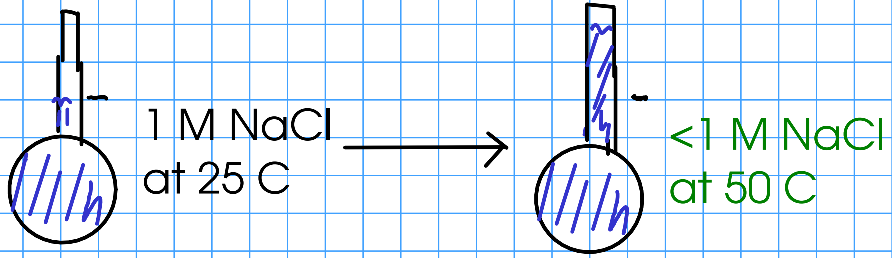
MOLARITY

- In the previous example, we converted between three of the four units that we discussed: mass percent, molality, and mole fraction.

- We didn't do MOLARITY, because the information given in the previous problem was not sufficient to determine molarity!

$$\underline{M} = \frac{\text{moles solute}}{\underline{\text{L solution}}}$$



Molarity is based on VOLUME, while the other three units are based on MASS. (moles and mass can be directly converted)

Volume depends on TEMPERATURE!

- If you HEAT a solution, what happens to CONCENTRATION?

ex: $\underline{5.00 \text{ mol } Na_2SO_4}$ in $\underline{1 \text{ L solution}}$

└ constant when heated

└ increases. (thermal expansion)

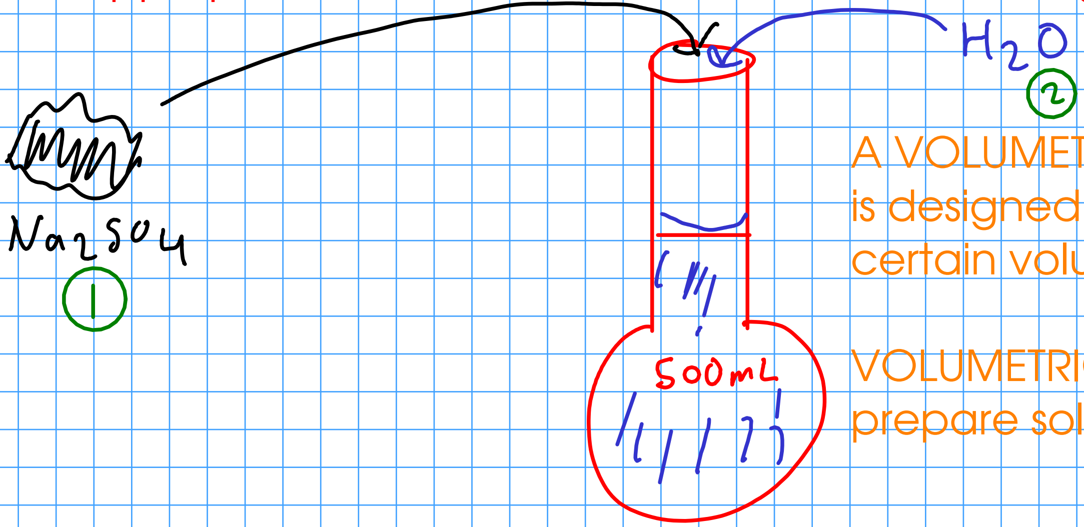
... the MOLAR CONCENTRATION decreases. (But the concentration in the other three units we discussed stays the same.)

- If you COOL a solution, the MOLAR CONCENTRATION increases. (The other three units stay the same!)

... we use MOLARITY so much because it's easy to work with. It is easier to measure the VOLUME of a liquid solution than it is to measure mass.

Example: How would we prepare 500. mL of 0.500 M sodium sulfate in water?

Dissolve the appropriate amount of sodium sulfate into enough water to make 500. mL of solution.



volumetric flask

A VOLUMETRIC FLASK is a flask that is designed to precisely contain a certain volume of liquid.

VOLUMETRIC FLASKS are used to prepare solutions.

