

Some sample colligative properties and concentration problems ..

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



$$\Delta T_f = K_f \times C_m \leftarrow C_m = \frac{\text{mol urea}}{\text{kg H}_2\text{O}}$$

$K_f, \text{H}_2\text{O} = 1.858^\circ\text{C/m}$
 $T_{f, \text{pure H}_2\text{O}} = 0.000^\circ\text{C}$

We need to convert the mass percentage information to molality. Let's assume a basis.

$$\frac{41 \text{ g urea}}{100 \text{ g solution}}$$

Let's assume 100 grams solution (the bottom of the mass percent unit)

mass percent

Convert mass urea (41g) to moles...

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

Subtract to find mass water...

$$100 \text{ g solution} - 41 \text{ g urea} = 59 \text{ g H}_2\text{O} = 0.059 \text{ kg H}_2\text{O}$$

Calculate C_m ...

$$C_m = \frac{\text{mol urea}}{\text{Kg H}_2\text{O}} = \frac{0.6826279511 \text{ mol urea}}{0.059 \text{ Kg H}_2\text{O}} =$$

$$= 11.56996527 \text{ m urea}$$

Find ΔT_f ...

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

$$\Delta T_f = (1.858^\circ\text{C/m})(11.56996527 \text{ m}) = 21^\circ\text{C}$$

Now find freezing temperature of solution...

$$T_f = T_{f, \text{H}_2\text{O}} - \Delta T_f$$

$$= 0.000^\circ\text{C} - 21^\circ\text{C}$$

$$T_f = -21^\circ\text{C}$$

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.

$$\Delta T_f = K_f \times C_m \leftarrow \frac{\text{mol unknown}}{\text{kg } C_6H_{12}}$$

ΔT_f is 2.5°C
 K_f is 1.86°C/m (labeled as 1.860°C/m in the image)
 C_m is mol unknown / kg C_6H_{12}

Our initial goal is to find the MOLES unknown, as we need it to find molecular weight!

Find C_m ...

$$2.5^\circ\text{C} = (1.86^\circ\text{C/m}) \times C_m$$

$$C_m = 0.125\text{ m}$$

to get moles out of molality, we need to find out the actual mass in kg of 20.0 mL of cyclohexane

find mass cyclohexane from volume and density...

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

now find the moles unknown from C_m and the mass cyclohexane

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

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

$$0.0019475\text{ mol} = \text{mol unknown}$$

find molecular weight...

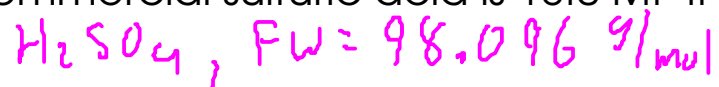
$$MW = \frac{\text{mass unknown}}{\text{mol unknown}}$$

$$MW = \frac{0.2436 \text{ g}}{0.0019475 \text{ mol}} = 125.0834403 \text{ g/mol}$$

Rounding...

$$130 \text{ g/mol}$$

Commercial sulfuric acid is 18.0 M. If the density of the acid is 1.802 g/mL, what is the molality?



$$\frac{18.00 \text{ mol H}_2\text{SO}_4}{\text{L solution}} \longrightarrow \frac{\text{mol H}_2\text{SO}_4}{\text{Kg solvent}}$$

molarity (definition) molality (definition)

Since we aren't given an amount of solution, we'll assume a basis to start solving the problem. Assume 1 L solution (bottom of the starting molarity unit). This means we know the solution contains 18.00 mol sulfuric acid.

We need to find kg solvent. To get there, let's start with the 1L solution ... find the mass of solution.

$$1 \text{ L} = 1000 \text{ mL} \quad 1000 \text{ mL} \times \frac{1.802 \text{ g}}{\text{mL}} = 1802 \text{ g solution}$$

Since the solution contains BOTH sulfuric acid and solvent, we can just subtract out the mass of sulfuric acid. But first, we need to find the mass of sulfuric acid...

$$18.0 \text{ mol H}_2\text{SO}_4 \times \frac{98.096 \text{ g H}_2\text{SO}_4}{\text{mol H}_2\text{SO}_4} = 1765.728 \text{ g H}_2\text{SO}_4$$

$$1802 \text{ g solution} - 1765.728 \text{ g H}_2\text{SO}_4 = 36.272 \text{ g solvent}$$

$$= 0.036272 \text{ Kg solvent}$$

Calculate molality... $\frac{\text{mol H}_2\text{SO}_4}{\text{Kg solvent}}$
molality (definition)

$$\frac{18.0 \text{ mol H}_2\text{SO}_4}{0.036272 \text{ Kg solvent}} = \boxed{496 \text{ m H}_2\text{SO}_4}$$