Name _____ Chemistry ___/___/___

Conductance, Colligative Properties, Freezing Point Depression & Boiling Point Elevation

Conductance

A solutions ability to conduct electricity is known as **conductance**. When a solution contains charged particles (ions) it will carry an electrical charge. These charged particles that carry an electrical current are referred to as **electrolytes**. When ionic compounds dissociate in water they are electrolytes. Molecular compounds do not dissociate in water and will not conduct an electrical charge. The amount of dissociation will determine if the substance is a nonelectrolyte, weak electrolyte or strong electrolyte. A **nonelectrolyte** does not dissociate and thus does not conduct electricity. A **weak electrolyte** experiences only a small amount of dissociation and only conducts a small amount of electricity. A **strong electrolyte** completely or largely dissociates and exhibits high conductivity.

Reminder: Ionic compounds are composed of a metal and a non-metal. Molecular compounds are composed of two or more non-metals covalently bonded

Colligative Properties

Colligative properties are properties of a solution that depend on the amount of particles dissolved in solution. Boiling point elevation, freezing point depression and vapor pressure lowering are all colligative properties. The more particles added to a solution, the greater the extent of the effect. **Ionic compounds dissociate only when they are added to a polar solution, molecular compounds do not.** For example:

$NaCl(s) \rightarrow Na^{+}(aq) + Cl^{-}(aq)$ (sodium chloride dissociates to form 2 particles)
$CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2Cl^{-}(aq)$ (calcium chloride dissociates to form 3 particles, 1 calcium and 2 chlorine)
$AlCl_3(s) \rightarrow Al^{3+}(aq) + 3Cl^{-}(aq)$ (aluminum chloride dissociates to form 4 particles, 1 aluminum and 3 chlorine)
$C_6H_{12}O_6(s) \rightarrow C_6H_{12}O_6(s)$ (glucose is a molecular compound and does not dissociate, so only 1 particle is added)

As particles are added to a solution the boiling point of the solution is raised, the freezing point of the solution is lowered and the vapor pressure of the solution is lowered.

Freezing Point Depression & Boiling Point Elevation

Freezing Point Depression & Boiling Point Elevation are two colligative properties caused when a solute is added to a solution. For freezing point depression, the formula is: $\mathbf{\Delta T_f = imK_f}$. $\mathbf{\Delta T_f}$ is the change in the freezing point. The "**m**" in the equation represents molality. $\mathbf{K_f}$ is the molal freezing point depression, which is equal to the change in the freezing point for a 1 molal solution of a nonvolatile molecular solute. K_f values can be found in the chart below. The "i" refers to the number of particles formed when the substance is dissolved in the solvent. **Remember, ionic substances dissociate in polar solvents, molecular substances do not.** Nothing dissociates in a non-polar solvent. For boiling point elevation, the formula is the same, except you would use K_b instead of K_f. The chart below lists the freezing and boiling points for several solvents as well as their constants.

Solvent	Polar/Non-Polar	Freezing Point ºC	k_F(ºC/m)	Boiling Point ºC	k_B(ºC/m)
Acetic acid (CH_3COOH)	Polar	16.66	3.90	117.90	2.53
Benzene (C_6H_6)	Non-Polar	5.50	5.10	80.10	2.53
Cyclohexane (C_6H_{12})	Non-Polar	6.50	20.2	80.72	2.75
Camphor ($C_{10}H_{16}O$)	Non-Polar	178.40	40.0	207.42	5.61
p-Dichlorobenzene ($C_6H_4Cl_2$)	Non-Polar	53.10	7.1	174.1	6.2
Napthalene ($C_{10}H_8$)	Non-Polar	80.29	6.94	217.96	6.2
Nitrobenzene ($C_6H_5NO_2$)	Non-Polar	5.8	8.1	211.0	5.24
Phenol (C_6H_5OH)	Non-Polar	43.0	7.27	181.8	3.56
Water (H_2O)	Polar	0.00	1.86	100.0	0.52

For example: Calculate the boiling point and freezing point if 1.5 moles of $AlCl_3$ is dissolved in 1200. grams of water.

Determine how many particles enter solution.

$AlCl_3$ is ionic and the solvent is polar (water) so it dissociates. $AlCl_3 \rightarrow Al^{3+} + 3Cl^{1-}$ = 4 particles

You should then determine the molality

1.5 / 1.200 = 1.250 (Remember molality is moles/kilogram)

Find the K_b & K_f values from the chart.

The K_b value for water is: 0.52
The K_f value for water is: 1.86

Plug in your values and solve.

