Some sample colligative propoerties 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

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

PS09
$K_f = 1.858\,°C/m$
$T_f = 0.000\,°C$

We need to find Cm, and for that we need the mol urea and the kg water.

41% urea : $\dfrac{41 \text{ g urea}}{100 \text{ g solution}} \longrightarrow \dfrac{\text{mol urea}}{\text{kg } H_2O}$

mass percent (definition)

molality (definition)

Assume a basis of 100 g solution, so that there are 41g urea. Convert to moles.

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

Find mass water by subtraction ...

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

Find Cm ...

$$C_m = \frac{0.6826279511 \text{ mol urea}}{0.059 \text{ kg } H_2O} = 11.5696527 \text{ m urea}$$

Find DELTA Tf (freezing point DEPRESSION) ...

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

$$\Delta T_f = (1.858\,^\circ C/m)(11.5696527 \text{ m urea})$$

$$= 21\,^\circ C$$

To find the freezing point of the solution, subtract

$$T_{f,\text{solution}} = 0.000\,^\circ C - 21\,^\circ C = \boxed{-21\,^\circ C}$$

freezing point
of pure water

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.

$$\underbrace{\Delta T_f}_{2.5^\circ C \text{ (given)}} = \underbrace{K_f}_{20.0^\circ C/m \text{ (p509)}} \times C_m$$

$$C_m = \frac{\text{mol unknown}}{\text{kg } C_6H_{12}}$$

First, calculate Cm ...

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

$$C_m = 0.125\,m \rightarrow \frac{0.125 \text{ mol unk}}{\text{kg } C_6H_{12}}$$

To find the moles unknown in the experiment, we need to know how many kg of cyclohexane we actually used (0.125 moles of unknown is the amount of unknown PER KILOGRAM cyclohexane!)

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

(densiry of cyclohexane)

So the moles of unknown are ...

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

To find the molecular weight ...

$$MW = \frac{g\ unk}{mol\ unk} = \frac{0.2436\ g}{0.0019475\ mol\ unk} = \boxed{130\ g/mol}$$

(125.0834403)

calculator answer

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

$$\frac{18.0 \text{ mol } H_2SO_4}{\text{L solution}} \longrightarrow \frac{? \text{ mol } H_2SO_4}{\text{kg solvent}}$$

molarity

molality

Assume a basis of 1L sulfuric acid solution. This means we know the moles of sulfuric acid already (18.0 moles). First, find the mass of SOLUTION (from the 1L basis).

$$\underset{(1L)}{1000 \text{ mL}} \times \underset{(\text{density})}{\frac{1.802 \text{ g}}{\text{mL}}} = 1802 \text{ g solution}$$

We know the mass of SOLUTION now, but we need the mass of the SOLVENT. We need to subtract out the mass of sulfuric acid ... which will leave us wirh the mass of solvent. But how much does the sulfuric acid weigh? Convert 18.0 moles sulfuric acid to mass using the FORMULA WEIGHT ...

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

Subtract to find mass solvent...

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

Find the molality...

$$C_m = \frac{\text{mol } H_2SO_4}{\text{kg solvent}} = \frac{18.0 \text{ mol } H_2SO_4}{0.036272 \text{ kg solvent}} = \boxed{496\, m\ H_2SO_4}$$