29.6 g Na_2SO_4, 425.4 g water ← previous solution

$$X_{Na_2SO_4} = \frac{\text{mol } Na_2SO_4}{\text{mol Solution}} \quad \begin{matrix} ① \\ ② \end{matrix}$$

1 - Convert 29.6 grams sodium sulfate to moles. Use FORMULA WEIGHT. Since we already did this to find molality, we will just use the previous calculation.
2 - To find moles solution, we need to find the moles WATER, and then ADD it to the moles of sodium sulfate.

① 0.208377331 9 mol Na_2SO_4

H_2O: H - 2 x 1.008
O - 1 x 16.00
18.016 g H_2O = mol H_2O

$$425.4 \text{ g } H_2O \times \frac{\text{mol } H_2O}{18.016 \text{ g } H_2O} = 23.61234458 \text{ mol } H_2O$$

total = 0.2083773319 mol + 23.61234458 mol = 23.82072191 mol solution

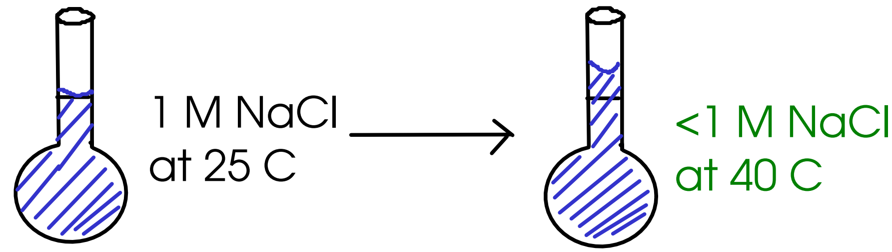
$$X_{Na_2SO_4} = \frac{0.2083773319 \text{ mol } Na_2SO_4}{23.82072191 \text{ mol solution}} = \boxed{0.00875}$$

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: $\underbrace{5.00 \text{ mol } Na_2SO_4}_{\text{constant when heated}}$ in $\underbrace{1 \text{ L solution}}_{\text{increases, (thermal expansion)}}$

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

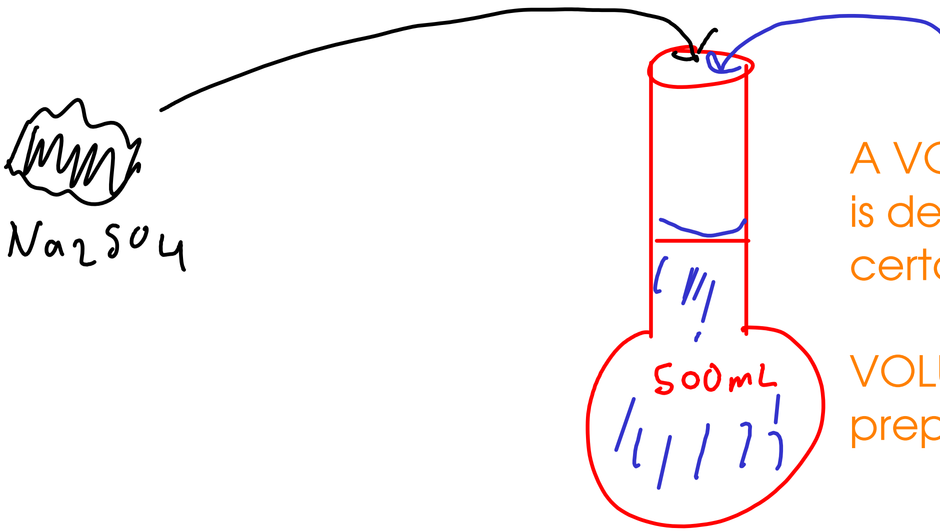
- If you COOL a solution, the MOLAR CONCENTRATION increases. (The other three units stay the same!)

... 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.



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.

* 500 mL = 0.500 L

Start with 500 mL of solution, then calculate the moles sodium sulfate required to make 0.500 M solution.

$$\underset{\text{(molarity)}}{0.500\ M} = \frac{\text{mol } Na_2SO_4}{\underset{\uparrow\ 500\text{ mL volume}}{0.500\ L}} \rightarrow 0.250 \text{ mol } Na_2SO_4$$

Solve for mol sodium sulfate

To prepare solution, we need to WEIGH OUT the sodium sulfate, so change to mass.

$142.05\text{ g } Na_2SO_4 = \text{mol } Na_2SO_4$

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

To prepare the solution, add 35.5 g sodium sulfate to 500 mL volumetric flask, then fill to the mark with distilled/deionized water.

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?

$M_1V_1 = M_2V_2$

$M_1 = 0.500\ M$ $\quad M_2 = 0.333\ M$

$V_1 = ?$ $\quad V_2 = 150.\ mL$

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

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

To prepare the solution, take 99.9 mL of the 0.500 M sodium sulfate solution, then add distilled water until the total volume is 150. mL.

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 $\quad\quad\quad\quad\quad\quad\quad\quad$ 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"

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

molality (definition) molarity (definition)

To solve this problem, we will ASSUME A BASIS of 1 kg solvent. With a basis of 1 kg solvent, we know that there are 0.688 moles of CA. So to finish solving the problem, we have to calculate the VOLUME of SOLUTION. We can calculate volume by using DENSITY, but we'll first have to find the mass of the solution. First, let's find the mass of CA ...

192.125 g CA = mol CA

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

(1 kg solvent = 1000 g solvent)

So the mass of solution is ...

1000 g solvent + 132.182 g CA = 1132.182 g solution

To find volume, use density ... 1.049 g = mL

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

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