Solutions

CHEM 104 (WOOHOO!)
PLI 25
Wednesday, July 6, 2016

Chapter 13

1. A solution is prepared by mixing 1.00 g ethanol (C_2H_5OH) with 100.0 g of water to give a final volume of 101 mL. Calculate the molarity, mass percent, mole fraction, and molality of ethanol in this solution.

Molarity: $1.00\,g\ C_2H_5OH\left(\frac{1\,mol}{46.07\,g}\right) = 2.17\times10^{-2}\,mol \rightarrow M = \frac{mol}{L} = \frac{2.17\times10^{-2}\,mol}{0.101\,L} = \boxed{0.215\,M}$

Mass percent: $\frac{\text{mass of } C_2H_5OH}{\text{mass solution}} = \frac{1.00\,g\ C_2H_5OH}{101\,g\ soln}(100\%) = \boxed{0.990\%\ C_2H_5OH}$

Mole fraction: $\frac{\text{moles } C_2H_5OH}{\text{total moles}} \rightarrow 100.0\,g\ H_2O\left(\frac{1\,mol}{18\,g}\right) = 5.56\,mol\ H_2O \rightarrow \frac{0.0217\,mol}{0.0217+5.56\,mol} = \boxed{0.00389}$

Molality: $\frac{\text{moles } C_2H_5OH}{kg\ H_2O} = \frac{0.0217\,mol}{0.100\,kg} = \boxed{0.217\,m}$

2. Calculate the expected vapor pressure at 25°C for a solution prepared by dissolving 158.0 g common table sugar (molar mass = 342.3 g/mol) in 643.5 cm³ of water. At 25°C, the density of water is 0.9971 g/cm³ and the vapor pressure is 23.76 mmHg.

$P_{soln} = \chi_{H_2O}\cdot P^{o}_{soln}$

① Find moles sucrose: $158.0\,g\ sucrose\left(\frac{1\,mol}{342.3\,g}\right) = 0.4616\,mol\ sucrose$

② Find moles water: $643.5\,cm^3\left(\frac{0.9971\,g}{cm^3}\right)\left(\frac{1\,mol}{18.0\,g}\right) = 35.60\,mol\ H_2O$

③ Find mol fraction of H_2O:

$\chi_{H_2O} = \frac{35.60}{35.60+0.4616} = 0.9873$

④ Find P_{soln}: $P_{soln} = \chi_{H_2O}\cdot P^{o}_{soln} = 0.9873\,(23.76\,mmHg) = \boxed{23.46\,mmHg}$

3. Consider the following solutions:

0.10 *m* Na_3PO_4 in water	0.20 *m* $CaBr_2$ in water
0.20 *m* KCl in water	0.20 *m* HF in water

a. Assuming complete dissociation of the soluble salts, please circle the solution(s) that would have the same boiling point as 0.40 *m* glucose ($C_6H_{12}O_6$, non-electrolyte) in water.

b. Which solution would have the largest freezing-point depression and why?

The $CaBr_2$ solution would have the largest ΔT_{fp} because its effective molarity is 0.60 M. Since ΔT_{fp} depends on K_{fp} (−1.86°C/M for all water-solvent solutions) and effective molarity of the solute ($i\cdot M_{solute}$), ΔT_{fp} is largest for the largest $i\cdot M_{solute}$

c. How many grams of glucose per liter should be used for an intravenous solution that is isotonic with the 7.65 atm osmotic pressure of blood at body temperature, 37.0°C?

$\pi = MRT \rightarrow M = \frac{\pi}{RT} = \frac{7.65\,atm}{0.082\frac{atm\cdot L}{mol\cdot K}(310\,K)} = 0.3009\,\frac{mol}{L}$

$0.3009\,\frac{mol}{L}\left(\frac{180.16\,g}{mol}\right) = \boxed{54.2\,g/L}$

4. A 2.00 g sample of a large biomolecule was dissolved in 15.0 g carbon tetrachloride (CCl_4). The boiling point of this solution was determined to be 77.85°C. Calculate the molar mass of the biomolecule. For carbon tetrachloride, the boiling point constant, K_{bp}, is 5.03°C•Kg/mol, and the boiling point of pure carbon tetrachloride is 76.50°C.

$\Delta T_{bp} = K_{bp} \cdot m$ $\Delta T_{bp} = T_f - T_i = 77.85°C - 76.50°C = 1.35°C$

$m = \frac{\Delta T_{bp}}{K_{bp}} = \frac{1.35°C}{5.03°C \cdot kg/mol} = 0.268\ m$

$0.015\ kg\ \text{solvent} \left(\frac{0.268\ \text{moles solute}}{kg\ \text{solvent}} \right) = 4.026 \times 10^{-3}\ \text{moles solute}$

$\frac{2.00\ g}{4.026 \times 10^{-3}\ mol} = \boxed{497\ g/mol}$

5. What mass of ethylene glycol ($C_2H_6O_2$), in grams, must be added to 1.0 kg of water to produce a solution that boils at 105.0°C? The boiling point elevation constant for water, K_{bp}, is 0.512°C/*m*. $\Delta T = 105.0°C - 100°C = 5.0°C$ $K_{bp} = 0.512°C/m$

$\Delta T_{bp} = K_{bp} \cdot m$

$m = \frac{\Delta T_{bp}}{K_{bp}} = \frac{5.0°C}{0.512°C/m} = 9.766\ m \rightarrow 9.766\ mol \left(\frac{}{kg\ H_2O} \right) = 9.766\ mol$

$9.766\ mol \left(\frac{62.07\ g}{mol} \right) = \boxed{606\ g\ C_2H_6O_2}$

6. Ion hydration enthalpies:

Ion	$\Delta H_{hydration}$ (kJ/mol)
Li^+	-545
Na^+	-418
K^+	-351
Mg^{2+}	-1923
Cl^-	-338

* When comparing hydration enthalpies, think about the attraction between the ion and water

Talking about the magnitude of the $\Delta H_{hydration}$

a. Explain why the hydration enthalpy falls as you go down group 1.

Hydration enthalpy falls as ion size increases, because attraction between water and ion decreases as size increases.

b. Explain why the value for Mg^{2+} is so much greater than that of Na^+.

attraction between water and Mg^{2+} is greater due to increased charge (and slightly decreased size).

c. Would the value for Ca^{2+} be more negative or less negative than that of Mg^{2+}?

The value for Ca^{2+} would be less negative due to increased size.

d. If the $-\Delta H_{lattice}$ for $MgCl_2$ is +2526 kJ/mol, estimate the enthalpy change for a solution of $MgCl_2$.

$\Delta H_{solution} = -\Delta H_{lattice} + \Delta H_{hydration}$

$= 2526\ \frac{kJ}{mol} + \left[-1923\ \frac{kJ}{mol} + 2(-338\ kJ/mol) \right]$

$= \boxed{-73\ kJ/mol}$