Exercise 11.5

Colligative Properties

Name: _____

Date: _____ Per: _____

When a solute is added to a solvent, the vapor pressure of the solvent (above the resulting solution) is less than the vapor pressure above the pure solvent. This affects both the freezing point and boiling point of the solution. The change in freezing/boiling point is based on the identity of the solvent – the identity of the solute makes no difference as long as it will not leave the solution prior to phase change (i.e., it must be non-volatile for boiling point elevation). The important aspect of the solute is how many particles are produced by its dissolution.

Electrolytes (ionic compounds) dissociate into multiple ions and their concentrations must be adjusted to reflect this in calculations. The *van't Hoff factor* (*i*) represents the multiplicative effect of an electrolyte dissociating (e.g., 1 mol $CaCl_2$ dissociates to produce 3 moles of solute particles). Strictly speaking, the van't Hoff factor will be less than the actual number of ions produced and decreases as the concentration of the electrolyte increases. As more ions enter solution there is a greater probability that ions will interact and temporarily combine, acting as a single particle. This interaction is called ion-pairing. When the actual van't Hoff factor is not provided, it is passable to use the number of ions produced to approximate the effects of dissociation.

1. Fill in the blanks using the following terms: colligative properties, depression, elevation, lowering, proportional, solute.

   The effects in solution of a nonvolatile (a)_____ on the properties of a solvent are called (b)_____. They include freezing point (c)_____, boiling point (d)_____, and (e)_____ vapor pressure. In each case, the magnitude of the effect is (f)_____to the number of solute molecules or ions present in the solution.

2. Classify each statement as always true (AT), sometimes true (ST) or never true (NT)

   _____ a. When added to 1000 g of water, 2 moles of a solute will increase the boiling point.

   _____ b. One mole of solute A will depress the freezing point of 1000 g of water.

   _____ c. Addition of a nonvolatile solute will lower the boiling point.

   _____ d. Addition of a nonvolatile solute will lower the freezing point of a solvent.

3. An equal number of moles of NaCl and K_2CO_3 are dissolved in equal volumes of water. Which solution has the higher

   a. boiling point? _____

   b. vapor pressure? _____

   c. freezing point? _____

4. Determine an approximate van't Hoff factor for each of the following solutes.

   a. Aluminum chloride _____

   b. Sodium iodide _____

   c. Magnesium hydroxide _____

   d. Sucrose ($C_{12}H_{22}O_{11}$) _____

5. In World War II, soldiers in the Saharan desert needed a supply of antifreeze to protect the radiators of their vehicles. Since the temperature in the Sahara almost never drops to 0°C, why was the antifreeze necessary?

   _____

   _____

   _____

Answers: 6) -4.46 °C 7) -23.2 °C 8) 102 °C 9) -103 °C , 92.2 °C 10) 130 °C 11) 90.2 °C 12) 67.8 °C

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Freezing Point Depression

The freezing point of a solution is always lower than the freezing point of the pure solvent in the solution. The change in freezing point can be calculated using the formula below:

$$\Delta T_f = K_f(i)m_{solute}$$

This value represents the change in freezing point, not the new freezing point, so its value must be subtracted from the pure solvent's typical freezing point.

Boiling Point Elevation

The boiling point of a solution is always higher than the boiling point of the pure solvent in the solution. The change in boiling point can be calculated using the formula below:

$$\Delta T_b = K_b(i)m_{solute}$$

This value represents the change in boiling point, not the new boiling point, so its value must be added to the pure solvent's typical boiling point.

DIRECTIONS: Calculate the following in the space provided:

6. What is the freezing point of a solution with a **non-electrolyte** solute dissolved in water if the concentration of the solution is 2.40 *m*?

7. What is the freezing point of a solution that contains 2.50 mol of $MgCl_2$ in 600. g of water?

8. What is the boiling point of a solution in which 55.0 g KCl is dissolved in 500. g of H_2O?

9. 3.40 moles of non-electrolyte solute are dissolved in 400. grams of chloroform, what will the new freezing point and boiling point be?

10. Find the boiling point of a solution with 70.9 g of NaCl in 600. g of acetic acid.

11. Benzene (C_6H_6) is a non-polar solvent. If 48.1 g of methane (CH_4) is dissolved in 750. g of benzene, what will the boiling point of the solution be?

12. Chloroform is a polar solvent with the formula $CHCl_3$. If 40.0 grams of $CaCl_2$ is dissolved in 600. grams of $CHCl_3$, determine the boiling point of the solution.

solvent	normal freezing point (°C)	K_f (°C/m)
water	0.0	1.86
acetic acid	16.6	3.9
benzene	5.5	5.12
chloroform	-63.5	4.68
nitrobenzene	5.67	8.1

solvent	normal boiling point (°C)	K_b (°C/m)
water	100.0	0.512
acetic acid	118.1	3.07
benzene	80.1	2.53
chloroform	61.3	3.63
nitrobenzene	210.9	5.24

Answers: 6) -4.46 °C 7) -23.2 °C 8) 102 °C 9) -103 °C , 92.2 °C 10) 130 °C 11) 90.2 °C 12) 67.8 °C