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 four different concentration units in CHM 111:

(1) MASS PERCENTAGE

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

%, % w/w

(2) MOLARITY

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

M or $\underline{M}$

(3) MOLALITY

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

m

(4) MOLE FRACTION

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

X_A

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

mass percent: $\frac{g\ Na_2SO_4}{g\ solution} \times 100 = 6.50$ (given)

↑ 455 g (given)

First, find the grams sodium sulfate by using the definition of mass percentage.

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

÷100
×455 g

$$g\ Na_2SO_4 = 29.575\ g\ Na_2SO_4 \text{ in solution}$$

To prepare the solution, we also need to know the amount of water. Find by subtraction.

$$455\ g\ solution - 29.575\ g\ Na_2SO_4 = 425.425\ g\ H_2O$$

So, add 29.6 grams sodium sulfate to 425.4 grams water to prepare 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

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

molality (definition)

1 - Calculate moles sodium sulfate. 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 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) $$425.4 \text{ g } H_2O \times \frac{\text{Kg}}{10^3 \text{ g}} = 0.4254 \text{ kg } H_2O$$

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

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

29.6 g Na_2SO_4, 425.4 g water ← previous solution

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

mole fraction (definition)

1 - Convert 29.6 grams sodium sulfate to moles. We already did this to find molality, so we can re-use the number.

2 - This is the total moles of both sodium sulfate and water. We need to find the moles of water. Convert 425.4 grams water to moles using FORMULA WEIGHT.

① 0.2083773319 mol Na_2SO_4

② H_2O: H - 2 × 1.008
O - 1 × 16.00

18.016 g H_2O = mol H_2O

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

mol solution = 0.2083773319 mol Na_2SO_4 + 23.61234458 mol H_2O
= 23.82072191 mol solution

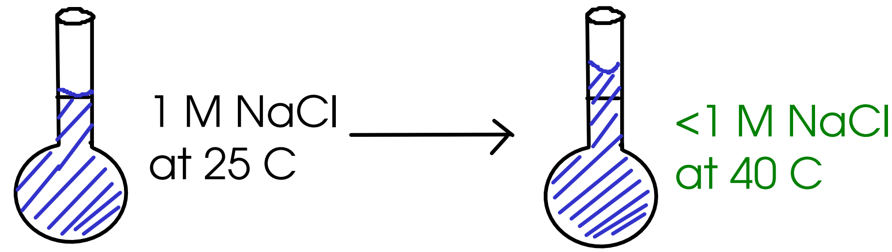
$$X_{Na_2SO_4} = \frac{0.2083773319 \text{ mol } Na_2SO_4}{23.82072191 \text{ mol solution}} = \boxed{0.0120}$$

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!

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



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.)

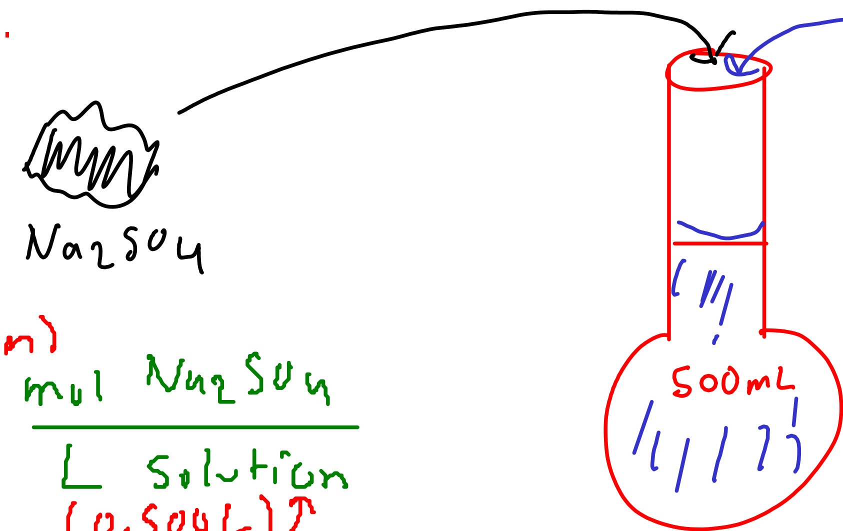
- If you COOL a solution, the MOLAR CONCENTRATION increases. (The other three units stay the same!)

... 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.

$$M = \frac{\text{mol } Na_2SO_4}{\text{L solution}} \quad (M = 0.500\text{ M};\ \text{L solution} = 0.500\text{ L})$$

molarity (definition)

* 500mL = 0.500L

We already know the desired molarity (0.500 M) and we know the volume of solution (500 mL, or 0.500 L). We simply need to find the mass of sodium sulfate to dissolve.

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

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

Add 35.5 grams sodium sulfate to 500 mL volumetric flask and dilute to the mark with deionized or distilled 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)

$$M_1 V_1 = M_2 V_2$$

before diution

after dilution

Since the number of moles of solute stays the same, this equality must be true!