# CONCENTRATION

- When you discuss a solution, you need to be aware of:
  - what materials are in the solution
  - how much of each material is in the solution

- CONCENTRATION is the amount of one substance compared to the others in a solution. This sounds vague, but that's because there are many different ways to specify concentration!

- We will discuss three different concentration units in CHM 111:

(1) MOLARITY

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

(2) MOLALITY

$$= \frac{\text{moles solute}}{\text{kg solvent}} \qquad m$$

(3) MOLE FRACTION

$$= \frac{\text{moles component A}}{\text{moles solution}} \qquad X_A$$

What's the MOLALITY and MOLE FRACTION OF SOLUTE of a solution that contains 29.6 grams of sodium sulfate dissolved in 425.4 grams of distillied water?

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

Definition of molality

1) Calculate moles sodium sulfate. Convert 29.6 grams of sodium sulfate to moles using FORMULA WEIGHT.

2) Calculate kg water. Convert 425.4 g water to kg.

① $Na_2SO_4$: Na : 2 x 22.99
S : 1 x 32.07
O : 4 x 16.00
142.05 g $Na_2SO_4$ = mol $Na_2SO_4$

$$29.6\ g\ Na_2SO_4 \times \frac{mol\ Na_2SO_4}{142.05\ g\ Na_2SO_4} = 0.208377331 9\ mol\ Na_2SO_4$$

② $Kg = 10^3 g$

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

$$m = \frac{0.208377331 9\ mol\ Na_2SO_4}{0.4254\ kg\ H_2O} = \boxed{0.490\ m\ Na_2SO_4}$$

29.6 g $Na_2SO_4$, 425.4 g water ← previous solution

$$\frac{\text{moles } Na_2SO_4 \ ①}{\text{moles solution} \ ②}$$

Definition of mole fraction

1) Find moles sodium sulfate. Convert 29.6 grams of sodium sulfate to moles. Use FORMULA WEIGHT. (Already done, just use previous calculation.)
2) Find moles solution. The moles solution equals the moles of sodium sulfate PLUS the moles of water. Convert 425.4 grams water to moles to find moles water.

① 0.208377319 mol $Na_2SO_4$

② $H_2O$: H: 2 x 1.008
O: 1 x 16.00
16.016 g $H_2O$ = mol $H_2O$

$$425.4\ g\ H_2O \times \frac{\text{mol } H_2O}{16.016\ g\ H_2O} = 23.61234458 \text{ mol } H_2O$$

mol solution = mol $Na_2SO_4$ + mol $H_2O$ =
0.208377319 + 23.61234458 = 23.82072191 mol solution

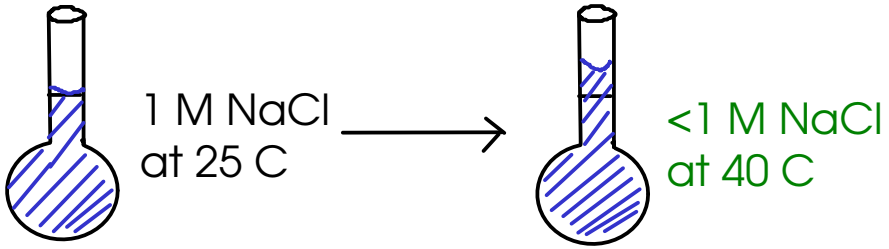
$$X_{Na_2SO_4} = \frac{0.208377319 \text{ mol } Na_2SO_4}{23.82072191 \text{ mol solution}} = \boxed{0.00875}$$

# 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!

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




Molarity is based on VOLUME, while the other two 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.)

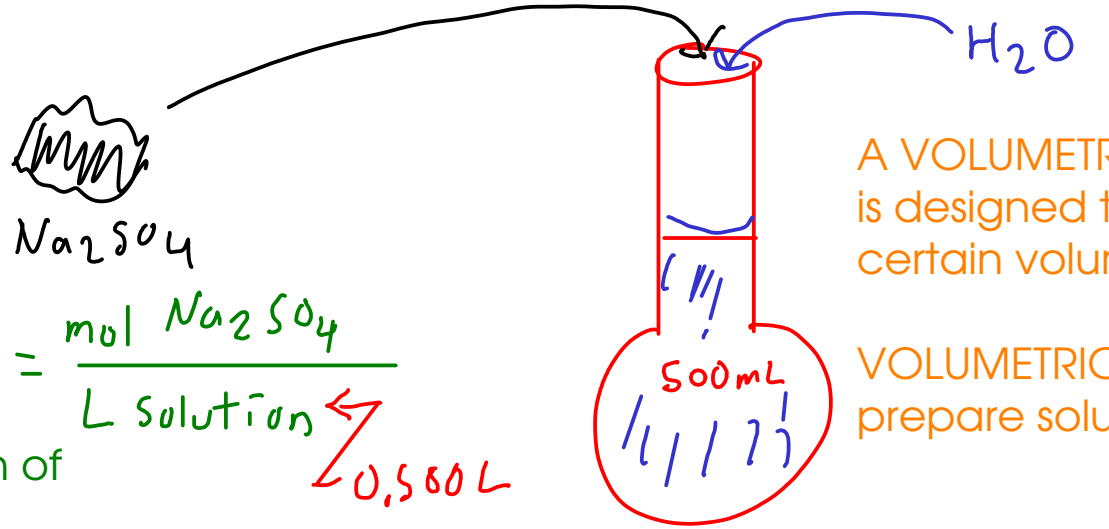
- If you COOL a solution, the MOLAR CONCENTRATION increases. (The other three units stay the same!)

... 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.




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.

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

0.500 L

Definition of molarity

*500mL = 0.500L

Start by noticing that the only part of the definition of molarity that we DON'T know is the moles of sodium sulfate. Calculate that!

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

Now, convert 0.250 mol sodium sulfate to mass. Use FORMULA WEIGHT.

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

Weigh 35.5 grams 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)"

2. Take a previously prepared solution ("stock 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.

$M \times V$

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

... 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?

$M_1V_1 = M_2V_2$

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

$V_1 = \boxed{99.9\ mL}$

$M_1 = 0.500\ M$

$V_1 = ?$

$M_2 = 0.333\ M$

$V_2 = 150.\ mL$

Take 99.9 mL of the 0.500 M sodium sulfate solution, then add enough water so that the TOTAL volume is 150. mL. (Often we'd say "dilute to 150. mL" here).