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?

Let's find MOLALITY first ...

$$\frac{\text{moles } Na_2SO_4 \ (1)}{\text{kg } H_2O \ (2)}$$

molality (definition)

To find molality, we need to calculate: (1) the moles sodium sulfate and (2) the mass of water in kilograms.

(1) Find moles sodium sulfate. Use formula weight to convert 29.6 grams of sodium sulfate to moles.

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

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

(2) Find mass water. We already know the mass in grams, so just convert to kg.

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

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

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

29.6 g Na_2SO_4, 425.4 g water ← previous solution

Like before, start with the definition of the unit we need

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

We need to find (1) moles of sodium sulfate, and (2) the total moles of all components in the solution.

(1) Moles sodium sulfate calculated already when we did the molality calculation.

0.2083773319 mol Na_2SO_4

(2) We need to find the moles water, then add them to the moles of sodium sulfate.

H_2O: H - 2 x 1.008
O - 1 x 16.00

16.016 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 Na_2SO_4 + 23.61234458 mol H_2O
= 23.82072191 mol

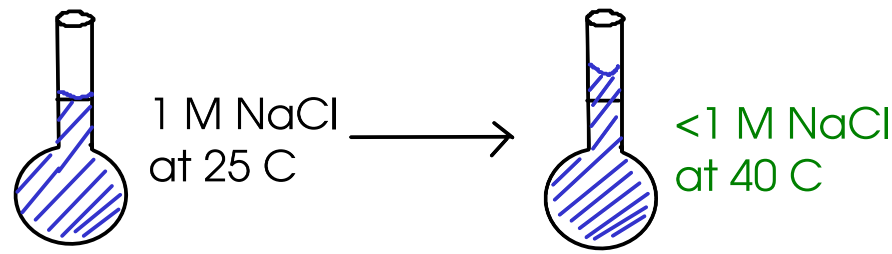
$$X_{Na_2SO_4} = \frac{0.2083773319 \text{ mol } Na_2SO_4}{23.82072191 \text{ mol}} = \boxed{0.00875}$$

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 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.)

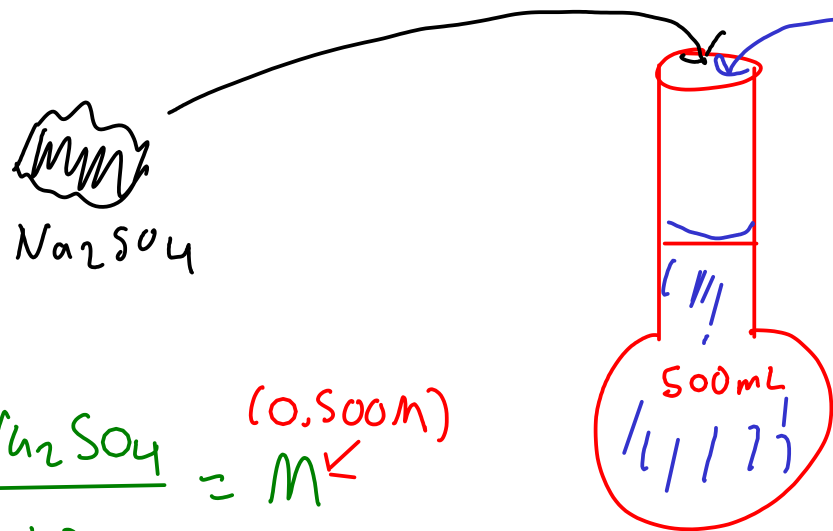
- If you COOL a solution, the MOLAR CONCENTRATION increases. (The other three units stay the same!)

... 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.



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.

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

(0.500 M) → M; (0.500 L) → L solution

molarity (definition)

$*$ 500 mL = 0.500 L

Start with the defintion. We already know molarity (0.500 M) and volume (0.500 L), so we calculate moles of sodium sulfate. Then, convert to grams.

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

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

Put 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.

$$M \times V$$

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

... 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?

$$M_1V_1 = M_2V_2$$

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

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

$M_1 = 0.500\,M$

$V_1 = ?$

$M_2 = 0.333\,M$

$V_2 = 150.\,mL$

Start with 99.9 mL of 0.500 M sodium sulfate, then add water until the volume is 150. mL.