

CHEM 1220 Lecture Notes

OpenStax Chemistry 2e

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COURSE ADMINISTRATIVE DETAILS

- My office hours
- Intro to my research
- Introductory Quiz
- Grading details
 - Exams - 40, Final - 15, Online Homework - 15, Book Homework - 15, Quizzes - 15
 - Online homework
 - Frequent quizzes
- Importance of reading and learning on your own
- Learning resources
 - My Office Hours
 - Tutoring services - <https://www.suu.edu/academicsuccess/tutoring/>
- Show how to access Canvas
 - Calendar, Grades, Modules, etc.
 - Quizzes
 - Textbook
- Introduction to chemistry
 - Ruby fluorescence
 - Levomethamphetamine
 - Rubber band elasticity
 - Structure of the periodic table
 - Salt on ice and purifying hydrogen peroxide

CHAPTER 0

1210 REVIEW

There is a whole semester of material from 1210, and these are only the topics which are *most* important for success in 1220

- Composition of atoms and ions (protons, neutrons and electrons)
- Chemical formulas and names
 - Formulas and molar masses
 - Polyatomic ion names
 - Naming ionic compounds
 - Naming binary molecular compounds
 - Naming acids
- Balancing molecular equations
- Solubility rules
- Fundamentals of acid/base chemistry
- Measurements in chemistry
 - Converting from measurements to moles and back
 - Stoichiometry and predicting amounts
 - Limiting reactants
- Enthalpy of reaction and heat equations
- Lewis structures

CHEM 1210 Review Quiz

CHAPTER 10

LIQUIDS AND SOLIDS

10.1 Intermolecular Forces

- Many physical properties of solids, liquids, and gases can be explained by the strength of attractive forces between particles (Figure 10.5)
- Phase changes happen due to the interplay between kinetic energy and intermolecular forces (Figure 10.2)
- Pressure can also play a role in phase changes, as discussed later
- These *intermolecular forces* come in different varieties
 - Dispersion Forces Non-polar molecules, impacted by polarizability, molecular weight, and surface area
 - * Dominant in non-polar molecules
 - * Created by induced dipoles (Figure 10.6)
 - * Impacted by polarizability (Table 10.1)
 - * Impacted by molecular weight (hydrocarbons from methane to wax)
 - * Impacted by molecule shape (Figure 10.7 compares the boiling points of pentane isomers)
 - Dipole-Dipole Forces
 - * Dominant in polar molecules
 - * Results from attraction between permanent dipoles (Figure 10.9)
 - Hydrogen Bonding
 - * Dominant only in molecules capable of hydrogen bonding
 - * Must contain a hydrogen-donor atom (H attached to N, O, or F)
 - * Must contain a hydrogen-acceptor atom (lone pair of electrons attached to N, O, or F)
 - * Hydrogen bonds are more than just particularly strong dipole-dipole forces. They have strong directionality according to VSEPR
 - * Figures 10.10, 10.14, and other figures on the Internet show water, DNA, and proteins all organized by hydrogen bonds
 - * Figures 10.11 and 10.12 illustrate how much hydrogen bonds exceed dipole-dipole forces in strength

10.2 Properties of Liquids

- Viscosity is a fluid's resistance to flow

- We intuitively know that both water and honey flow...but at very different rates
- Viscosity is proportional to the strength of intermolecular forces (high IF = high viscosity)
- As temperature increases, kinetic energy is able to overcome intermolecular forces and viscosity decreases
- Table 10.2 gives the viscosities of some common substances (note the unusual units!)
- Surface tension is a force which minimizes a fluid's surface area
 - Cohesive vs. adhesive forces
 - Bulk molecules have lower energy than surface molecules due to being *surrounded* by cohesive forces (Figure 10.16)
 - Figure 10.17 illustrates a waterbug supporting itself on water surface tension
 - Surface tension is often in conflict with gravity and other forces, making most liquids rounded but not perfect spheres
 - Surface tension is proportional to intermolecular forces (Table 10.3)
 - Surface tension can be strongly affected by addition of certain solutes, called surfactants
- Capillary action is a force between a fluid and narrow channels or capillaries of solid materials
 - Due to adhesive forces with the solid, liquids will be drawn up (or, less often, pushed down) a capillary
 - Figure 10.19 shows how paper towels are made to maximize capillary action, so they soak up water-based spills
 - The top of the liquid (called the meniscus) will curve differently depending on the relative strength of cohesive and adhesive forces (Figure 10.18)
 - Figure 10.20 shows capillary action in a variety of situations, including capillary repulsion
 - Remember that when measuring volumes, convention is to read the *bottom* of the meniscus regardless of how it curves
 - Don't worry about the formula given here

