Guide to Chapter 10. Liquids and Solids

Answers in red

We will spend three lecture days on this chapter.

Read the introductory paragraph to Chapter 10.

Read Section 10.1 Polar Covalent Bonds and Dipole Moments.
Learning Objective 1: Given the formula of a molecular compound determine if it is polar or non polar covalent.

Learning Objective 2: Know the definition of STP. Know the standard molar volume (22.4 L)

Do Problems 1 - 4 at the end of the section.

Do the following end-of-chapter problems: 22, 30, 36, 38

Read Section 10.2 Intermolecular Forces and Section 10.3 Some Properties of Liquids
Learning Objective 3: Given the formula of a compound, determine the major attractive force. (ionic = ion-ion and ion-dipole) and (molecular and covalent = dipole-dipole, hydrogen bonding, or London dispersion forces.

Learning Objective 4: Given a list of compound formulas rank their attractive forces in order of strength.

Learning Objective 5: Describe the relationship between size and strength of London dispersion forces.

Learning Objective 6: Describe the relationship between size and strength of London dispersion forces.

Do Problems 5 and 6 at the end of Section 10.2.

Do the following end-of-chapter problems: 32, 34, 40

Problem Club Question A. (a) Create a graph (general appearance only) with MM on the x-axis and boiling points on the y-axis for these similar compounds: NH₃, PH₃, AsH₃, and SbH₃ (b) Repeat for CH₄, SiH₄, GeH₄, and SnH₄

Answer: boiling points (°C): (a) NH₃ = -33, PH₃ = -87, AsH₃ = -55, SbH₃ = -17  (b) CH₄ = -164, SiH₄ = -111, GeH₄ = -89, and SnH₄ = -52

Problem Club Question B. Why is iodine a solid?
Answer: very substantial London-dispersion forces due to the large MM

Problem Club Question C. Circle the chemical with the highest melting point:
Answers in red
(a) F₂ or Cl₂  (b) F₂ or FCl  (c) Cl₂ or FCl
(d) NaCl or Cl₂  (e) HF or HBr  (f) CH₃CH₂CH₃ or CH₃CH₂CH₂OH

Problem Club Question D. True or False:
Answers in red
T  F  Covalent bonds are weaker than London-dispersion forces
T  F  Dipole forces are stronger than London-dispersion forces
T  F  Only non-polar molecules have London-dipersion forces
T  F  CaS and KCl have similar MM's, however CaS should have a much larger mp.
T  F  The heat of vaporization increases with MM for the series (BH₂)ₙ
Problem Club Question E. Which exhibits hydrogen bonding in the liquid form? (Central atom underlined where necessary)

(a) \( \text{H}_2\text{O} \)  
(b) HI  
(c) HBr  
(d) CH\(_3\)OH  
(e) N(CH\(_3\))\(_3\)  
(f) CH\(_3\)OCH\(_3\)  
(g) HCHO  
(h) CH\(_3\)COOH (shown at right)

Read Section 10.4 Phase Changes.

Learning Objective 7: Given a set of compounds, predict their relative orders of boiling point, melting point, \( \Delta H_{\text{vap}} \), or vapor pressure.

Learning Objective 8: Know the physical properties of liquids in terms of their

- a. vapor pressure
- b. evaporation/condensation
- c. normal boiling point
- d. sublimation
- e. surface tension
- f. viscosity
- g. cohesive, adhesive forces
- h. melting freezing

Learning Objective 9: Explain how each of the following parameters affect the rate of evaporation of a liquid.

- a. intermolecular forces
- b. temperature
- c. surface area

Do Problems 7 and 8 at the end of the section.

Do the following end-of-chapter problems: 42, 44, 46, 48, 50, 52

Problem Club Question F. (ACS-Style) Answer: C

Problem Club Question G. (ACS-Style) Answer: C

Read Section 10.5. Evaporation, Vapor pressure and Boiling Point. Read this section for qualitative understanding. We will not use the Clausius-Clapeyron Equation, but will spend time with Figures 10.12 and 10.13.

