How would you prepare 455 grams of an aqueous solution that is 6.50% sodium sulfate by mass?

$$\underset{\uparrow\ 6.50}{\text{mass \%}} = \frac{\text{mass } Na_2SO_4}{\underset{\uparrow\ 455g}{\text{mass solution}}} \times 100$$

Start a concentration calculation by writing the definition of the unit(s) you're using!

We know everything here except the mass of sodium sulfate. We can solve the defintion above to calculate that mass.

$$6.50 = \frac{\text{mass } Na_2SO_4}{455g} \times 100$$

$$29.6g = \text{mass } Na_2SO_4$$

Subtract to find the mass of water in the solution.

$$\underset{\text{total}}{455g} - \underset{Na_2SO_4}{29.6g} = 425.4g\ H_2O$$

Add 29.6 grams of sodium sulfate to 425.4 grams water to make the 6.50% solution.

What's the MOLALITY and MOLE FRACTION OF SOLUTE of the previous solution?

29.6 g Na_2SO_4, 425.4 g water ← previous solution

Let's find molality. Write the definition.

$$\frac{\text{moles } Na_2SO_4 \text{ ①}}{\text{Kg } H_2O \text{ ②}}$$

definition of molality

We need to find out two things to solve this one.
(1) Moles sodium sulfate. Find by converting 29.6 grams of sodium sulfate to moles. Use FORMULA WEIGHT.
(2) Kg of water. Convert 425.4 grams water to kilograms.

① Na_2SO_4: Na - 2x22.99
S - 1x32.07
O - 4x16.00

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

$$29.6\text{ g } Na_2SO_4 \times \frac{\text{mol } Na_2SO_4}{142.05\text{ g } Na_2SO_4} = 0.2083773319\text{ mol } Na_2SO_4$$

② $\text{kg} = 10^3\text{ g}$

$$425.4\text{ g } H_2O \times \frac{\text{kg}}{10^3\text{ g}} = 0.4254\text{ kg } H_2O$$

$$m = \frac{\text{moles } Na_2SO_4}{\text{Kg } H_2O} = \frac{0.2083773319\text{ mol } Na_2SO_4}{0.4254\text{ kg } H_2O} = \boxed{0.490\text{ m } Na_2SO_4}$$

29.6 g Na_2SO_4, 425.4 g water ← previous solution

Finally, find mole fraction. As before, start with the definition.

$$\frac{\text{mol } Na_2SO_4 \quad ①}{\text{total moles solution} \quad ②}$$

Mole fraction
(definition)

We need to calculate the numerator and denominator of the fraction.

(1) Moles sodium sulfate. Convert 29.6 grams sodium sulfate to moles. We've already got that number since we found it as part of our molality calculation.

2) Total moles. We need to add the moles of sodium sulfate to the moles of water, which means we need to find the moles of water. Convert 425.4 grams water to moles using formula weight.

H_2O: H − 2×1.008

O − 1×16.00

18.016 g H_2O = mol H_2O

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

$$X_{Na_2SO_4} = \frac{0.2083773319 \text{ mol } Na_2SO_4}{0.2083773319 \text{ mol } Na_2SO_4 + 23.61234458 \text{ mol } H_2O} = \boxed{0.00875}$$

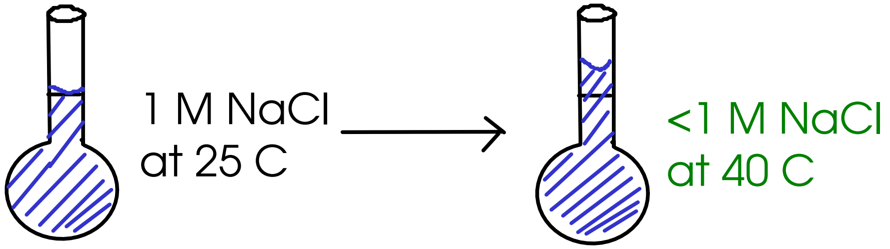
MOLARITY

- 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.)

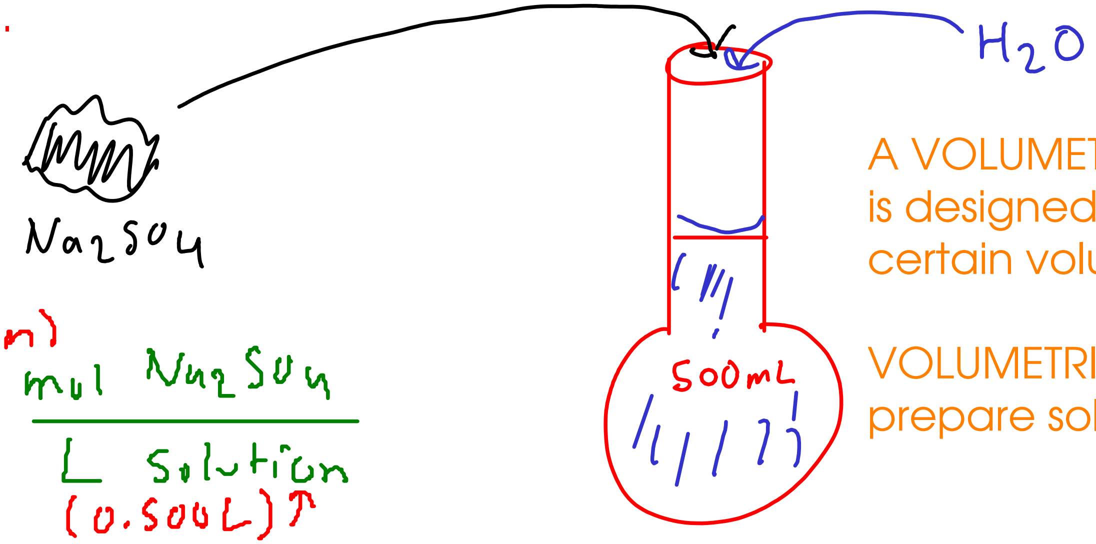
- If you COOL a solution, the MOLAR CONCENTRATION increases. (The other three units stay the same!)

... 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.

*500mL = 0.500L

$$\overset{(0.500\,m)}{M} = \frac{mol\ Na_2SO_4}{\underset{(0.500L)}{L\ solution}}$$

molarity (defintion)

Write down the defintion of molarity and fill in the things we know (concentration ... 0.500 M, and volume ... 500. mL or 0.500 L). The only thing we don't know yet is the moles of sodium sulfate. Calculate it.

$$0.500 \frac{mol}{L} = \frac{mol\ Na_2SO_4}{0.500L} \ ; \ 0.250\ mol = mol\ Na_2SO_4$$

To measure the 0.250 mol sodium sulfate, we'll need to know the weight, Convert moles to mass.

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

Add 35.5 grams sodium sulfate to a 500 mL volumetric flask, then add DI 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)

$$M_1V_1 = M_2V_2$$

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?

$M_1V_1 = M_2V_2$

$M_1 = 0.500\ M$

$V_1 = ?$

$M_2 = 0.333\ M$

$V_2 = 150.\ mL$

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

$V_1 = 99.9\ mL$ of $0.500\ M\ Na_2SO_4$

Measure out 99.9 mL of 0.500 M sodium sulfate, then add enough water to make the total volume 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 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.