Some sample colligative properties and concentration problems ..

What is the freezing point of a 41% solution of urea in water?

$(NH_2)_2CO$: urea , FW = 60.062 g/mol

$\Delta T_f = K_f \times C_m$ ← $C_m = \dfrac{\text{mol urea}}{\text{Kg } H_2O}$

p509, $K_{f,H_2O} = 1.858\ ^\circ C/m$

$T_{f,\text{pure } H_2O} = 0.000\ ^\circ C$

We need to convert the mass percentage information to molality. Let's assume a basis.

$\dfrac{41\text{ g urea}}{100\text{ g solution}}$ Let's assume 100 grams solution (the bottom of the mass percent unit)

mass percent

Convert mass urea (41g) to moles...

$41\text{ g urea} \times \dfrac{\text{mol urea}}{60.062\text{ g urea}} = 0.6826279511\text{ mol urea}$

Subtract to find mass water...

$100\text{ g solution} - 41\text{ g urea} = 59\text{ g } H_2O = 0.059\text{ kg } H_2O$

Calculate Cm...

$$C_m = \frac{\text{mol urea}}{\text{Kg } H_2O} = \frac{0.682627951\text{ mol urea}}{0.059\text{ Kg } H_2O} =$$

$$= 11.56996527\text{ m urea}$$

Find delta Tf...

$$\Delta T_f = K_f \times C_m$$

$$\Delta T_f = (1.858\,^{\circ}C/m)(11.56996527\text{ m}) = 21\,^{\circ}C$$

Now find freezing temperature of solution...

$$T_f = T_{f,H_2O} - \Delta T_f$$

$$= 0.000\,^{\circ}C - 21\,^{\circ}C$$

$$\boxed{T_f = -21\,^{\circ}C}$$

0.2436 g of an unknown substance is dissolved in 20.0 mL of cyclohexane, C_6H_{12}
If the freezing point depression of this solution is 2.5 C, what is the molecular weight of the unknown? The density of cyclohexane at the temperature the cyclohexane volume was measured is 0.779 g/mL.

$\Delta T_f = K_f \times C_m \leftarrow \frac{\text{mol unknown}}{\text{Kg } C_6H_{12}}$

ΔT_f = 2.5 °C; K_f = p509, 20.0 °C/m

Our initial goal is to find the MOLES unknown, as we need it to find molecular weight!

Find Cm ...

$2.5\,°C = (20.0\,°C/m) \times C_m$

$C_m = 0.125\,m$

to get moles out of molality, we need to find out the actual mass in kg of 20.0 mL of cylcohexane

find mass cyclohexane from volume and density...

$20.0\,\text{mL} \times \frac{0.779\,\text{g}}{\text{mL}} = 15.58\,\text{g} = 0.01558\,\text{Kg } C_6H_{12}$

now find the moles unknown from Cm and the mass cyclohexane

$C_m = \frac{\text{mol unk}}{\text{Kg } C_6H_{12}}$ $\quad 0.125\,m = \frac{\text{mol unk}}{0.01558\,\text{Kg } C_6H_{12}}$

$0.0019475\,\text{mol} = \text{mol unknown}$

find molecular weight...

$$MW = \frac{\text{mass unknown}}{\text{mol unknown}}$$

$$MW = \frac{0.2436\,g}{0.0019475\,mol} = 125.0834403\ g/mol$$

Rounding...

$$\boxed{130\ g/mol}$$

Commercial sulfuric acid is 18.0 M. If the density of the acid is 1.802 g/mL, what is the molality?

H_2SO_4, FW = 98.096 g/mol

$$\frac{18.00 \text{ mol } H_2SO_4}{\text{L solution}} \longrightarrow \frac{\text{mol } H_2SO_4}{\text{Kg solvent}}$$

molarity (definition)

molality (definition)

SInce we aren't given an amount of solution, we'll assume a basis to start solving the problem. Assume 1 L solution (bottom of the starting molarity unit). This means we know the solution contains 18.00 mol sulfuric acid.

We need to find kg solvent. To get there, let's start with the 1L solution ... find the mass of solution.

$$1 L = 1000 mL \qquad 1000 mL \times \frac{1.802 g}{mL} = 1802 g \text{ solution}$$

Since the solution contains BOTH sulfuric acid and solvent, we can just subtract out the mass of sulfuric acid. But first, we need to find the mass of sulfuric acid...

$$18.0 \text{ mol } H_2SO_4 \times \frac{98.096 g\, H_2SO_4}{\text{mol } H_2SO_4} = 1765.728 g\, H_2SO_4$$

$$1802 g \text{ solution} - 1765.728 g\, H_2SO_4 = 36.272 g \text{ solvent}$$

$$= 0.036272 Kg \text{ solvent}$$

Calculate molality...

$$\frac{\text{mol } H_2SO_4}{\text{Kg solvent}}$$

molality (definition)

$$\frac{18.0 \text{ mol } H_2SO_4}{0.036272 \text{ Kg solvent}} = \boxed{496\ m\ H_2SO_4}$$