PERCENTAGE COMPOSITION

- sometimes called "percent composition" or "percent composition by mass"
- the percentage of each element in a compound, expressed in terms of mass

Example: Find the percentage composition of barium chloride.

$BaCl_2$: Ba: $1 \times 137.3 = 137.3$

Cl: $2 \times 35.45 = 70.90$

These numbers are the masses of each element in a mole of the compound!

$208.2\ g\ BaCl_2 = mol\ BaCl_2$

$$\%Ba = \frac{137.3\ g\ Ba}{208.2\ g\ BaCl_2} \times 100 = 65.95\%\ Ba$$

$$\%Cl = \frac{70.90\ g\ Cl}{208.2\ g\ BaCl_2} \times 100 = 34.05\%\ Cl$$

These percentages should sum to 100% within roundoff error.

So far, we have

- looked at how to determine the composition by mass of a compound from a formula
- converted from MASS to MOLES (related to the number of atoms/molecules)
- converted from MOLES to MASS

Are we missing anything?

- What about SOLUTIONS, where the desired chemical is not PURE, but found DISSOLVED IN WATER?
- How do we deal with finding the moles of a desired chemical when it's in solution?

MOLAR CONCENTRATION *

- unit: MOLARITY (M): moles of dissolved substance per LITER of solution

$$M = \text{molarity} = \frac{\text{moles of SOLUTE}}{\text{L SOLUTION}}$$

(SOLUTE ← dissolved substance)

6.0 M HCl solution: $\frac{6.0 \text{ mol HCl}}{\text{L}}$

If you have 0.250 L (250 mL) of 6.0 M HCl, how many moles of HCl do you have?

6.0 mol HCl = L

$$0.250 \text{ L} \times \frac{6.0 \text{ mol HCl}}{\text{L}} = 1.5 \text{ mol HCl}$$

*See SECTIONS 4.7 - 4.10 for more information about MOLARITY and solution calculations (p 154 - 162 - 9th edition) (p 156-164 - 10th edition)

If you need 0.657 moles of hydrochloric acid, how many liters of 0.0555 M HCl do you need to measure out?

0.0555 mol HCl = L

This solution is too dilute for this situation ... we'd need a huge volume of it!

$$0.657 \text{ mol HCl} \times \frac{\text{L}}{0.0555 \text{ mol HCl}} = \boxed{11.8 \text{ L of } 0.0555 \text{ M HCl}}$$

(11800 mL)

What if we used 6.00 M HCl?

6.00 mol HCl = L

$$0.657 \text{ mol HCl} \times \frac{\text{L}}{6.00 \text{ mol HCl}} = \boxed{0.110 \text{ L of } 6.00 \text{ M HCl}}$$

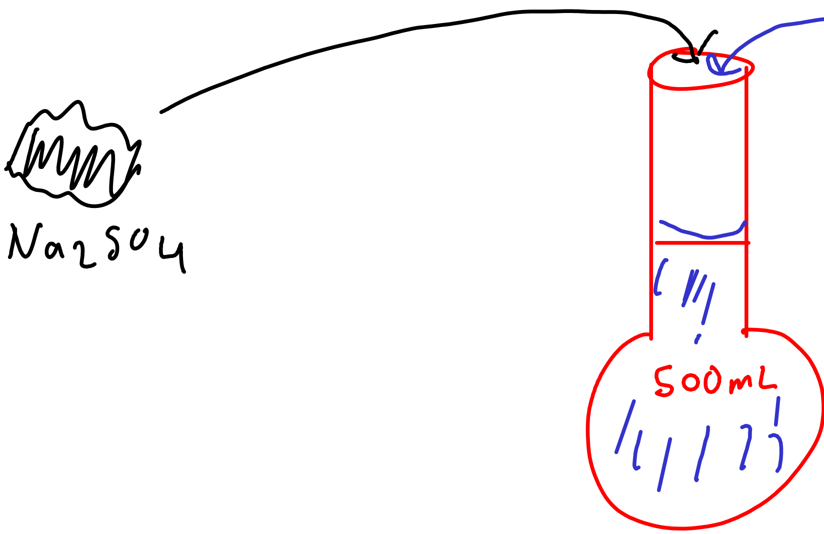
(110 mL)

This solution would be usable, as 110. mL is not an overly large volume for our lab!