Calculate the moles of sodium sulfate in 500. mL (0.500 L) solution, then convert to grams.

$$\underline{M} = \frac{\text{mol } Na_2SO_4}{\text{L solution}}$$

$$0.500 \text{ mol } Na_2SO_4 = 1L$$

$$0.500L \times \frac{0.500 \text{ mol } Na_2SO_4}{1L} = 0.250 \text{ mol } Na_2SO_4$$

$$142.04 \text{ g } Na_2SO_4 = \text{mol } Na_2SO_4$$

$$0.250 \text{ mol } Na_2SO_4 \times \frac{142.04 \text{ g } Na_2SO_4}{\text{mol } Na_2SO_4} = 35.5 \text{ g } Na_2SO_4$$

Dissolve 35.5 g of sodium sulfate in enough water to make 500 mL of solution.

More on MOLARITY

To prepare a solution of a given molarity, you generally have two options:

① Weigh out the appropriate amount of solute, then dilute to the desired volume with solvent (usually water)

② Take a previously prepared solution of known concentration and DILUTE it with solvent to form a new solution

- Use DILUTION EQUATION

The dilution equation is easy to derive with simple algebra.

$$M \times V$$

$$\frac{mol}{L} \times L = \text{moles solute}$$

... but when you dilute a solution, the number of moles of solute REMAINS CONSTANT. (After all, you're adding only SOLVENT)

$$M_1 V_1 = M_2 V_2$$

↖ Since the number of moles of solute stays the same, this equality must be true!

before diution

after dilution

$M_1V_1 = M_2V_2$ ... the "DILUTION EQUATION"

M_1 = molarity of concentrated solution

V_1 = volume of concentrated solution

M_2 = molarity of dilute solution

V_2 = volume of dilute solution

The volumes don't HAVE to be in liters, as long as you use the same volume UNIT for both volumes!

Example: Take the 0.500 M sodium sulfate we discussed in the previous example and dilute it to make 150. mL of 0.333 M solution. How many mL of the original solution will we need to dilute?

$M_1V_1 = M_2V_2$

$M_1 = 0.500\,M$ $V_1 = ?$

$M_2 = 0.333\,M$ $V_2 = 150.\,mL$

$(0.500\,\underline{M})\,V_1 = (0.333\,\underline{M})(150.\,mL)$

$V_1 =$ 99.9 mL of 0.500 M Na_2SO_4, then dilute to 150 mL with water

MOLARITY and the other concentration units

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

molarity $\qquad\qquad\qquad\qquad$ molality

$$\frac{\text{moles A}}{\text{L solution}} \longrightarrow \frac{\text{moles A}}{\text{kg solvent}}$$

* 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"

$$\frac{0,688 \text{ mol CA}}{1 \text{ kg solvent}} \longrightarrow \frac{? \text{ mol CA}}{? \text{ L solution}}$$

molality (m)

molarity (M)

* Assume 1 kg of solvent, meaning that the number of moles of CA is 0.688 mol.

* Next, find the volume of the solution. Use the density of the solution, but there's a catch!

* We'll have to calculate the total mass of the SOLUTION - meaning the mass of the solvent (1000 g here) PLUS the mass of the CA solute.

$$0,688 \text{ mol CA} \times \frac{192.125 \text{ g CA}}{\text{mol CA}} = 132,182 \text{ g CA}$$

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

* Now, we can use the density!

$$1132,182 \text{ g} \times \frac{\text{mL}}{1,049 \text{ g}} \times \frac{10^{-3} \text{ L}}{\text{mL}} = 1,079296 \text{ L solution}$$

* Divide the moles CA (0.688 mol) and the volume of solution (1.079296 L) to get MOLARITY (M)

$$\frac{0,688 \text{ mol CA}}{1,079296 \text{ L solution}} = \boxed{0,637 \ \underline{M} \text{ CA}}$$

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

$$\frac{8.50\,g\ NH_4Cl}{100\,g\ \text{solution}} \longrightarrow \frac{?\ mol\ NH_4Cl}{?\ kg\ \text{solvent}}$$

mass percent

molality

mass solvent: $100g - 8.5g = 91.5g\ H_2O$

moles ammonium chloride: $8.50g\ NH_4Cl \times \frac{mol}{53.491\,g} = 0.15891\ mol\ NH_4Cl$

$$m = \frac{0.15891\ mol}{0.0915\ kg} = \boxed{1.74\ m\ NH_4Cl}$$