MOLARITY and the other concentration units

- To convert between molarity and the other three concentration units we've studied, you have to know more about the solution. For example:

molarity $\dfrac{\text{moles A}}{\text{L solution}}$ $\longrightarrow$ molality $\dfrac{\text{moles A}}{\text{kg solvent}}$

* To perform this conversion, you can assume a liter of solution, which will give you the number of moles present. But you've then got to have a way to convert the volume of SOLUTION to the mass of the SOLVENT. How?

* You need DENSITY (which depends on temperature). The density of the solution will allow you to find the total mass of the solution.

* If you subtract out the mass of the SOLUTE, then what you have left is the mass of the SOLVENT. Express that in kilograms, and you have all the information you need to find molality!

* You'll run into the same situation when you use any of the other mass or mole based units. DENSITY is required to go back and forth between MOLARITY and these units.

Example: If a solution is 0.688 m citric acid, what is the molar concentration (M) of the solution? The density of the solution is 1.049 g/mL

$H_3C_6H_5O_7$: 192.125 g/mol "CA"

$$\frac{0.688 \text{ mol CA}}{\text{Kg solvent}} \longrightarrow \frac{? \text{ mol CA}}{\text{L solution}}$$

molality molarity

To solve this problem, assume a basis of 1 kg solvent. That means the solution contains 0.688 moles CA. This will be the same number of moles after the conversion, so all we have to do now is find out the volume of the solution. We've got to calculate the mass of the solution. We already know the solvent weighs 1 kg (1000g), so we must find out how much the CA weighs.

192.125 g CA = mol CA

$$0.688 \text{ mol CA} \times \frac{192.125 \text{ g CA}}{\text{mol CA}} = 132.182 \text{ g CA}$$

So the total mass of solution is ...

1000 g solvent + 132.182 g CA = 1132.182 g solution

The volume is ...

$$1132.182 \text{ g} \times \frac{\text{mL}}{1.049 \text{ g}} = 1079.296473 \text{ mL} = 1.079296473 \text{ L}$$

$$M = \frac{\text{mol CA}}{\text{L solution}} = \frac{0.688 \text{ mol}}{1.079296473 \text{ L}} = \boxed{0.637 \text{ M CA}}$$

An aqueous solution is 8.50% ammonium chloride by mass. The density of the solution is 1.024 g/mL
Find: molality and molarity.

NH_4Cl : 53.491 g/mol H_2O: 18.016 g/mol

$$\frac{8.50\text{ g } NH_4Cl}{100\text{ g solution}} \longrightarrow \frac{\text{mol } NH_4Cl}{\text{kg } H_2O}$$

mass percent   molality

Assume a basis of 100 g solution. This means we have 8.50 g ammonium chloride.

Find moles ammonium chloride

$$8.50\text{ g } NH_4Cl \times \frac{\text{mol } NH_4Cl}{53.491\text{ g } NH_4Cl} = 0.1589052364\text{ mol } NH_4Cl$$

Find mass water

$$100\text{ g solution} - 8.50\text{ g } NH_4Cl = 91.50\text{ g } H_2O = 0.09150\text{ kg } H_2O$$

So the molality is:

$$m = \frac{\text{mol } NH_4Cl}{\text{kg } H_2O} = \frac{0.1589052364\text{ mol } NH_4Cl}{0.09150\text{ kg } H_2O} = \boxed{1.74\text{ m } NH_4Cl}$$

An aqueous solution is 8.50% ammonium chloride by mass. The density of the solution is 1.024 g/mL
Find: molality and molarity.

NH_4Cl : 53.491 g/mol H_2O: 18.016 g/mol

$$\frac{8.50\ g\ NH_4Cl}{100\ g\ solution} \rightarrow \frac{mol\ NH_4Cl}{L\ solution}$$

mass percent   molarity

As before, assume a basis of 100g solution. We can re-use the calculated moles of ammonoum chloride. So we just have to find the solution volume.

$0.1589052364\ mol\ NH_4Cl$ (found earlier)

Find volume solution

$$100\ g\ solution \times \frac{mL}{1.024\ g} = 97.65625\ mL = 0.09765625\ L$$

Molarity is:

$$M = \frac{mol\ NH_4Cl}{L\ solution} = \frac{0.1589052364\ mol\ NH_4Cl}{0.09765625\ L} = \boxed{1.63\ M\ NH_4Cl}$$

COLLIGATIVE PROPERTIES

- properties unique to solutions.

- depend only on the CONCENTRATION of a solution and not the IDENTITY of the solute**

**ionic solutes: Remember that they dissociate into MULTIPLE IONS!

1. Freezing point depression
   - The freezing temperature of a SOLUTION gets lower as the CONCENTRATION of a solution increases.

2. Vapor pressure lowering
   - The vapor pressure of a solution (pressure of sovent vapor over a liquid surface) goes DOWN as solution concentration goes UP

3. Boiling point elevation
   - The boiling temperature of a solution increases as the concentration of the solution increases.

4. Osmotic pressure
   - The pressure required to PREVENT the process of osmosis

FREEZING POINT DEPRESSION

$$\Delta T_f = K_f \times c_m$$

- c_m — concentration of solute (molality)
- K_f — Freezing point depression constant (for SOLVENT)
- ΔT_f — Freezing point depression: The amount the freezing temperature is LOWERED by the solute.

- Applications: In chemistry, this effect is often used to determine the molecular weight of an unknown molecule.