CH1020 ***Answers to Worksheet***

Vapor Pressure (Clausius-Clapeyron equation), Colligative Properties, Henry's Law

1. Explain how each of the following affects the vapor pressure of a liquid:
    a. surface area ***no effect***
    b. temperature ***vapor pressure increases with increasing temperature because average kinetic energies of molecules increase.***
    c. intermolecular forces ***vapor pressure would decrease with increasing intermolecular attractive forces because fewer molecules would have sufficient kinetic energy to overcome the attractive forces and escape to the vapor phase***
    d. volume of the liquid ***no effect***
    e. pressure of the air above the liquid ***no effect. The pressure of the air above the liquid determines how quickly liquid-vapor equilibrium is reached but not the equilibrium vapor pressure.***

2. Explain the following observations
    a. water evaporates more quickly on a hot, dry day than on a hot humid day
    On a humid day, there are more gaseous water molecules in the air and more are recaptured by the surface of the liquid, making evaporation slower.

    b. it takes longer to boil eggs at high altitudes than at lower ones.
    At high altitude, atmospheric pressure is lower and water boils at a lower temperature. The eggs must be cooked longer at the lower temperature.

3. What is the effect of a nonvolatile solute on the vapor pressure of a liquid? Why is the vapor pressure of a solution different from the vapor pressure of the pure liquid solvent?
The vapor pressure of the solution is lower than the vapor pressure of the pure solvent. This is related to dynamic equilibrium. In dynamic equilibrium, the rate of vaporization is equal to the rate of condensation. When a nonvolatile solid is added, the solute particles interfere with the ability of the solvent particles to vaporize because they occupy some of the surface area formerly occupied by the solvent. The rate of vaporization is therefore diminished compared to that of the pure solvent. The change in the rate of vaporization creates an imbalance in the rates; the rate of condensation is now greater than the rate of vaporization. The net effect is that some of the molecules that were in the gas phase condense into the liquid. As they condense, the reduced number of molecules in the gas phase causes the rate of condensation to decrease. Eventually, the two rates become equal again, but only after the concentration of molecules in the gas phase has decreased, which means a lower vapor pressure for the solution compared to the pure solvent.

4. Explain why the lower vapor pressure for a solution containing a nonvolatile solute results in a higher boiling point and lower melting point compared to the pure solvent.

A nonvolatile solute lowers the vapor pressure of a solution relative to that of the pure solvent. The vapor pressure lowering occurs at all temperatures, which shifts the vaporization curve in the phase diagram. This means the temperature must be raised above the pure solvent normal boiling point for the solution vapor pressures to be raised to 1 atm. This shift also results in lowering of where the vapor pressure curve intersects the solid-gas curve. The net effect is that the solution has a lower melting point and a higher boiling point than the pure solvent.

5. What are colligative properties?
   Colligative properties depend on the amount of solute and not the type of solute. Examples of colligative properties are vapor pressure lowering, freezing point depression, boiling point elevation, and osmotic pressure.

6. Explain van't Hoff factor and its role in determining the colligative properties of solutions containing ionic solutes.
   Van't Hoff factor is the moles of particles per moles of formula unit dissolved. The van't Hoff factor often does not match its theoretical value because the ionic solute is not completely dissolved into the expected number of ions, leaving ion pairs in solution. The result is that the number of particles in the solution is not as high as theoretically expected.

7. What is the molality of a solution prepared by dissolving 86.9 g of diethyl ether, $C_4H_{10}O$, in 425 g of benzene, C_6H_6?
   2.76 m
8. Calcium nitrite is used as a corrosion inhibitor in lubricants. What is the molality of a solution prepared by dissolving 18.5 g of calcium nitrite in 83.5 g of distilled water?
   1.68 m

9. Isoamyl salicylate (molar mass = 208.25 g/mol) has a pleasant aroma and is used in perfumes and soaps. Which one of the following combinations gives a 0.75 *m* solution of isoamyl salicylate in ethyl alcohol (*d* = 0.7893 g/mL)?
   a. ***117.2 g isoamyl salicylate in 950.0 mL of ethyl alcohol***
   b. 117.2 g isoamyl salicylate in 750.0 mL of ethyl alcohol
   c. 117.2 g isoamyl salicylate in 750.0 mL of solution
   d. 117.2 g isoamyl salicylate in 592.0 g of ethyl alcohol

10. You add 1.00 kg of ethylene glycol ($C_2H_6O_2$) antifreeze to your car radiator, which contains 4450. g of water. What are the boiling and freezing points of the solution?
    Boiling point = 101.85 ^oC freezing point = - 6.73 ^oC

11. Calculate the freezing point of a 1.7 *m* aqueous ethylene glycol ($C_2H_6O_2$) solution.
    -3.2^oC
12. An aqueous solution of sucrose, $C_{12}H_{22}O_{11}$, boils at 112^{o}C. What is the molality?

23.5 m

13. What is the freezing point of a solution that contains 15.0 g of ethylene glycol, $C_2H_6O_2$, in 250 g of water? ***-1.8^oC***

14. What mass of ethylene glycol ($C_2H_6O_2$), in grams, must be added to 1.00 kg of water to produce a solution that boils at 105.0 ^oC?
6.1×10^2 g of $C_2H_6O_2$

15. A 4.367 g sample of an unknown hydrocarbon is dissolved in 21.35 g benzene. The freezing point of solution is observed to be -0.51^oC. Calculate the molar mass of the unknown. ***174 g/mol***

16. Calculate the molar mass of a compound if 4.00 g of the compound plus 50.0 g of water forms a solution which has a boiling point of 100.41^oC.
99.9 g/mol

17. Which aqueous solution will have the highest boiling point?
a. 0.50 M $C_{12}H_{22}O_{11}$ b. 0.50 M NaCl c. ***0.50 M $MgCl_2$***

18. Calculate the freezing point and boiling point of each aqueous solution.
a. 0.100 m K_2S ***fp = -0.558^oC, bp = 100.154^oC***

b. 21.5 g of $CuCl_2$ in 4.50×10^2 g water ***fp = -1.98^oC, bp = 100.546^oC***

c. 5.5 % $NaNO_3$ by mass (in water) ***fp = -2.5^oC, bp = 100.70^oC***

19. A 0.100 M ionic solution has an osmotic pressure of 8.3 atm at 25^oC. Calculate the van't Hoff factor (i) for this solution.

i = 3.39

20. A 1.2 m aqueous solution of an ionic compound with the formula MX_2 has a boiling point of 101.4 ^oC. What is the theoretical van't Hoff factor? What is the experimental van't Hoff factor.

i(theoretical) = 3
i(measured) = 2.3