Learning Objective 10: Explain how the pressure above a liquid affects the bp of a liquid.

Learning Objective 11: Explain the relationship between the vapor pressure of a liquid and the temperature.

Learning Objective 12: What is the sign of the amount of heat energy, \( q \), needed for evaporation/condensation and melting/freezing?

Learning Objective 13: Write simple chemical equations showing the "equilibrium" occurring during a change of state.

Learning Objective 14: Phase change calculations:

- a. Given the amount of a substance and its \( \Delta H_{\text{fus}} \) determine the quantity of heat, \( q \), needed to melt the solid or freeze the liquid. Watch the sign of this determined amount of heat energy!

- b. Given the amount of a substance and its \( \Delta H_{\text{vap}} \), determine the quantity of heat, \( q \), needed to boil the liquid or condense the gas. Pay attention to the sign of this determined amount of heat energy.

- c. Sketch a heating or cooling curve showing the plot of temperature vs. \( q \) for a given substance from the solid state to the gas state or from gas to solid. You will be given the bp and mp in order to do this.

Problem Club Question H. How much heat is imparted to your hand when you hold it in steam at 100\(^\circ\)C and 3.0 g of steam condenses to liquid water at 100\(^\circ\)C? \( \Delta H_{\text{vap}} = +40.7 \text{ kJ/mol} \)

Answer: 6.8 kJ

Problem Club Question I. How much heat is taken from your tongue when you melt a 10-g ice cube at 0\(^\circ\)C to form water at 0\(^\circ\)C? \( \Delta H_{\text{fus}} = +6.0 \text{ kJ/mol} \)

Dr. Mattson, General Chemistry, Chm 203, Guide to Chapter 10. Liquids and Solids
Problem Club Question J. Ethanol has a normal boiling point that is 80 °C. Plot the equilibrium vapor pressure for ethanol (y-axis) against the temperature (x-axis)

Answer: Should appear to the left of the line for water.

Problem Club Question K. How much heat it would take to vaporize 250 mL of water at 19 °C to steam at 100 °C? (You will need to look up a few constants from the textbook.)

Answer: +650 kJ

Problem Club Question L. (ACS-Style) Answer: A

Problem Club Question M. (ACS-Style) Answer: C

Problem Club Question N. (ACS-Style) Answer: A

Problem Club Question O. (ACS-Style) Answer: A

Problem Club Question P. (ACS-Style) Answer: D

Problem Club Question Q. (ACS-Style) Answer: A

Problem Club Question R. (ACS-Style) Answer: D

Read Section 10.6. Kinds of Solids

Learning Objective 15: Given the formula of a compound, predict the type of solid it will form. The possible types of solids include network covalent, ionic, molecular, or metallic.

Learning Objective 16: Given the physical properties of an unknown solid, predict the type of solid.

Do the following end-of-chapter problems: 66

Problem Club Question S. Carbon dioxide crystallizes in one of the cubic cells we have studied. There are four CO$_2$ molecules per unit cell. (a) What unit cell is used by CO$_2$? (b) How many oxygen atoms are there per unit cell?

Answer: (a) fcc  (b) eight

Skip Section 10.7.

Read Section 10.8. Unit Cells and the Packing of Spheres in Crystalline Solids and 10.9 Structures of Some Ionic Solids

Learning Objective 17: Given a sketch crystalline unit cell, determine the number of atoms or ions that are present in the unit cell.

Learning Objective 18: Given a sketch crystalline unit cell, determine the number of formula units within the unit cell and the empirical formula of the compound.

Do Problems 11 – 13 at the end of Section 10.8 and Problems 15 and 16 at the end of Section 10.9.

Do the following end-of-chapter problems: 24, 25, 82, 84, 86, 90, 92

Problem Club Question T. Polonium is the only metal known to crystallize in the simple cubic cell arrangement. How many Po atoms are there per unit cell?

