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

$$\text{mass \%} = \frac{\text{mass } Na_2SO_4}{\text{mass solution}} \times 100$$

6.50 ↑

↑ 455g

Start concentration calculations by writing out the definition(s) of the unit(s) you're going to be using.

We know both the percentage (6.50) and the total mass of the solution (455g), so the only thing we need to calculate in the defintiion is the mass of sodium sulfate.

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

↓ ① ×455

② ÷100

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

We also need to know the amount of water to add to the sodium sulfate. Calculate by subtraction.

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

So dissolve 29.6 grams sodium sulfate in 425.4 grams water.

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

Again, start off with the definition of the unit, in this case MOLALITY.

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

molality (definition)

(1) Convert 29.6 grams sodium sulfate to moles. Use FORMULA WEIGHT.

(2) Convert 425.4 grams water to kilograms.

① Na_2SO_4: Na: 2×22.99

S: 1×32.07

O: 4×16.00

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

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

② $$425.4 \text{ g } H_2O \times \frac{\text{Kg}}{10^3 \text{ g}} = 0.4254 \text{ Kg } H_2O$$

$\text{Kg} = 10^3 \text{ g}$

Now, calculate molaity:

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

29.6 g Na_2SO_4, 425.4 g water ← previous solution

Again, start with the definition of the unit. Here, it's MOLE FRACTION.

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

mole fraction (definition)

(1) Convert 29.6 grams of sodum sulfate to moles using FORMULA WEIGHT. But ... we've already done that in the previous example, so let's go ahead and use that number.

(2) Total moles of solution is the sum oif all the moles of all components. We already know the sodium sulfate from (1) We'll need to calculate the moles of water. Convert 425.4 grams water to moles.

① $0.2083773319 \text{ mol } Na_2SO_4$

---

② H_2O - H: 2×1.008

O: 1×16.00

$18.016 \text{ g } H_2O = \text{mol } H_2O$

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

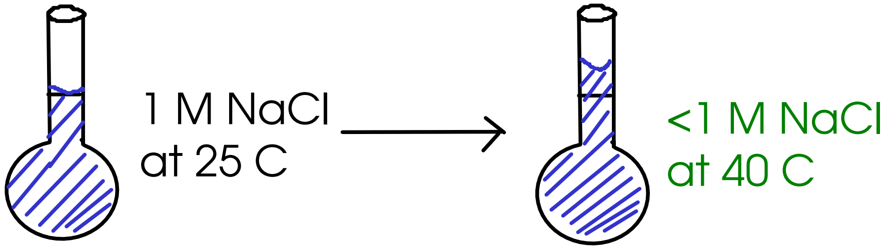
$$\frac{\text{mol } Na_2SO_4}{\text{total mol solution}} = \frac{0.2083773319 \text{ mol } Na_2SO_4}{0.2083773319 \text{ mol } Na_2SO_4 + 23.61234458 \text{ mol } H_2O} = \boxed{0.00875}$$

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: $\underline{5.00 \text{ mol } Na_2SO_4}$ 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.)

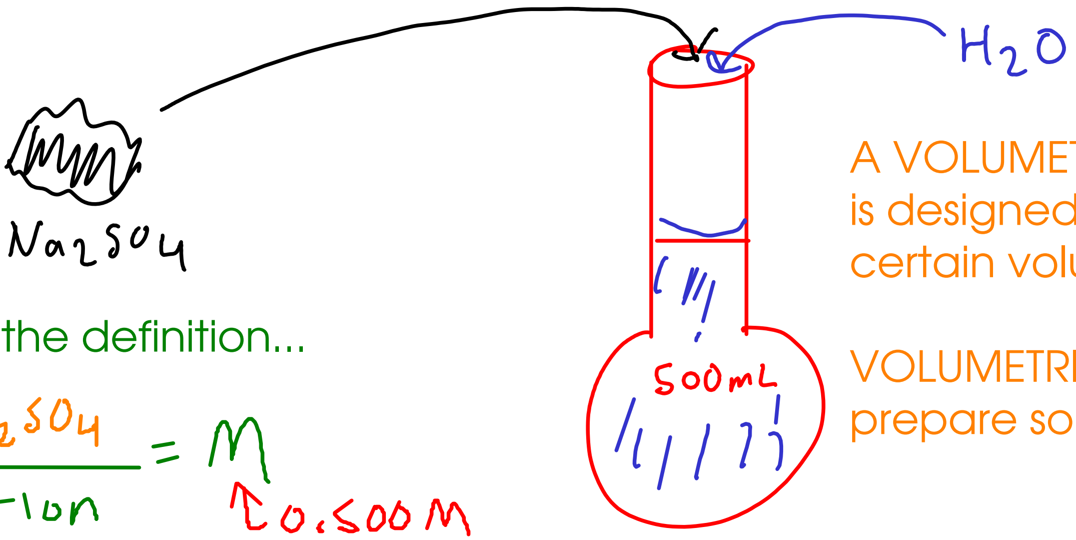
- If you COOL a solution, the MOLAR CONCENTRATION increases. (The other three units stay the same!)

... 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.

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

Start with the definition...

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

↑0.500 M

↑0.500L (500mL)

We can calculate the moles sodium sulfate (we know everthing else in the definition!)

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

Now convert moles sodium sulfate to mass...

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

Add 35.5 grams sodium sulfate to a 500 mL volumetric flask, and then add water to the mark for a total of 500 mL 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)"

"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?

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

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

$$M_1V_1 = M_2V_2$$

$$(0.500\ M)(V_1) = (.333\ M)(150.\ mL)$$

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

Measure out 99.9 mL of 0.500 M sodium sulfate solution, then add enough water to make a total volume of 150. mL (use a volumetric flask or graduated cylinder)