Some sample colligative propoerties problems ...

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

$(NH_2)_2CO$: urea

$\Delta T_f = K_f \times C_m$

p509;

$K_{f,water} = 1.858\ °C/m$

$T_{f,water} = 0.000°C$

$C_m = \frac{\text{mol urea}}{\text{kg water}}$

We need to find moles urea and kilograms water. We have the mass percentage of the solution, so we'll have to start there!

41% urea: $\frac{41\text{ g urea}}{100\text{ g solution}}$; mass water: $100\text{ g} - 41\text{ g} = 59\text{ g} = 0.059\text{ kg}$

We need mass WATER, so subtract out the urea!

We've assumed a basis of 100 g solution, so let's see how many moles of urea are in 41 g ...

$(NH_2)_2CO$: N: 2 x 14.01
H: 4 x 1.008
C: 1 x 12.01
O: 1 x 16.00
60.062 g/mol

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

Find Cm:

$$C_m = \frac{\text{mol urea}}{\text{kg water}} = \frac{0.6826279511 \text{ mol urea}}{0.059 \text{ kg}} =$$

$$= 11.5699652\underline{7}\ \underline{m} \text{ urea}$$

Now, we can find delta T:

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

pSo9:

$K_{f,\text{water}} = 1.858\ °C/m$

$T_{f,\text{water}} = 0.000\ °C$

$$\Delta T_f = (1.858\ °C/m)(11.56996527\ \underline{m} \text{ urea})$$

$$= 21\ °C$$

And $T_{f,\text{solution}} = 0\ °C - 21\ °C = \boxed{-21\ °C}$

A compound (containing Mn, C, O) is 28.17% Mn, 30.80% C. A solution of the compound containing 0.125 g in 5.38 g cyclohexane freezes at 5.28 C. What is the molecular formula?

To solve this problem, we need to determine two things: the MOLECULAR WEIGHT of the compound, and the RATIO OF ATOMS OF EACH ELEMENT in the compound. Let's do the molecular weight first...

$\Delta T_F = K_F \times C_m$

PS09: $K_{F,cyc} = 20.0\ ^\circ C/m$, $T_{F,cyc} = 6.55^\circ C$

$C_m = \dfrac{\text{mol unknown}}{\text{kg cyc}}$ ← We want to find moles unknown!

$5.38\ g = 0.00538\ kg$

First, find Cm

$(6.55^\circ C - 5.28^\circ C) = (20.0\ ^\circ C/m)\ C_m$; $C_m = 0.0635\ \underline{m}$

Now, moles of unknown.

$$0.00538\ \text{kg cyc} \times \frac{0.0635\ \text{mol unk}}{\text{kg cyc}} = 3.4163 \times 10^{-4}\ \text{mol unk}$$

So the molecular weight is ...

$$\frac{0.125\ g}{3.4163 \times 10^{-4}\ \text{mol unk}} = \underline{366\ g/mol}$$

Molecular weight of unknown!

Now, we need to convert the mass data given to a ratio of MOLES for the formula ...

28.17 % Mn , 30.80 % C , 100 − 28.17 − 30.80 = 41.03 % O

Assuming 100 g of the compound for the formula calculation, we have:

$$Mn: 28.17 \text{ g Mn} \times \frac{\text{mol Mn}}{54.94 \text{ g Mn}} = 0.512741172 \rightarrow 1 \text{ mol Mn}$$

$$C: 30.80 \text{ g C} \times \frac{\text{mol C}}{12.01 \text{ g C}} = 2.564529559 \rightarrow 5.002 \text{ mol C}$$

$$O: 41.03 \text{ g O} \times \frac{\text{mol O}}{16.00 \text{ g O}} = 2.564375 \rightarrow 5.001 \text{ mol O}$$

To reduce this ratio, divide all parts of the ratio by the smallest number ...

So the EMPIRICAL FORMULA (smallest whole number ratio) is:

MnC_5O_5

Mn: 1 × 54.94
C: 5 × 12.01
O: 5 × 16.00
194.99 g/mol

Now, compare 195 g/mol to 366 g/mol:

195 × 2 = 390, closer to 366 than 195 × 3 ... So,

$Mn_2C_{10}O_{10}$

56 grams of a sample contain 0.51 mole fraction propane and the remainder butane. What are the masses of propane and butane in the sample?