$\Delta T_f = imK_f$

$\Delta T_f = (4)(1.250)(1.86)$

ΔT_f = 9.3. The freezing point would decrease by 9.3 ºC.
Freezing Point of water: -9.3ºC

$\Delta T_b = imK_b$

$\Delta T_b = (4)(1.25)(0.52)$

ΔT_b = 2.6. The boiling point would increase by 2.6 ºC.
Boiling point of water: 102.6ºC

Homework:

1. Define conductance –

2. Define electrolyte –

3. What determines whether a substance is a nonelectrolyte, weak electrolyte or strong electrolyte?

4. Label each of the following as an electrolyte or nonelectrolyte.
   a. NaCl
   b. $C_{12}H_{22}O_{11}$
   c. $C_6H_{12}O_6$
   d. KBr
   e. AlF_3
   f. C_6H_{12}

5. Define colligative properties –

6. What are the three colligative properties?

7. What type of compounds dissociate in polar solvents, ionic or molecular?

8. Write the dissociation of each of the following:
   a. GaF_3
   b. CaI_2
   c. KBr

9. Which of the following solutes would have the greatest increase in the boiling point of water?
   a. 1 mole of $C_{12}H_{22}O_{11}$ b. 1 mole of AlI_3 c. 1 mole of CsF d. 1 mole of $BaBr_2$

10. What is the formula to be used to calculate freezing point depression?

11. What is the formula to be used to calculate boiling point elevation?

12. What is the freezing point and boiling points of the following solutions?
    a. 2.90 moles of $MgSO_4$ in 1300. grams of water.

    b. 3.40 moles of NaCl dissolved in 700. grams of camphor.

c. 320. grams of $CaCl_2$ dissolved in 2200. grams of phenol.

d. 420. grams of $C_{12}H_{22}O_{11}$ dissolved in 1800. grams of napthalene.

e. 318 grams of $(NH_4)_3PO_4$ dissolved in 680. grams of water.

13. The molality of the glucose in a 1.0-molar glucose solution can be obtained by using which of the following?
(A) Volume of the solution (B) Temperature of the solution (C) Solubility of glucose in water
(D) Degree of dissociation of glucose (E) Density of the solution

14. Which of the following aqueous solutions has the highest boiling point?
(A) 0.10 M potassium sulfate, K_2SO_4 (B) 0.10 M hydrochloric acid, HCl
(C) 0.10 M ammonium nitrate, NH_4NO_3 (D) 0.10 M magnesium sulfalte, $MgSO_4$
(E) 0.20 M sucrose, $C_{12}H_{22}O_{11}$

15. The weight of H_2SO_4 (molecular weight 98.1) in 50.0 milliliters of a 6.00-molar solution is
(A) 3.10 grams (B) 12.0 grams (C) 29.4 grams (D) 294 grams (E) 300. grams

16. Which of the following solutions has the lowest freezing point?
(A) 0.20 *m* $C_6H_{12}O_6$, glucose (B) 0.20 *m* NH_4Br (C) 0.20 *m* $ZnSO_4$
(D) 0.20 *m* $KMnO_4$ (E) 0.20 *m* $MgCl_2$

17. For each of the following, use appropriate chemical principles to explain the observation. Include chemical equations as appropriate.
When table salt (NaCl) and sugar ($C_{12}H_{22}O_{11}$) are dissolved in water, it is observed that
(i) both solutions have higher boiling points than pure water, and
(ii) the boiling point of 0.10 *M* NaCl(*aq*) is higher than that of 0.10 *M* $C_{12}H_{22}O_{11}$(*aq*).
what occurs in solution that accounts for the difference between the results obtained in parts (b) and (c).

18. An unknown compound contains only the three elements C,H, and O. A pure sample of the compound is analyzed and found to be 65.60 percent C and 9.44 percent H by mass.
(a) Determine the empirical formula of the compound.
(b) A solution of 1.570 grams of the compound in 16.08 grams of camphor is observed to freeze at a temperature 15.2 Celsius degrees below the normal freezing point of pure camphor. Determine the molar mass and apparent molecular formula of the compound. (The molal freezing-point depression constant, K_f, for camphor is 40.0 kg-K-mol^{-1}.)
(c) When 1.570 grams of the compound is vaporized at 300 °C and 1.00 atmosphere, the gas occupies a volume of 577 milliliters. What is the molar mass of the compound based on this result?
(d) Briefly describe what occurs in solution that accounts for the difference between the results obtained in parts (b) and (c).