is mixing a spontaneous process?
- What is the driving force of forming a gas mixture?
- Draw qualitatively the Gibbs energy change when forming a binary gas mixture.
- How does the mixing entropy change when forming a binary mixture?
- How can you decide whether a solution or a physical mixture is formed?
- Name an application of the Clausius-Clapeyron equation.
- You get a NSF proposal to review from a colleague showing preliminary data of a new synthesis of a new bombastic compound (super strong). He claims that the superior tensile strength is related to a fipple point (as he calls it) in the phase diagram of this one pot (one component) compound. "Fipple point alloys", where 4 different phases are in equilibrium, develops fast into a new NSF buzzword since the PI has a face book page. (He got quickly 10 invited talks ...) Would you recommend the \$650,000 award? (In 2016 quadruple point materials have indeed been proposed theoretically.)
- Plot the chemical potential as a function of pressure for solids, liquids, and gases.

- Is the Gibbs energy typically increasing or decreasing with pressure? Why?
- If you increase the pressure what happens with the boiling and melting temperatures? Why?
- Is heat put in a system always increases the temperature linearly? Yes/No? Why?
- Can you freeze water without changing the temperature? Yes/No? How?
- Pressure cooker. How does it work? What is the idea?
- Why are lakes freezing from the top?
- Ice skating on CO2. Is that possible?
- Dry ice. What is that?

#### **Class 20 – Solutions**

- What is a homogeneous mixture?
- What is a partial molar quantity?
- If you mix two liquid components together what is the final volume?
- Write down the total differential of the Gibbs energy, considering G = G(T, P, n<sub>i</sub>)
- What is the definition of the chemical potential?
- How would you explain to your younger cousin what the chemical potential is?
- What is the chemical potential for a pure one component system?
- What is the rule for a stable phase using the chemical potential?
- Recall that Gibbs energy follows for 2<sup>nd</sup> law and the chemical potential is closely related to Gibbs energy. What are the connections here?
- What has the partial molar volume to do with the chemical potential?
- Why is this idiotic study guide in the PowerPoints?

### Class 21 & 22 – Rault's law

- How can you verify that a liquid solution behaves ideally?
- Compare Raoult's and Dalton's laws.
- What happens if you open a pop can?
- You have a 60 liters volume gas tank at 50 bar pressure. How long can you stay at 50 meters under water? Lung volume may be 5 liters and it will be exchanged every 10 seconds.
- At alpha century they don't have hemoglobin. How could that work? The natives there also breeze oxygen to keep their exoskeleton functioning. By the way, the *nabradi –gung* (pronounced λφιυτψγφ) look like lobster. NASA is likely still working on a verification of this hypothesis.
- What is the idea of a distillation?
- Pchem is hard, but you get a free trip around the Sun (once a year). Correct? Yes/No?
- What is the definition of the chemical potential?
- How would you explain to your younger cousin what the chemical potential is?
- What is the chemical potential for a pure one component system?
- Recall that Gibbs energy follows for 2<sup>nd</sup> law and the chemical potential is closely related to Gibbs energy. What are the connections here?
- What has the partial molar volume to do with the chemical potential?
- Rault's law is just empiric it has no real theoretical foundation. Yes/No? Why?

#### Class 23 – Vapor pressure

- Colligative is a new tooth paste brand or something. Yes/No?
- Write the chemical potential for a solution?

- Vapor pressure lowering is basically the same as Rault's law?
- Rault's law is the story about adding partial pressures. Yes/No?
- What is the simplest qualitative model to explain the effect? Is that explanation entirely correct?
- What has vapor pressure to do with entropy?
- What is the thermodynamic definition of a solution?
- Find an interesting problem related to vapor pressure at the internet.

## Class 24 – Boiling point / freezing point

- What is a normal boiling point?
- Is there more than one boiling point? If yes, where would these be?
- Boiling points are freezing points shift in the same direction when a solution is made. Correct/wrong?
- A solution has a greater entropy than the pure solvent? Correct/wrong?
- Vapor pressure lowering is based on intermolecular interactions only, it does not exist for ideal solutions?
- For a spontaneous process such as  $A \rightarrow B$  the chemical potentials are what?
- Name applications for boiling point / freezing point variations in solutions.
- Draw a diagram using the chemical potential to explain how the boiling point / freezing point are affected by the formation of a solution.
- You build a time machine and go back in time. While wondering around 10,000 years ago you met a cave man hanging out in front of this home. At that point you realize that you forgot your watch at home and ask the fellow "what time is it" since you won't like to be late for dinner at home. His responds is "ug-ug-grin-ug ...". He doesn't understand your question and becomes angry at you. Clearly that was a bad question and all your fault or what is going on here?
- Is it called boiling point elevation of depression? Why?
- Why did they use to dump salt on icy roads in the winter?
- After a long day in the lab two hungry graduate students come finally home and start cooking spaghetti. One remembers to put oil and table salt in the water, the other forgot to purchase salt. Who will have dinner ready first? Why? Who may have better tasting spaghetti?

#### **Class 25 – Osmotic pressure**

- Where is the osmotic pressure coming from? What is the mechanism that generated it?
- Name applications which take advantage of the osmotic pressure.
- The osmotic pressure was not important enough to award a Nobel price to the one who described it first. Correct? Wrong?
- Who got the Nobel prize in chemistry in the year when you took this class?
- The osmotic pressure is proportional to what? Assume an ideal solution.
- How is the osmotic pressure described for a real solution? Do an internet/literature search?
- What is the osmotic pressure of typical see water?
- What is a derivation of van't Hoff's equation for the osmotic pressure?
- What is the connection of the osmotic pressure and the chemical potential?
- How to obtain the molar mass from the osmotic pressure?

#### **Class 26 – Equilibrium constant**

- What is the connection of Gibbs energy and the equilibrium constant?
- Extent of a reaction. What is that?

- Write down the equilibrium condition using the Gibbs energy and the "extend of the reaction".
- How can you calculate the pressure dependence of the equilibrium constant?
- What is the effect of entropy on the equilibrium of a chemical reaction?

### Class 27 – van't Hoff etc.

- Find a French speaking fried to find out how to pronounce "le Chatelier" correctly.
- Find an example of that principle from le Chatelier that was not already discussed in class.
- Find a YouTube movie on the subject.
- What is the difference between the van't Hoff equation and le Chatelier?
- In what way can an equilibrium be manipulated?
- Do you know other equations which are similar to the van't Hoff equation for K?