Know: $X_{C_3H_8} = 0.51$

$X_{C_4H_{10}} = (1 - 0.51) = 0.49$

Want: mass C_3H_8, mass C_4H_{10} in 56 g

How do we get from MOLE FRACTION to the masses we need?

$X_{C_3H_8} = \frac{\text{mol } C_3H_8}{\text{total moles}}$

Let's assume ... FOR NOW ... that there's one mole of solution! (Right now, we're ignoring the 56 grams of solution we actually DO have!)

mol $C_3H_8 = 0.51 \times 1 = 0.51$ mol C_3H_8

mol $C_4H_{10} = 0.49 \times 1 = 0.49$ mol C_4H_{10}

Now, convert these to masses...

$$g\ C_3H_8 = 0.51 \text{ mol } C_3H_8 \times \frac{44.094\ g\ C_3H_8}{\text{mol } C_3H_8} = 22.48794\ g\ C_3H_8$$

$$g\ C_4H_{10} = 0.49 \text{ mol } C_4H_{10} \times \frac{58.12\ g\ C_4H_{10}}{\text{mol } C_4H_{10}} = 28.4788\ g\ C_4H_{10}$$

50.96674 g solution

Use the ratio of mass propane/total mass to find the amount of propane in 56 g sample, then do a similar thing for the butane.

$$56\,g \times \frac{22.48794\,g\ C_3H_8}{50.96674\,g\ \text{solution}} = 24.71\,g\ C_3H_8$$

$$56\,g \times \frac{28.47788\,g\ C_4H_{10}}{50.96674\,g\ \text{solution}} = 31.29\,g\ C_4H_{10}$$

So, 25 g C_3H_8 and 31 g C_4H_{10} are in the 56 g sample!

Commercial sulfuric acid (98% by mass) is 18 M. What is the density of the solution, and what is the molality?

Want: $\text{density} = \frac{\text{mass solution}}{\text{volume solution}}$

Know: $18\ M = \frac{\text{mol } H_2SO_4}{\text{L solution}}$

$98\% = \frac{\text{g } H_2SO_4}{100\text{ g solution}}$

Let's start by working with MOLARITY (since it's the only place we can get any information about volume). Assume a basis of 1 L of solution.

$$1\text{ L} \times \frac{18\text{ mol } H_2SO_4}{\text{L}} = 18\text{ mol } H_2SO_4$$

We need mass of solution. We can find mass of SULFURIC ACID be changing this from mass to moles... H_2SO_4: 98.086 g/mol

$$18\text{ mol } H_2SO_4 \times \frac{98.086\text{ g } H_2SO_4}{\text{mol } H_2SO_4} = 1765.548\text{ g } H_2SO_4$$

Since the solution is 98% sulfuric acid ...

$$(\text{mass solution}) \times (0.98) = 1765.548\text{ g } H_2SO_4$$

$$\text{mass solution} = 1801.579592\text{ g solution}$$

Now we can find DENSITY:

$$\text{density} = \frac{\text{mass solution}}{\text{volume solution}} = \frac{1801.579592\text{ g solution}}{1000\text{ mL}} = 1.8\text{ g/mL}$$

$$\text{molality} = \frac{\text{mol } H_2SO_4}{\text{kg } H_2O}$$

If we keep our assumption of 1L of solution, we know the moles sulfuric acid (18 mol). We also know the mass sulfuric acid and the total mass of the solution...

So we can find mass water by subtraction...

$$1801.579592 \text{ g solution} - 1765.548 \text{ g } H_2SO_4 = 36.03159184 \text{ g } H_2O$$

$$= 0.03603159184 \text{ kg } H_2O$$

$$\frac{18 \text{ mol } H_2SO_4}{0.03603159184 \text{ kg } H_2O} = \boxed{5\bar{0}0 \text{ m } H_2SO_4}$$