Some sample colligative properties and concentration problems ...

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

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

$\Delta T_f = K_f \times C_m$; $C_m = \frac{\text{mol urea}}{\text{Kg } H_2O}$

P509 - $T_{F,H_2O} = 0.000^oC$

$K_{f,H_2O} = 1.858\ ^oC/m$

We need to find Cm ... the molal concentration ... by finding moles of urea and kilograms water:

$\frac{41\text{g urea}}{100\text{g solution}} \rightarrow \frac{\text{mol urea}}{\text{Kg } H_2O}$

mass percent → molality

Assume a basis of 100 grams solution and work from there. That means we have 41 grams urea. Convert to moles.

$41\text{g urea} \times \frac{\text{mol urea}}{60.062\text{g urea}} = 0.682627951\text{ mol urea}$

Calculate the mass water by subtraction...

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

$C_m = \frac{\text{mol urea}}{\text{Kg } H_2O} = \frac{0.682627951\text{ mol urea}}{0.059\text{ Kg } H_2O} = 11.56996527\text{ m urea}$

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

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

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

$$C_m = \frac{\text{mol urea}}{\text{Kg } H_2O} = \frac{0.682627951 \text{ mol urea}}{0.059 \text{ Kg } H_2O} = 11.56996527 \text{ m urea}$$

Solve for delta T ...

$$\Delta T_f = (1.858\ ^\circ C/m)(11.56996527 \text{ m urea}) = 21.49699548\ ^\circ C$$

Calculate the freezing temperature of the solution by subtracting delta T from the freezing temperature of pure water.

$$T_{f,sol} = 0.000^\circ C - 21.49699548\ ^\circ C = \boxed{-21^\circ C}$$

(2) 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.

$\Delta T_F = K_F \times C_m \longrightarrow C_m = \frac{\text{mol unk}}{\text{Kg } C_6H_{12}}$

ΔT_F: $2.5^\circ C$; K_F: $20.0^\circ C/m$ (p509)

First, calculate Cm (molal concentration of unknown):

$2.5^\circ C = (20.0^\circ C/m) \times C_m$

$C_m = 0.125\ m$

For the molecular weight calculation, we need to find out the moles of unknown. To get it out of molality, we'll have to multiply molality by the mass of cyclohexane used!

Find mass cyclohexane:

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

Find moles unknown.

$0.01558\text{ Kg } C_6H_{12} \times \frac{0.125\text{ mol unk}}{\text{Kg } C_6H_{12}} = 0.0019475\text{ mol unk}$

Now find molecular weight...

$MW = \frac{\text{mass unk}}{\text{mol unk}} = \frac{0.2436\text{ g}}{0.0019475\text{ mol}} = \boxed{130\text{ g/mol}}$ (2 SF)

(3) 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

$$\frac{18.0 \text{ mol } H_2SO_4}{\text{L solution}} \rightarrow \frac{\text{mol } H_2SO_4}{\text{Kg solvent}}$$

molarity → molality

Assume a basis of 1L solution. This means that we know there are 18.0 moles of sulfuric acid in solution. Next, we'll work on finding the mass of solution. Use density.

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

(1 L = 1000 mL)

To get the mass of the solVENT, we'll need to subtract out the mass of sulfuric acid. We can calculate that from moles...

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

Subtract to get mass solvent:

$$1802 \text{ g solution} - 1765.728 \text{ g } H_2SO_4 = 36.272 \text{ g solvent}$$
$$= 0.036272 \text{ Kg solvent}$$

Find molality:

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