Some sample colligative propoerties problems from the book...

12.97 p521

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

$(NH_2)_2CO$: urea

$$\Delta T_F = K_f \times C_m$$

p500, $K_{f,H_2O} = 1.858\ ^oC/m$

$T_{F,H_2O} = 0.000\ ^oC$

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

We need to find mol urea and kg water. We know mass percentage, so we'll have to start there.

41% urea : $\frac{41\text{ g urea}}{100\text{ g solution}}$; We need mass WATER to find molality!

mass water = 100g − 41g = 59g

Find moles urea using formula weight and mass.

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

$$41\text{ g urea} \times \frac{\text{mol urea}}{60.062\text{ g urea}} = 0.682627981\text{ mol urea}$$

So, Cm is:

$$C_m = \frac{\text{mol urea}}{\text{kg water}} = \frac{0.682627981\text{ mol urea}}{0.059\text{ kg water}} = 11.56996527\ \underline{m}\ \text{urea}$$

$$C_m = \frac{\text{mol urea}}{\text{kg water}} = \frac{0.682627951 \text{ mol urea}}{0.059 \text{ kg water}} = 11.56996527 \text{ m urea}$$

Now we can find delta Tf:

$$\Delta T_F = \underbrace{K_f}_{\text{p500, } K_{f,H_2O} = 1.858\,^{\circ}C/m} \times C_m$$

$$\Delta T_F = \left(1.858\,^{\circ}C/m\right) \times \left(11.56996527 \text{ m urea}\right) = 21.49699548\,^{\circ}C$$

$$\text{So, } T_f = 0.000\,^{\circ}C - 21.49699548\,^{\circ}C = \boxed{-21\,^{\circ}C}$$

12.105, p 521

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?

$\Delta T_f = K_f \times C_m$

$T_{f,cyc} = 6.55°C$, $K_{f,cyc} = 20.0°C/m$

$C_m = \dfrac{\text{mol unknown}}{\underbrace{\text{kg cyc}}_{5.38\,g = 0.00538\,kg}}$

First, find Cm, then find mol unknown.

$(6.55°C - 5.28°C) = (20.0°C) \times C_m$

$C_m = 0.0635\,m$

Now find moles unknown

$0.0635\,m = \dfrac{\text{mol unknown}}{0.00538\,kg}$, $\text{mol unknown} = 3.4163 \times 10^{-4}\,mol$

Molecular weight:

$$\frac{\text{mass unknown}}{\text{mol unknown}} = \frac{0.125\,g}{3.4163 \times 10^{-4}\,mol} = \underbrace{366\ g/mol}_{\text{Molecular weight of unknown.}}$$

Find empirical formula from the mass data given

28.17 % Mn

30.80 % C

$100\% - 28.17\% - 30.80\% = 41.03\%$ O

Convert this mass data to a MOLAR ratio:

to reduce to whole numbers, divide each term by the smallest (in this case, 0.512...)

Assume 100 g

$28.17\ g\ Mn \times \frac{mol\ Mn}{54.94\ g\ Mn} = 0.512741122\ mol\ Mn$ → 1 mol Mn

$30.80\ g\ C \times \frac{mol\ C}{12.01\ g\ C} = 2.564529559\ mol\ C$ → 5.001 mol C

$41.03\ g\ O \times \frac{mol\ O}{16.00\ g\ O} = 2.564375\ mol\ O$ → 5.001 mol O

1 Mn : 5 C : 5 O

So the EMPIRICAL formula is: MnC_5O_5

Mn: 1 x 54.94

C: 5 x 12.01

O: 5 x 16.00

194.99 g/mol ; compare to MW = 366 g/mol

194.99 times 2 is 390, closest to 366. So molecular formula is empirical times 2

$Mn_2C_{10}O_{10}$