+ WS 8.8 - Molality & Colligative Properties

1. Molality (*m*) represents the number of moles of solute in one kg of solvent. The units of molality are thus mol / kg.

2. Compute the molality (*m*) of 78 g of NaCl in 1000 g of H_2O.

$$\frac{78\text{ g}}{1000\text{ g}} \times \frac{1\text{ mol}}{58.5\text{ g}} \times \frac{1000\text{ g}}{1\text{ kg}} = 1.3\text{ m}$$

3. Compute the molality (*m*) of 23.7 g of $NaNO_3$ in 250 ml of H_2O.
(*Hint: the density of water is 1g/ml*)

$$\frac{23.7\text{ g}}{250\text{ mL}} \times \frac{1\text{ mol}}{85\text{ g}} \times \frac{1\text{ mL}}{1\text{ g}} \times \frac{1000\text{ g}}{1\text{ kg}} = 1.1\text{ m}$$

4. What is the molar mass of a substance in which 475.6 g of the substance is dissolved in 2 L of water yielding a 2 *m* solution?

2 L → 2 kg

$$\frac{475.6\text{ g}}{2\text{ kg}} \times \frac{1\text{ mol}}{x\text{ g}} = 2 \qquad x = 118.9$$

5. The van't Hoff factor (*i*) indicates how many moles of solute are in a solution, per mole of solid solute added to the solution. For example, in water one mole of $C_6H_{12}O_6$ does not form any ions, so i=1. In water, one mole of NaCl will yield one mole of Na+ ions and one mole of Cl- ions, so i=2.

In water, one mole of $CaCl_2$ forms one mole of Ca+ ions and two moles of Cl- ions, so i= 3. In contrast, in water, one mole of $NaNO_3$ forms 1 mole(s) Na and 1 mole(s) NO_3, so i= 2.

6. What is the freezing point depression of water in a solution of 10.0 g of NaCl and 1300 g of water? (k_f for water is -1.86 °C/*m*)

1300 g → (1.3 kg)

$$\frac{10.0\text{ g}}{1.3\text{ kg}} \times \frac{1\text{ mol}}{58.5\text{ g}} = 0.13\text{ m}$$

$$\Delta T = (-1.86\text{ °C/m})(0.131\text{ m})(2) = -0.487\text{ °C}$$

7. What is the actual freezing point for an aqueous solution of 25 g of $CaCl_2$ in 500 ml of water?

500 ml → 0.5 kg

$$\frac{25\text{ g}}{0.5\text{ kg}} \times \frac{1\text{ mol}}{111\text{ g}} = 0.45\text{ m}$$

$$\Delta T = (-1.86\text{ °C/m})(0.45\text{ m})(3) = -2.51\text{ °C}$$

8. How many grams of NaCl are required to lower the freezing point of 1.0 L of water by 6 °C? How many grams of $CaCl_2$ would be required to achieve the same temperature change?

NaCl: $6^\circ = (1.86)(m)(2)$ $\quad m = 1.61\text{ m}$ $\quad 1\text{ kg} \times \frac{1.61\text{ mol}}{1\text{ kg}} \times \frac{58.5\text{ g}}{1\text{ mol}} = 94.2\text{ g}$

$CaCl_2$: $6^\circ = (1.86)(m)(3)$ $\quad m = 1.075$ $\quad 1\text{ kg} \times \frac{1.075\text{ mol}}{1\text{ kg}} \times \frac{111\text{ g}}{1\text{ mol}} = 119\text{ g}$

9. What is the boiling point elevation for an aqueous solution of 50. g of NaCl in 475 ml of water?
(kb for water is 0.51 °C/*m*)

$\frac{50.\text{ g}}{0.475\text{ kg}} \times \frac{1\text{ mol}}{58.5\text{ g}} = 1.8\text{ m}$

$\Delta T = (0.51)(1.8)(2)$

$= 1.84\,^{\circ}\text{C}$

10. In water, HCl forms two ions and hence *i*=2. In benzene, however, HCl does not form any ions and *i*=1. Pure benzene boils at 80.1 °C. Imagine that you have 1000 g of water and 1000 g of benzene in separate beakers. Into each beaker you add 250 g of HCl. What will be the new boiling points of benzene and water?
(kb for benzene is 2.53 °C/*m* while the kb for water is 0.51 °C/*m*)

benzene $\frac{250\text{ g}}{1\text{ kg}} \times \frac{1\text{ mol}}{36.5\text{ g}} = 6.85\text{ m}$ $\Delta T = (2.53)(6.85)(1) = 17.3^{\circ}\text{C} + 80.1^{\circ}\text{C} = 97.4^{\circ}$

water $\frac{250\text{ g}}{1\text{ kg}} \times \frac{1\text{ mol}}{36.5} = 6.85\text{ m}$ $\Delta T = (0.51)(6.85)(2) = 6.99^{\circ}\text{C} + 100^{\circ}\text{C} = 107^{\circ}\text{C}$

11. Suppose 65.0 g of a nonionic substance is dissolved in 2.00 L of water. The freezing point is observed to decrease by 1.30 °C. What is the molar mass of the substance?
(kf for water is -1.86 °C/*m*)

$\Delta T = K_B \cdot m \cdot i$

$-1.30 = (-1.86)(m)(1)$

$m = 0.699\text{ g/kg}$

molality ↓ molar mass ↓

$\frac{65\text{ g}}{2\text{ kg}} \times \frac{1\text{ mol}}{x\text{ g}} = 0.699$

$x = 46.5$