Week 12 KEY

Conceptual Questions

1. In the phase diagram for water, why does the melting point curve have a negative slope?

Because ice is less dense than water.

2. Is the boiling point raised or lowered at higher elevations? Why?

The boiling point is LOWER at higher elevations because the external pressure is less, therefore the vapor pressure reaches the external pressure at a lower temperature.

3. The boiling point of butane (lighter fluid) is 30.2°F. Why is it a liquid in lighters at room temp?

If you exposed it to atmospheric pressure it would spontaneous evaporate, but it is kept under pressure inside lighters, so it remains a liquid (albeit an extremely volatile one) inside the lighter.

4. In the following titrations, would a reaction occur? If so, what would you expect the pH to be at the equivalence point? (<7, =7, >7)
   a. Sodium acetate titrated with HCl – Acetate converted to acetic acid, pH < 7 at eq. point
   b. Acetic acid titrated with HBr – Weak acid + strong acid = no reaction
   c. $HClO_4$ titrated with KOH – Strong acid and strong base, pH = 7 at eq. point
5. Why is Cl_2 a gas at room temperature, Br_2 a liquid, and I_2 a solid?

These are all non-polar molecules, but there are still London dispersion forces between the molecules. The larger the molecule, the more intermolecular forces, which raises the boiling point. bP - $I_2 > Br_2 > Cl_2$

6. How many atoms occupy the unit cell of a simple cubic, body-centered cubic, and face-centered cubic structure?

Simple cubic = 1
Face-centered cubic = 4
Body-centered cubic = 2

Chapter 10 Questions

1. How much heat is required to change 0.50 mol of ice at -10.0 C into 0.5 mol of steam at 120°C?

$$q_{H_2O(s),\,-10°C \to 0°C} = 0.5\,mol\left(\frac{18.0169\,g}{mol}\right)\left(\frac{2.03\,J}{g\,°C}\right)(0 - -10°C)$$

$= 182.86\,J$ to heat ice from -10°C to 0°C

$$q_{fusion} = 0.5\,mol\left(\frac{6010\,J}{mol}\right) = 3010\,J$$ to melt ice to water

$$q_{H_2O(l),\,0°C \to 100°C} = 0.5\,mol\left(\frac{18.0169\,g}{mol}\right)\left(\frac{4.18\,J}{g\,°C}\right)(100°C - 0°C)$$

$= 3765.3\,J$ to heat water to 100°C

$$q_{vaporization} = 0.5\,mol\left(\frac{40790\,J}{mol}\right) = 20395\,J$$ to turn water to steam

$$q_{H_2O(g),\,100°C \to 120°C} = 0.5\,mol\left(\frac{18.0169\,g}{mol}\right)\left(\frac{1.99\,J}{g\,°C}\right)(120°C - 100°C)$$

$= 358.52\,J$ to heat steam to 120°C

$$q_{TOTAL} = 27.7\,kJ$$

2. An ice cube at 0°C weighing 100 g is dropped into 1 kg of water at 20°C. Does all of the ice melt? If not, how much of it remains? **What is the final temperature?**

*ICE will gain heat
*water will lose heat

$$q_{gained} = -q_{lost}$$

heat lost by water:

$$q_{H_2O(l),\,20°C \to T_f} = 1000g\left(4.18\tfrac{J}{g°C}\right)(T_f - 20°C)$$
$$= 4180\tfrac{J}{°C}T_f - 83600J = q_{lost}$$

heat gained by ice:

$$q_{fusion,\,H_2O(s),\,0°C \to T_f} = 100g\left(\tfrac{mol}{18.016g}\right)\left(6010\tfrac{J}{mol}\right) + 100g\left(4.18\tfrac{J}{g°C}\right)(T_f - 0°C)$$
$$= 33359.24J + 4180\tfrac{J}{°C}T_f = q_{gained}$$

$$33359.24J + 4180\tfrac{J}{°C}T_f = -4180\tfrac{J}{°C}T_f + 83600J$$
$$4598T_f = 50241\,J/°C$$

$\therefore T_f = 10.93°C$, all ice melted

a. Now consider 10 ice cubes at 0°C, each weighing 100 g are dropped into 1 kg of water at 20°C. **Does all of the ice melt? If not, how much of it remains? What is the final temperature?**

1a. ICE = 10 × 100g = 1000g
WATER = 1000g

if we assume the same procedure as before...

q_{lost} (by water) = $4180 \frac{J}{°C} T_f - 83600 J$

q_{gained} (by ice) = $333592 J + 4180 \frac{J}{°C} T_f$

$q_{gained} = -q_{lost}$

$33359.2 J + \cancel{4180 \frac{J}{°C}} T_f = -\cancel{4180 \frac{J}{°C}} T_f + 83600 J$

$333592 J \neq 83600 J$

∴ these are clearly not equal. T_f drops out, telling us $T_f = 0°C$.

