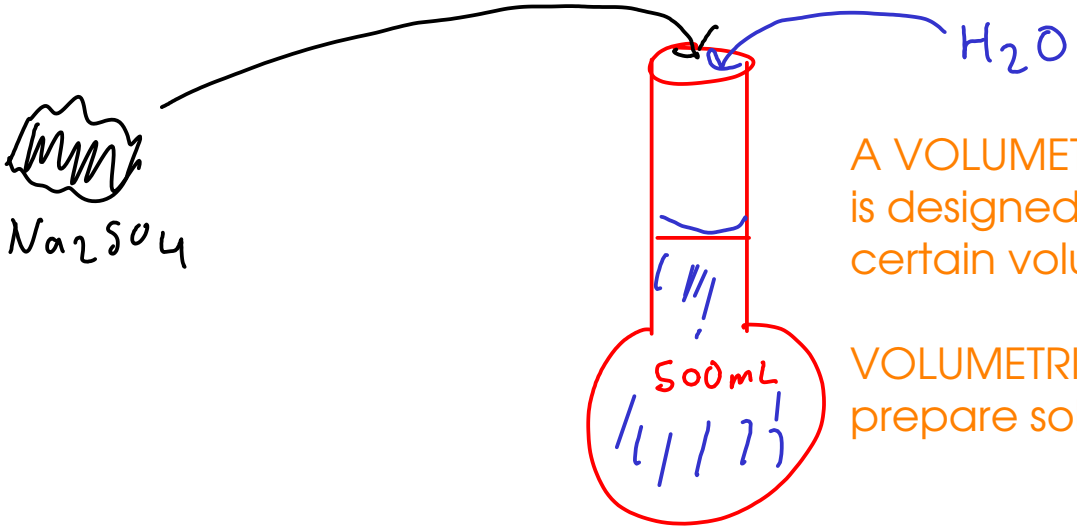
Example: How would we prepare 500. mL of 0.500 M sodium sulfate in water?

Na_2SO_4 : 142.05 g/mol

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



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.

We will use the VOLUME and the MOLARITY to find out how many MOLES of sodium sulfate need to be dissolved. Then, we can convert MOLES to MASS using FORMULA WEIGHT.

$1\ mL = 10^{-3}\ L$ $\quad 0.500\ mol\ Na_2SO_4 = 1\ L$

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

$142.05\ g\ Na_2SO_4 = 1\ mol\ Na_2SO_4$

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

To prepare the solution, put 35.5 g of sodium sulfate into a 500 mL volumetric flask, then fill to the mark with deionized 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)

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!

$M_1 V_1$: before dilution

$M_2 V_2$: 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 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?

$M_1V_1 = M_2V_2$

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

$V_1 =$ 99.9 mL of 0.500 M Na_2SO_4

$M_1 = 0.500\,M$

$V_1 = ?$

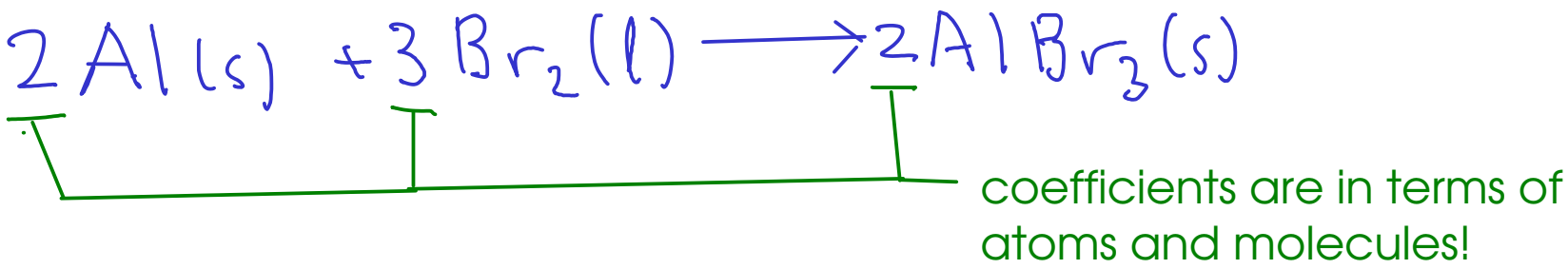
$M_2 = 0.333\,M$

$V_2 = 150\,mL$

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 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 $Al = 26.98$

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

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

You can combine all three steps on one line if you like!

① $159.80\ g\ Br_2 = mol\ Br_2$ ② $2\ mol\ Al = 3\ mol\ Br_2$ ③ $26.98\ g\ Al = mol\ Al$

$$25.0\ g\ Br_2 \times \underbrace{\frac{mol\ Br_2}{159.80\ g\ Br_2}}_{①} \times \underbrace{\frac{2\ mol\ Al}{3\ mol\ Br_2}}_{②} \times \underbrace{\frac{26.98\ g\ Al}{mol\ Al}}_{③} = \boxed{2.81\ g\ Al}$$

Things we can do:

If we have ...	... and we need ...	Use ...
MASS	MOLES	FORMULA WEIGHT
SOLUTION VOLUME	MOLES	MOLAR CONCETRATION (MOLARITY)
MOLES OF A	MOLES OF B	BALANCED CHEMICAL EQUATION

Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?

$$2HCl(aq) + Na_2CO_3(s) \longrightarrow H_2O(l) + CO_2(g) + 2NaCl(aq)$$

1 - Convert 25.0 grams sodium carbonate to moles. Use FORMULA WEIGHT.
2 - Convert moles of sodium carbonate to moles HCl. Use CHEMICAL EQUATION.
3 - Convent moles HCl to volume of 6.00 M HCl solution. Use MOLARITY (6.00 M HCl).

Na_2CO_3 – Na: 2×22.99
C: 1×12.01
O: 3×16.00
$105.99\ g\ Na_2CO_3 = mol\ Na_2CO_3$

① $25.0\ g\ Na_2CO_3 \times \frac{mol\ Na_2CO_3}{105.99\ g\ Na_2CO_3} = 0.2358713086\ mol\ Na_2CO_3$

$2\ mol\ HCl = mol\ Na_2CO_3$

② $0.2358713086\ mol\ Na_2CO_3 \times \frac{2\ mol\ HCl}{mol\ Na_2CO_3} = 0.4717426172\ mol\ HCl$

Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?

$$2HCl(aq) + Na_2CO_3(s) \longrightarrow H_2O(l) + CO_2(g) + 2NaCl(aq)$$

1 - Convert 25.0 grams sodium carbonate to moles. Use FORMULA WEIGHT.
2 - Convert moles of sodium carbonate to moles HCl. Use CHEMICAL EQUATION.
3 - Convent moles HCl to volume of 6.00 M HCl solution. Use MOLARITY (6.00 M HCl).

$6.00\ mol\ HCl = L$

③ $0.4717426172\ mol\ HCl \times \frac{L}{6.00\ mol\ HCl} = 0.07866\ L\ of\ 6.00\ M\ HCl$

We calculated volume in liters, but the problem asks us specifically for milliliters. We need to do a quick unit conversion

$mL = 10^{-3} L$

$$0.07866\ L \times \frac{mL}{10^{-3}\ L} = \boxed{78.6\ mL\ of\ 6.00\ M\ HCl}$$