Answer: one

Problem Club Question U. What is the volume of a fcc unit cell in which the atoms have a radius of 1.49 x $10^{-8}$ cm? Express this value in pm$^3$

Answer: 7.49 x $10^{-23}$ cm$^3$ or (b) 7.49 x $10^7$ pm$^3$
Problem Club Question V. Refer to the volume you calculated for the fcc unit cell in the previous problem. (a) How many atoms are there per unit cell for the fcc unit cell? (b) If these were gold atoms, what is the mass of these atoms? (You need to use Avogadro’s number, \(6.02 \times 10^{23}\)) (c) What is the formula for density? (d) What is the density of this substance?

Answer: (a) four  (b) \(1.31 \times 10^{-21}\) g  (c) density \(= m/V\)  (d) 17.5 g/cm\(^3\)

Problem Club Question W. A crystalline compound contains \(X\) anions and \(Y\) cations in a cubic lattice. If each unit cell contains \(X\) anions at the corners and at the face centers and \(Y\) cations at the body center, what is the formula of the compound?

Answer: \(YX_4\)

Problem Club Question X. (ACS-Style) Answer: C

Problem Club Question Y. (ACS-Style) Answer: B

Problem Club Question Z. (ACS-Style) Answer: C

Problem Club Question AA. (ACS-Style) Answer: C

Read Section 10.10. Structures of Some Covalent Network Solids.

Problem Club Question BB. (ACS-Style) Answer: A

Read Section 10.11 Phase Diagrams.

Learning Objective 19: Given a phase diagram, locate or define the following terms with an "equilibrium equation:

- a. condensation
- b. evaporation
- c. sublimation
- d. super cooled liquid
- e. triple point
- f. normal bp and freezing point
- g. critical point
- h. equilibrium
- i. critical temperature, critical pressure

Learning Objective 20: Identify the parts of a given phase diagram: melting curve, vapor curve, sublimation curve, triple point, and critical point, etc.

Learning Objective 21: Given a phase diagram, determine the phase (s, l, g, etc.) at a given temperature and pressure.

Learning Objective 22: At a given pressure, determine the changes of phase that occur when the temperature is changed.

Learning Objective 23: At a given temperature, determine the changes of phase that occur when the pressure is changed.

Learning Objective 24: Given information such as the triple point, normal bp and normal mp, qualitatively construct a rough phase diagram and answer question concerning the substance.

Do Problems 17 and 18 at the end of the section.

Do the following end-of-chapter problems: 26

Problem Club Question CC. Refer to the phase diagram for CO\(_2\) discussed in class. Sketch it and label all parts; (b) What is the phase of CO\(_2\) at 0\(^\circ\)C and 1 atm pressure? (c) Referring to the conditions in (b), would it be possible to change phases without changing temperature? If so, what phase change would this be? (d) Suppose your tank of CO\(_2\) is stored in a room that is at 100\(^\circ\)F. Is CO\(_2\) a permanent or condensable gas? (e) The blade of an ice skate causes a huge increase in pressure to the ice as the blade passes overhead. What occurs in terms of the phase diagram for water? (f) What phase of H\(_2\)O is present at 800 mmHg and -20 \(^\circ\)C? What phase transition occurs (if any) when the H\(_2\)O is warmed to 50\(^\circ\)C? What would have happened if the pressure were decreased to 700 mmHg instead of increasing the temperature?
Answer: (b) gas  (c) Yes, increasing the pressure to form a liquid  (d) permanent gas  (e) water melts under tremendous pressure  (f) solid, melts, nothing.

Problem Club Question DD. (ACS-Style) Answer: D

Problem Club Question EE. (ACS-Style) Answer: B

Problem Club Question FF. (ACS-Style) Answer: B

Problem Club Question GG. (ACS-Style) Answer: C

Problem Club Question HH. (ACS-Style) Answer: C