Quiz 10.1 - Intermolecular Forces and Liquid Properties

Homework 10.1

- 10.11: Predicting trends in boiling points
- 10.21: Identifying intermolecular forces
- 10.25: Affect of temperature on viscosity

10.3 Phase Transitions

- Vaporization and condensation are the transitions between liquid and gas phases
 - The enthalpy of vaporization (ΔH_{vap}) is the energy required to transition from liquid to gas phase
 - Enthalpy of condensation is the opposite $\Delta H_{con} = -\Delta H_{vap}$
 - In a closed volume, these processes will reach a *dynamic equilibrium*
 - The partial pressure of the liquid at this equilibrium state is called its *vapor pressure* (Figure 10.22)
 - Higher intermolecular forces lead to lower vapor pressures
 - Higher temperatures increase the vapor pressure due to increased kinetic energy (Figure 10.23)
- Boiling points
 - Figure 10.24 shows vapor pressure curves and the normal boiling points of several liquids
 - Boiling points generally depend on the pressure (pressure cookers, boiling water to freezing, etc.)
 - The Clausius-Clapeyron equation defines these curves (Note the rearrangements I've made)

$$P = Ae^{-\Delta H_{vap}/RT} \quad \ln P = -\frac{\Delta H_{vap}}{RT} + \ln A \quad \ln \left(\frac{P_2}{P_1} \right) = -\frac{\Delta H_{vap}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$
- Fusion (melting), freezing, sublimation, and deposition all have their enthalpies and transition temperatures
- These enthalpies are state functions, such that $\Delta H_{sub} = \Delta H_{fus} + \Delta H_{vap}$ (Figure 10.28)
- Heating and Cooling curves
 - When heat is added to a system, it will either cause a phase change, or a change in temperature
 - For phase changes, $q = n\Delta H_{change}$
 - For temperature changes, $q = mc\Delta T$, where c is the specific heat for that substance and phase
 - Sometimes ΔH_{change} is given as a -per gram value, and sometimes c is given as a -per mole value, but usually not :(
 - Figure 10.29 shows a typical heating curve (Work example 10.10 in the text)

Quiz 10.2 - Heating Curves

Homework 10.2

- 10.31: Temperature during a phase transition
- 10.39: Definition of normal boiling point
- 10.51: Heating curve problem

10.4 Phase Diagrams

- The stable phase at different temperatures and pressures is best illustrated with a phase diagram (Figures 10.30, 10.31)
- We can tell at a glance what transitions might occur as we increase or decrease either the temperature or pressure
- Note that at some pressures, sublimation may occur instead of fusion
- The triple point is a unique point where liquid, solid, and gas can all exist at equilibrium (contrast with a glass of icy water on a humid day)
- The critical point is where the distinction between liquid and solid phases disappears
- Figure 10.34 shows the phase diagram of CO_2
- Supercritical fluids exhibit some interesting properties, and are often great solvents (Nile Blue Youtube video)
- Critical points vary widely depending on the intermolecular forces, and other factors (Table in text)

Quiz 10.3 - Phase Diagrams

10.5 The Solid State of Matter

- Solids can be divided into *crystalline* and *amorphous* based on their structure at atomic scales
- Figure 10.37 shows the difference generally, Figure 10.38 shows crystalline and amorphous SiO_2
- Amorphous solids will not exhibit a sharp fusion transition temperature, but will instead grow soft and malleable over a temperature range
- Crystalline solids are diverse but always show long-range repeating order in their structure
 - Ionic solids (Figure 10.39) have high melting points, cleave along planes, and conduct electricity only in the liquid phase
 - Metallic solids (Figure 10.40) have mostly high melting points, are malleable and ductile, and conduct electricity and heat well
 - Covalent network solids (Figure 10.41) have very high melting points and are electrical insulators
 - Molecular solids (Figure 10.42) Have low to very low melting points and are electrical insulators
 - Crystalline solid properties are summarized in Table 10.4
- Even crystalline solids do not have perfect structure. Various types of defects are illustrated in Figure 10.45

