Chapter 13: Properties of Liquids

Kahoot!

1. "Like dissolves like" refers to similarities between ___ of two miscible solutions. Molecular weights, Intermolecular forces, Shapes, Densities
2. When NaOH dissolves, the container becomes hot. Therefore, we can conclude that the magnitude of $\Delta H_{solute} + \Delta H_{solvent}$ ___ ΔH_{mixing}. >, <, =, unrelated to
3. Which of the following compounds is miscible with water? CH_3OH, CH_4, C_6H_6, $CH_3CH_2OCH_2CH_3$
4. Which of the compounds is LEAST miscible with water? CH_3OH, CH_3CH_2OH, $CH_3CH_2CH_2OH$, $CH_3CH_2CH_2CH2OH$
5. ___ law says that the solubility of a gas in a liquid increases as the pressure of the gas increases. Boyle's, Charles', Henry's, Raoult's
6. The vapor pressure of a solution is proportional to the mole fraction of the solvent is what law? Boyle's, Charles', Henry's, Raoult's
7. In general, as the temperature of a solution increases, the solubility of a gaseous solution ___. Increases, decreases, remains unchanged, varies from gas to gas
8. The molality of a solution is defined as the amount of solute (in moles) divided by the ___. Volume of the solution (in L), Mass of the solvent (in kg), mass of the solution (in kg), total number of moles
9. Which solution has the lowest vapor pressure? 1M NaF, 2M NaF, 1M $CH_3CH_2CH_2OH$, 2M $CH_3CH_2CH_2OH$
10. Which are the reasons why the boiling point is raised when a solute is added? Solute-solvent intermolecular forces are stronger, T is lowered, vapor pressure is lowered, all are true
11. What raises the boiling point and lowers the freezing point? Adding solvent, removing solvent, adding solute, removing solute
12. What is the van't Hoff factor for Na_2SO_4? 1, 2, 3, 4
13. What is the van't Hoff factor for C_6H_{12}? 1, 2, 3, 4
14. A 0.100 molal solution of which compound will have the lowest freezing point? NaCl, $CaCl_2$, KI, $LiNO_3$
15. Which substance below is NOT a colloid? Butter, smoke, whipped cream, salt water

WhiteBoard Examples

Henry's Law Example: Calculate the solubility of oxygen in water at 20°C and an atmospheric pressure of 0.35 atm. The mole fraction of O_2 in the air is 0.209 and $k_{O2} = 1.3 \times 10^{-3}$ mol/L*atm.

What do we know? T = 20°C + 273.15 = 293.15K, $P_{total} = 0.35$ atm, $X_{O2} = 0.209$
$k_{O2} = 1.3 \times 10^{-3}$ mol/L*atm

What do we want to know? C_{O2}

What relationships do we know? $P_{O2} = P_{total} X_{O2}$, $C_{O2} = k_H P_{O2}$

The work: $P_{O2} = 0.35$ atm* 0.209 = 0.07315 atm
$C_{O2} = 1.3 \times 10^{-3}$ mol/L*atm*0.07315 atm = 9.5×10^{-5} mol/L

VP Example: What is the vapor pressure of water in a 50:50 mixture of glycerol (D_{C3H8O3} = 1.261 g/mL) and water at 25°C (P_{H2O} = 23.8 torr)?

What do we know? 50:50 mixture of glycerol, D_{C3H8O3} = 1.261 g/mL, P_{H2O} = 23.8 torr

What do we want to know? P_{soln}

What relationships do we know? $P_{soln} = \chi_{solvent} P_{solvent}$, $\chi_{solvent} = \dfrac{n_{solvent}}{n_{solute} + n_{solvent}}$

The work: assuming 100mL of glycerol and 100mL of water:

$$100 \text{ mL of } C_3H_8O_3 \times \frac{1.261\text{g}}{\text{mL}} \times \frac{1 \text{ mol}}{92.097 \text{ g}} = 1.37 \text{ mol of } C_3H_8O_3$$

$$100 \text{ mL of } H_2O \times \frac{1.000\text{g}}{\text{mL}} \times \frac{1 \text{ mol}}{18.016 \text{ g}} = 5.55 \text{ mol of } H_2O$$

$$X_{H_2O} = \frac{5.55 \text{ mol of } H_2O}{5.55 \text{ mol of } H_2O + 1.37 \text{ mol of } C_3H_8O_3} = 0.802$$

$$P_{soln} = 0.802 \times 23.8 \text{ torr} = 19.1 \text{ torr}$$

VP Mixture Example: At 20°C, the VP of ethanol is 45 torr and the VP of methanol is 92 torr. What is the VP at 20°C of a solution prepared by mixing 75g of methanol and 25g of ethanol?

What do we know? $P_{ethanol}$ = 45 torr, $P_{methanol}$ = 92 torr, $m_{ethanol}$ = 25g, $P_{methanol}$ = 75g

What do we want to know? P_{soln}

What relationships do we know? $P_{soln} = \chi_{ethanol} P_{ethanol} + \chi_{methanol} P_{methanol}$, $\chi_a = \dfrac{n_a}{n_{total}}$

The work:

$$25\text{g} \times \frac{1 \text{ mol } C_2H_5OH}{46.07\text{g}} = 0.5427 \text{ moles of } C_2H_5OH$$

$$75\text{g} \times \frac{1 \text{ mol } CH_3OH}{32.043\text{g}} = 2.3406 \text{ moles of } CH_3OH$$

$$X_{C_2H_5OH} = \frac{0.5427}{0.5427 + 2.3406} = 0.1882$$

$$X_{CH_3OH} = 1 - 0.1882 = 0.8118$$

$$P_{total} = X_{C_2H_5OH} P_{C_2H_5OH} + X_{CH_3OH} P_{CH_3OH} = 0.1882 * 45 torr + 0.8118 * 92 torr$$

$$P_{total} = 83 torr$$

Bpt Elevation Example: If the boiling point of a sample is 2.3 Celcius above the boiling point of pure water, what is the molality of NaCl in the sample?