Example: How would we prepare 500. mL of 0.500 M sodium sulfate in water?

$Na_2SO_4 : 142.05\ g/mol$

Dissolve the appropriate amount of sodium sulfate into enough water to make 500. mL of solution.



A VOLUMETRIC FLASK is a flask that is designed to precisely contain a certain volume of liquid.

VOLUMETRIC FLASKS are used to prepare solutions.

volumetric flask

To find out the amount of sodium sulfate, first use the volume and concentration to calculate the MOLES of sodium sulfate in the solution.

$0.500\ mol\ Na_2SO_4 = L \qquad mL = 10^{-3}\ L$

$$500\ mL \times \frac{10^{-3}\ L}{mL} \times \frac{0.500\ mol\ Na_2SO_4}{L} = 0.250\ mol\ Na_2SO_4$$

To find the mass (necessary to weigh the material out on a balance!), use formula weight:

$142.05\ g\ Na_2SO_4 = mol\ Na_2SO_4$

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

To make solution, add 35.5 g sodium sulfate to a 500 mL volumetric flask and 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.

$$M \times V$$

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

... but when you dilute a solution, the number of moles of solute REMAINS CONSTANT. (After all, you're adding only SOLVENT)

$$M_1V_1 = M_2V_2$$

before diution — after dilution

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

$M_1V_1 = M_2V_2$ ... 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 volume of added solvent!)

The volumes don't HAVE to be in liters, as long as you use the same volume UNIT for both volumes!

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?

$M_1V_1 = M_2V_2$

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

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

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

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

To prepare the 0.333 M solution, take 99.9 mL of 0.500 M solution and add enough water to make a volume of 150. mL.

CHEMICAL CALCULATIONS CONTINUED: REACTIONS

- Chemical reactions proceed on an ATOMIC basis, NOT a mass basis!

- To calculate with chemical reactions (i.e. use chemical equations), we need everything in terms of ATOMS ... which means MOLES of atoms

$$2\,Al(s) + 3\,Br_2(l) \rightarrow 2\,AlBr_3(s)$$

coefficients are in terms of atoms and molecules!

2 atoms Al = 3 molecules Br_2 = 2 formula units $AlBr_3$

2 mol Al = 3 mol Br_2 = 2 mol $AlBr_3$

- To do chemical calculations, we need to:
    - Relate the amount of substance we know (mass or volume) to a number of moles
    - Relate the moles of one substance to the moles of another using the equation
    - Convert the moles of the new substance to mass or volume as desired

$$2\,Al(s) + 3\,Br_2(l) \longrightarrow 2\,AlBr_3(s)$$

* Given that we have 25.0 g of liquid bromine, how many grams of aluminum would we need to react away all of the bromine?

(1) Convert grams of bromine to moles: Need formula weight $Br_2: 2 \times 79.90 = 159.80$

$159.80\,g\,Br_2 = mol\,Br_2$

$$25.0\,g\,Br_2 \times \frac{mol\,Br_2}{159.80\,g\,Br_2} = 0.15645\,mol\,Br_2$$

(2) Use the chemical equation to relate moles of bromine to moles of aluminum

$2\,mol\,Al = 3\,mol\,Br_2$

$$0.15645\,mol\,Br_2 \times \frac{2\,mol\,Al}{3\,mol\,Br_2} = 0.10430\,mol\,Al$$

(3) Convert moles aluminum to mass: Need formula weight $Al: 26.98$

$26.98\,g\,Al = mol\,Al$

$$0.10430\,mol\,Al \times \frac{26.98\,g\,Al}{mol\,Al} = \boxed{2.81\,g\,Al}$$