Since $q_{lost} < q_{gained}$, this means not all of the ice melts. (i.e. there is not enough heat in the water to melt 1000g of ice)

q_{lost} (WATER) = $-83600 J$

∴ 83600J is gained by the ice

AMOUNT OF ICE MELTED

$83600 J = m_{ICE} \left(\frac{mol}{18.016 g}\right)\left(6010 \frac{J}{mol}\right)$

∴ m_{ICE} (melted) = 250.6 g

∴ m_{ICE} (remaining) = 749.4 g

3. Rank the following in order of increasing polarizability and predict the order of their boiling points:
   a. $F_2 < CH_4 < C_2H_4, < C_2H_5OH < CH_2CH_2CH_2OH$ higher bP == higher polarizability
   b. $CH_4 < CH_3CH(CH_3)_2 < CH_3CH_2CH_2CH_3$
4. List the types of intermolecular forces that exist between molecules in each of the following species:
   a. CF_2H_2 – LDF, dipole-dipole
   b. FCN – LDF, dipole-dipole
   c. CH_3NH_2 – LDF, dipole-dipole, H-bonding
   d. H_3COCH_3 – LDF, dipole-dipole
   e. CH_3Cl – LDF, dipole-dipole
5. The mineral rutile crystalizes in a structure with 8 corner titanium atoms, 1 central titanium atom, 4 face oxygens, and 2 central oxygens. What is the structural formula for rutile? (This is a tetragonal structure and you aren't responsible for memorizing it, but treat it like a bcc/fcc hybrid)

$$8\left(\frac{1}{8}\right) + 1(1) = 2\ titanium\ atoms$$

$$4\left(\frac{1}{2}\right) + 2(1) = 4\ titanium\ atoms$$

Overall: Ti_2O_4 which reduces to TiO_2. TiO_2 can crystallize in many different structures, called polymorphs, but rutile is the most common and most stable.

6. Calculate the amount of heat given off when 138 g of steam at 172 °C is converted to ice with a temperature of -10 °C.

$$q_{H_2O(s),\ 172°C \rightarrow 100°C} = 138g\left(\frac{1.99\,J}{g°C}\right)(100°C - 172°C)\left(\frac{1\,kJ}{1000\,J}\right)$$
$$= -19.773\,kJ$$ cool steam to 100°C

$$q_{condensation} = 138g\left(\frac{mol}{18.016g}\right)\left(-40.79\,\frac{kJ}{mol}\right) = -312.45\,kJ$$
to condense steam to water

$$q_{H_2O(l),\ 100° \rightarrow 0°C} = 138g\left(\frac{4.18\,J}{g°C}\right)(0°C - 100°C)\left(\frac{1\,kJ}{1000\,J}\right)$$
$$= -57.684\,J$$ to cool water to 0°C

$$q_{freezing} = 138g\left(\frac{mol}{18.016g}\right)\left(-6.01\,\frac{kJ}{mol}\right) = -46.036\,kJ$$
to freeze water into ice

$$q_{H_2O(s),\ 0°C \rightarrow -10°C} = 138g\left(2.03\,\frac{J}{g°C}\right)(-10°C - 0°C)\left(\frac{1\,kJ}{1000\,J}\right)$$
$$= -2.801\,kJ$$ to cool ice to -10°C

$$q_{TOTAL} = -438.7\,kJ$$

7. Use the phase diagram of xenon (shown at the right) to answer the following questions.

a) When solid xenon is warmed at atmospheric pressure, does it melt or sublime? At what temperature does this occur? What happens if solid xenon is warmed at 0.5 atm?

@ 1 atm – xenon MELTS at ~160K
@ 0.5 atom – xenon SUBLIMES at ~110K

b) What term is used to refer to point A on the phase diagram?

The triple point, where all three phases intersect.

c) What phase(s) is present at 1 atm and 50 K?

Solid

d) What phase does xenon occupy at standard temperature and pressure?

Gas

Chapter 15:

1. What is the pH of a solution made by mixing
   a. 750 mL of 0.400 M NaOH and 250 mL of 0.800 M HCl? Strong-strong titration
   b. 100 mL of 0.100 M $NaHCO_3$ and 200 mL 0.100 M H_2CO_3? Buffered solution
   c. 100 mL of 0.250 M $NaHCO_3$ and 50 mL of 0.1 M NaOH? Weak acid titration
   d. 100 mL of 0.250 M $NaHCO_3$ and 50 mL of 0.1 M HCl? Weak base titration

a.

	OH^-	H^+	H_2O
B	0.3	0.2	
R	-0.2	-0.2	
A	0.1	0	
C	0.1	—	

$[OH^-] = 0.1$

$pOH = 1$

$\therefore pH = 13$

b.

	H_2CO_3	$+ H_2O \rightleftharpoons$	HCO_3^-	$+ H_3O^+$
I	.067		0.033	0
C	$-x$		$+x$	$+x$
E	$.067-x$		$.033+x$	x

assume neg

$$4.4\times10^{-7} = \frac{x(.033+x)}{(.067-x)}$$

$x = [H_3O^+] = 8.93\times10^{-7}$

$\therefore pH = 6.05$

c.

	HCO_3^-	$+ OH^-$	$\rightarrow CO_3^{2-}$	$+ H_2O$
B	.025	.005	0	
R	-.005	-.005	+.005	
A	.02	0	.005	
C	.133	—	.033	

	HCO_3^-	$+ H_2O \rightleftharpoons$	CO_3^{2-}	$+ H_3O^+$
I	.133		.033	0
C	$-x$		$+x$	$+x$
E	$.133-x$		$.033+x$	x

H_2CO_3 $K_{a_2} = 4.8\times10^{-11}$

x is neg

assume

$$4.8\times10^{-11} = \frac{x(.033+x)}{(.133-x)}$$

$x = [H_3O^+] = 1.93\times10^{-10}$

$\therefore pH = 9.71$