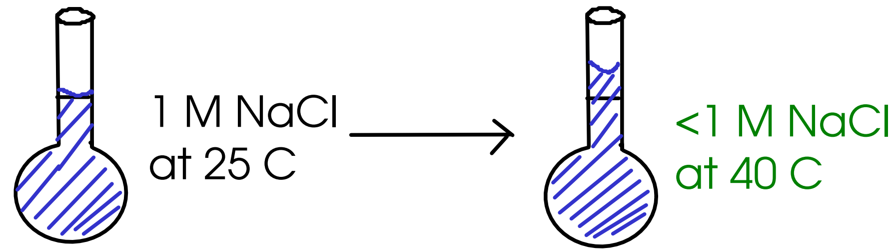
MOLARITY

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

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

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



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: 5.00 mol Na_2SO_4 in 1 L solution

5.00 mol Na_2SO_4: constant when heated

1 L solution: increases. (thermal expansion)

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

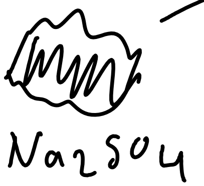
- If you COOL a solution, the MOLAR CONCENTRATION increases. (The other three units stay the same!)

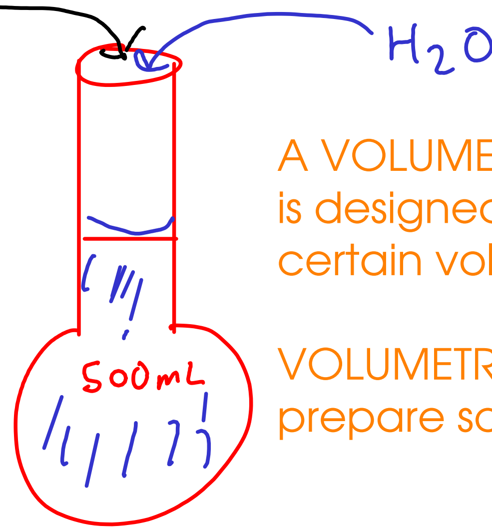
... we use MOLARITY so much because it's easy to work with. It is easier to measure the VOLUME of a liquid solution than it is to measure mass.

Na_2SO_4 : (142.05 g/mol)

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.





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

VOLUMETRIC FLASKS are used to prepare solutions.

$$0.500\,M = \frac{\text{mol } Na_2SO_4}{\text{L solution}}$$

definition of molarity

*500mL = 0.500L

= 0.500 L (500. mL flask!)

volumetric flask

Let's start by solving for moles of sodium sulfate (it's the only term in the definition we don't know!)

$$0.500 = \frac{\text{mol } Na_2SO_4}{0.500} \; ; \qquad 0.250 = \text{mol } Na_2SO_4$$

We need to put 0.250 mol sodium sulfate in the flask, so let's change that to grams so we can measure it on the balance!

$$0.250 \text{ mol } Na_2SO_4 \times \frac{142.05 \text{ g } Na_2SO_4}{\text{mol } Na_2SO_4} = \boxed{35.5 \text{ g } Na_2SO_4}$$

Put 35.5 grams of sodium sulfate into a 500. mL volumetric flask, then add water to the mark.

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)"

"stock solution"

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 ←(TOTAL VOLUME, NOT the volume water added!)

The volumes don't HAVE to be in liters, as long as you use the same volume UNIT for both V_1 and V_2

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?

$M_1V_1 = M_2V_2$

$(0.500\ M)V_1 = (0.333\ M)(150\ mL)$

$V_1 = \boxed{99.9\ mL\ \text{of}\ 0.500\ M\ Na_2SO_4}$

$M_1 = 0.500\ M$

$V_1 = ?$

$M_2 = 0.333\ M$

$V_2 = 150.\ mL$

Measure out 99.9 mL of 0.500 M sodium sulfate, then add enough water to make a total volume of 150. mL.
If you're in a hurry, you can do this in a single large graduated cylinder!

MOLARITY and the other concentration units

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

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

* 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"

$$\frac{\text{mol CA}}{\text{kg solvent}} \rightarrow \frac{\text{mol CA}}{\text{L solution}}$$

Definition of molality Definition of molarity

Assume a basis of exactly 1 kg of solvent. This means that we have 0.688 moles of CA dissolved in that 1 kg of solvent! So, all we need to find out to get the answer is how many liters of solution we have! We can convert between mass and volume using the DENSITY, but the density given is for the SOLUTION. So let's calculate how much the solution weighs!

FInd the mass of CA: $0.688 \text{ mol CA} \times \frac{192.125 \text{ g CA}}{\text{mol CA}} = 132.182 \text{ g CA}$

Total mass of solution is: $1000 \text{ g solvent} + 132.182 \text{ g CA} = 1132.182 \text{ g solution}$

Convert mass solution to volume: $1132.182 \text{ g solution} \times \frac{\text{mL}}{1.049 \text{ g}} = 1079.296473 \text{ mL}$

$= 1.079296473 \text{ L}$

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

An aqueous solution is contains 8.50 grams of ammonium chloride in each 100. grams of solution. The density of the solution is 1.024 g/mL. Find the molality and molarity of the solution.

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

$$\frac{8.50\,g\ NH_4Cl}{100g.\ solution} \longrightarrow \frac{mol\ NH_4Cl \quad ①}{Kg\ H_2O \quad ②}$$

Given information

Definition of molality

Let's use a basis of 100 grams solution. We know that there are 8.50 grams of ammonium chloride dissolved in the 100 grams solution.

(1) Convert 8.50 grams ammonium chloride to moles using formula weight.
(2) Find the mass of water by subtraction (then convert to kg).

① $8.50\,g\ NH_4Cl \times \frac{mol\ NH_4Cl}{53.491\,g\ NH_4Cl} = 0.158905236\,4\ mol\ NH_4Cl$

② $100\,g\ solution - 8.50\,g\ NH_4Cl = 91.5\,g\ H_2O = 0.0915\ kg\ H_2O$

$$m = \frac{mol\ NH_4Cl}{Kg\ H_2O} = \frac{0.1589052364\ mol\ NH_4Cl}{0.0915\ kg\ H_2O} = \boxed{1.74\,m\ NH_4Cl}$$