10.6 Lattice Structures in Crystalline Solids

- The structure of a crystalline solid is represented by a *unit cell*, the smallest repeatable unit of the structure
- Sometimes this microscopic structure is evidently manifested on macroscopic scales, but sometimes it isn't
- Unit cells are defined by lattice points that often lie at the center of certain atoms, and the cell edges often cut atoms in half, quarter, etc.
- Unit cells of metals
 - For metals, we should keep track of the quantity of atoms in a unit cell, the coordination number, and the relationship between the atomic radius and unit cell edge length
 - Simple cubic (Figure 10.49) 1 atom, Coordination=6, $l = 2r$
 - Body-centered cubic (Figure 10.51) 2 atoms, Coordination=8, $l = \frac{4}{\sqrt{3}}r$
 - Face-centered cubic (Figure 10.52) 4 atoms, Coordination=12, $l = \sqrt{8}r$
 - Figure 10.54 shows hexagonal closest packed and cubic closest packed structures
 - Find the radius of a gold atom, which has fcc structure and a density of $19.283\text{g}/\text{cm}^3$ (136pm)
 - Find the density of polonium, which has sc structure and an atomic radius of 140pm ($9.20\text{g}/\text{cm}^3$)
 - Figure 10.56 shows many non-cubic structures which are common as well
- Unit cells of ionic compounds
 - Anions are generally larger than cations, so ionic lattice points are generally the centers of anions
 - Cations occupy holes in the anionic lattice (Figures 10.57 and 10.58)
 - Unit cells of ionic structures share names with the metallic cells but look different because of the cations
 - Simple cubic (Figure 10.59)
 - Face-centered cubic (rock salt structure) (Figure 10.60)
 - Zinc blende (Figure 10.61)
 - Find the ionic bond length for NaCl which has rock salt structure and density of $2.17\text{g}/\text{cm}^3$ ($l = 564\text{pm}$)
- Crystal structure is determined through X-ray crystallography
 - X-rays reflected off a crystal surface can combine destructively or constructively to produce an interference pattern (Figure 10.63)
 - The X-rays will take different pathlengths depending on the angle of the X-ray beam and the crystal lattice constant (Figure 1.64)
 - An experimental setup and actual diffractogram are shown in Figures 10.65 and 10.66
 - We have a powerful X-ray instrument here at SUU

CHAPTER 11

SOLUTIONS AND COLLOIDS

11.1 The Dissolution Process

11.2 Electrolytes

11.3 Solubility

11.4 Colligative Properties

11.5 Colloids

CHAPTER 12

KINETICS

12.1 Chemical Reaction Rates

12.2 Factors Affecting Reaction Rates

12.3 Rate Laws

12.4 Integrated Rate Laws

12.5 Collision Theory

12.6 Reaction Mechanisms

12.7 Catalysis

CHAPTER 13

FUNDAMENTAL EQUILIBRIUM CONCEPTS

- 13.1 Chemical Equilibria**
- 13.2 Equilibrium Constants**
- 13.3 Shifting Equilibria: Le Châtelier's Principle**
- 13.4 Equilibrium Calculations**

CHAPTER 14

ACID-BASE EQUILIBRIA

- 14.1 Brønsted-Lowry Acids and Bases
- 14.2 pH and pOH
- 14.3 Relative Strengths of Acids and Bases
- 14.4 Hydrolysis of Salts
- 14.5 Polyprotic Acids
- 14.6 Buffers
- 14.7 Acid-Base Titrations

CHAPTER 15

EQUILIBRIA OF OTHER REACTION CLASSES

15.1 Precipitation and Dissolution

15.2 Lewis Acids and Bases

15.3 Coupled Equilibria

CHAPTER 16

THERMODYNAMICS

16.1 Spontaneity

16.2 Entropy

16.3 The Second and Third Laws of Thermodynamics

16.4 Free Energy

CHAPTER 17

ELECTROCHEMISTRY

- 17.1 Review of Redox Chemistry**
- 17.2 Galvanic Cells**
- 17.3 Electrode and Cell Potentials**
- 17.4 Potential, Free Energy, and Equilibrium**
- 17.5 Batteries and Fuel Cells**
- 17.6 Corrosion**
- 17.7 Electrolysis**

CHAPTER 21

NUCLEAR CHEMISTRY

- 21.1 Nuclear Structure and Stability**
- 21.2 Nuclear Equations**
- 21.3 Radioactive Decay**
- 21.4 Transmutation and Nuclear Energy**
- 21.5 Uses of Radioisotopes**
- 21.6 Biological Effects of Radiation**

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