$K_{b,water} = 0.52\,^{o}C \cdot kg / mol$

What do we know? $\Delta T_b = 2.3^oC$, $K_{b,water} = 0.52\,^oC \cdot kg / mol$

What do we want to know? m_{NaCl}

What relationships do we know? $\Delta T_b = k_b m$

The work:

$$m = \frac{\Delta T_b}{K_b} = \frac{2.3\,^oC}{0.52\,^oC/m} = 4.4\frac{moles\ NaCl}{1 kg\ H_2O}$$

Easy Osmotic Pressure Example: Calculate the osmotic pressure across a semipermeable membrane separating seawater (1.14 M) from a solution of normal saline (0.31 M) at a T = 20°C.

What do we know? T = 20°C or 273.15+20 = 293.15 K, $M = 1.14 - 0.31 = 0.83\underline{M}$, R = $0.0821\frac{L \cdot atm}{mol \cdot K}$

What do we want to know? Π = ?

What relationships do we know? Π = MRT

The work:

$$\Pi = MRT = 0.83\underline{M} \times 0.0821\frac{L \cdot atm}{mol \cdot K} \times 293.15K = 20\,atm$$

Difficult Osmotic Pressure Example: A solution was made by dissolving 5.00 mg of hemoglobin in water to give a final volume of 1.00 mL. The osmotic pressure of this solution was 1.91×10^{-3} atm at 25 ºC. Calculate the molar mass of hemoglobin.

What do we know? T = 25°C or 273.15+25 = 298.15 K, m_{hemo} = 5.00 mg, V = 1.00 mL, R = $0.0821\frac{L \cdot atm}{mol \cdot K}$, Π = 1.91×10^{-3} atm

What do we want to know? MW_{hemo} = ?

What relationships do we know? Π = MRT, MW = m_{hemo}/n_{hemo}

The work:

$$\pi = MRT \rightarrow M = \frac{\pi}{RT} = \frac{1.91\times10^{-3}\,atm}{0.0821\frac{L\cdot atm}{mol\cdot K}\times 298.15K} = 7.80\times10^{-5}\ \frac{moles\,hemoglobin}{L}$$

$$1.00\,mL\times\frac{1L}{1000\,mL}\times\frac{7.80\times10^{-5}\,moles\,hemoglobin}{L} = 7.80\times10^{-8}\,moles\,hemoglobin$$

$$molar\ mass\ hemoglobin = \frac{5.00\,mg\times\frac{1g}{1000\,mg}}{7.80\times10^{-8}\,moles\,hemoglobin} = 6.41\times10^{4}\ \frac{g}{mol}$$

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van't Hoff Freezing Point Example: The van't Hoff factor for a 0.05 m solution of magnesium sulfate is 1.3. What is the freezing point of the solution?
$K_{f,water} = 1.86\,^{o}C\cdot kg/mol$

What do we know? m = 0.05 mol/kg, i = 1.3, $K_{f,water} = 1.86\,^{o}C\cdot kg/mol$

What do we want to know? ΔT_f = ?

What relationships do we know? $\Delta T_f = iK_f m$

The work: $\Delta T_f = iK_f m = 1.3\times1.86\frac{^{o}C}{m}\times0.05\,m = 0.12\,^{o}C$

Bpt Elevation w/ van't Hoff: If the boiling point of a sample is 2.3 Celcius above the boiling point of pure water, what is the molality of NaCl in the sample?
$K_{b,water} = 0.52\,^{o}C\cdot kg/mol$

What do we know? ΔT_b = 2.3°C, i = 2, $K_{b,water} = 0.52\,^{o}C\cdot kg/mol$

What do we want to know? m_{NaCl}

What relationships do we know? $\Delta T_b = ik_b m$

The work: $m = \frac{\Delta T_b}{iK_b} = \frac{2.3\,^{o}C}{2*0.52\,^{o}C/m} = 2.2\frac{moles\ NaCl}{1kg\,H_2O}$

VP problem with van't Hoff Example: What is the VP of a solution containing 1L of water and 500 g of NaCl? (at 25^{o}C the VP of water is 23.8 torr)

What do we know? V_{H2O} = 1L, m_{NaCl} = 500g, P_{H2O} = 23.8 torr, i = 2

What do we want to know? P_{soln}

What relationships do we know? $P_{soln} = \chi_{H_2O} P_{H_2O}$ $\chi_{H_2O} = \dfrac{n_{H_2O}}{i \cdot n_{NaCl} + n_{H_2O}}$

The work:

$$n_{NaCl} = 500\ g \times \frac{1\ mol}{58.44\ g} = 8.56\ moles$$

$$\chi_{water} = \frac{55.5}{2 \bullet 8.56 + 55.6} = 0.764$$

$$P_{soln} = 0.764 \bullet 23.8\ torr = 18.2\ torr$$