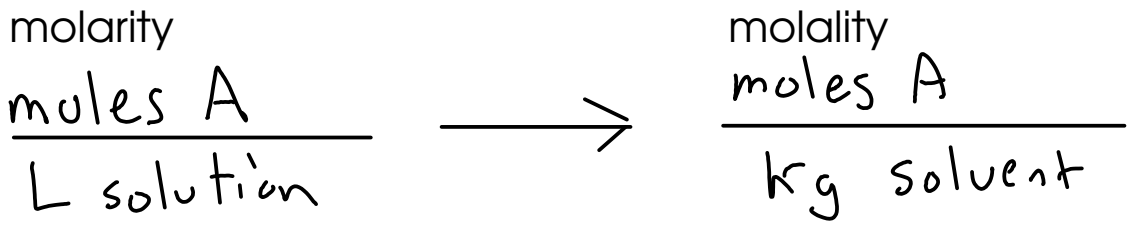
MOLARITY and the other concentration units

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



* 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 (definition) → molarity (definition)

1 - ASSUME A BASIS of 1 kg of SOLVENT. Each kilogram of solvent contains 0.688 mol CA.
2 - Find VOLUME OF SOLUTION. We know the DENSITY of the solution, but we know only the mass of the SOLVENT (not the solution). To use the denisty, we need to find the mass of the SOLUTION. Convert the moles of CA to mass, then add it to the mass of solvent - giving us the MASS OF SOLUTION.

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

$$\text{mass solution} = 1000 \text{ g solvent} + 132.182 \text{ g CA} = 1132.182 \text{ g solution}$$

Find volume solution:

$$1132.182 \text{ g solution} \times \frac{\text{mL}}{1.049 \text{ g}} \times \frac{10^{-3} \text{ L}}{\text{mL}} = 1.079296473 \text{ L}$$

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

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

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

Find molality:

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

molality

Find mol ammonium chloride:

$$8.50\ g\ NH_4Cl \times \frac{mol\ NH_4Cl}{53.491\ g\ NH_4Cl} = 0.158905236\ mol\ NH_4Cl$$

Find mass water:

$$100\ g\ solution - 8.50\ g\ NH_4Cl = 91.5\ g\ H_2O = 0.0915\ kg\ H_2O$$

Molality:

$$\frac{0.158905236\ mol\ NH_4Cl}{0.0915\ kg\ H_2O} = \boxed{1.74\ m\ NH_4Cl}$$

Mole fraction:

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

mass percent

mole fraction

We already know the moles ammonium chloride, so all we need to find is the moles of water.

Hint: We already know MASS of water from the previous calcualtion.

An aqueous solution is 8.50% ammonium chloride by mass. The density of the solution is 1.024 g/mL

Find: molality, mole fraction, molarity.

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

Find moles water:

$$91.5\text{ g } H_2O \times \frac{\text{mol } H_2O}{18.016\text{ g } H_2O} = 5.078818828\text{ mol } H_2O$$

$$X_{NH_4Cl} = \frac{0.158905236\text{ mol } NH_4Cl}{0.158905236\text{ mol } NH_4Cl + 5.078818828\text{ mol } H_2O}$$

$$= \boxed{0.0303}$$ (if we need Xwater, Xwater=1-Xammonium chloride)

Molarity:

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

mass percent molarity

We know moles ammonium chliride, so all we need to find is the volume of the solution in liters.

$$100\text{ g solution} \times \frac{\text{mL}}{1.024\text{ g}} \times \frac{10^{-3}\text{ L}}{\text{mL}} = 0.0976562\text{5 L}$$

$$M = \frac{0.158905236\text{ mol } NH_4Cl}{0.0976562\text{5 L}} = \boxed{1.63\ \underline{M}\ NH_4Cl}$$