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?

$\Delta T_f = K_f \times C_m$

$C_m = \dfrac{\text{mol unk}}{\text{kg cyc}}$ (kg cyc $= 0.00538$ kg)

p 500:
$T_{f,cyc} = 6.55\,°C$
$K_{f,cyc} = 20.0\,°C/m$

First, find Cm. Then, find moles unknown:

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

$C_m = 0.0635 \dfrac{\text{mol unk}}{\text{kg cyc}}$

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

Molecular weight:

$MW = \dfrac{\text{mass unk}}{\text{mol unk}} = \dfrac{0.125 \text{ g unk}}{3.4163 \times 10^{-4} \text{ mol unk}} = 366 \text{ g/mol}$

Molecular weight of unknown.

Find empirical formula from mass data...

28.17% Mn

30.80% C

100% − 28.17% − 30.80% = 41.03% O

Convert this MASS data to an equivalent MOLAR ratio:

Assume 100 g compound

To reduce this ratio to WHOLE NUMBERS, we will divide all the terms by the smallest one (0.512 here...)

$$28.17\,g\,Mn \times \frac{mol\ Mn}{54.94\,g\,Mn} = 0.512741722\ mol\ Mn \rightarrow 1\ mol\ Mn$$

$$30.80\,g\,C \times \frac{mol\ C}{12.01\,g\,C} = 2.564529559\ mol\ C \rightarrow 5\ mol\ C$$

$$41.03\,g\,O \times \frac{mol\ O}{16.00\,g\,O} = 2.564375\ mol\ O \rightarrow 5\ mol\ O$$

So the EMPIRICAL FORMULA of the unnown 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 366 g/mol

194.99 times 2 is 390, which is closer to the experimental weight of 366 g/mol than other possibilities. So the molecular formula is:

$$\boxed{Mn_2C_{10}O_{10}}$$

12.91, p 520

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 $X_{C_3H_8} = 0.51$

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

Want: mass C_3H_8

mass C_4H_{10}

... in 56 g

$$X_{C_3H_8} = \frac{\text{mol } C_3H_8}{\text{mol } C_3H_8 + \text{mol } C_4H_{10}}$$

We need to convert these MOLE fractions into an equivalent MASS ratio.
Let's assume we have a MOLE of the mixture!

$\text{mol } C_3H_8 = 0.51 \times 1 = 0.51 \text{ mol } C_3H_8$

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

Now, let's find the equivalent MASSES ... we need formula weights.

C_3H_8: 44.094 g/mol | C_4H_{10}: 58.12 g/mol

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

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

50.96674 g total

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

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

$$\overline{50.96674\ g\ total}$$

So, in 56 grams of sample...

$$56\ g \times \frac{22.48794\ g\ C_3H_8}{50.96674\ g\ total} = 24.7\ g\ C_3H_8$$

$$56\ g \times \frac{28.4788\ g\ C_4H_{10}}{50.96674\ g\ total} = 31.3\ g\ C_4H_{10}$$

So, the composition of the mixture is 25 grams propane, 31 grams butane.

12.103, p 521

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

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

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

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

Assume we have 1 L of solution.

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

We need mass of solution ... and we know it's 98% sulfuric acid. So, find the mass of sulfuric acid and then find the total mass using that percentage!

H_2SO_4: H: 2 × 1.008, S: 1 × 32.07, O: 4 × 16.00 = 98.086 g H_2SO_4/mol H_2SO_4

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

$1765.548 \text{ g } H_2SO_4 \times \frac{100 \text{ g solution}}{98 \text{ g } H_2SO_4} = 1801.579592 \text{ g solution}$

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 the same assumptions we made to find density, then we already know the moles sulfuric acid, the total mass of solution, and the mass of sulfuric acid.

FInd mass water by subtraction:

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

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

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