

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.

$\text{Na}_2\text{SO}_4: 142.05 \text{ g/mol}$

Na_2SO_4

H_2O

500 mL

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 know that we need 500. mL of solution, and that the concentration should be 0.500 M. From that, we can calculate the number of moles sodium sulfate, and then convert that number of moles to mass. This will tell us how much sodium sulfate to weigh out.

$$0.500 \text{ mol Na}_2\text{SO}_4 = \text{L} \quad | \quad \text{mL} = 10^{-3} \text{ L} \quad | \quad 142.05 \text{ g Na}_2\text{SO}_4 = \text{mol Na}_2\text{SO}_4$$

$$500. \text{ mL} \times \frac{10^{-3} \text{ L}}{\text{mL}} \times \frac{0.500 \text{ mol Na}_2\text{SO}_4}{\text{L}} \times \frac{142.05 \text{ g Na}_2\text{SO}_4}{\text{mol Na}_2\text{SO}_4} = \boxed{35.5 \text{ g Na}_2\text{SO}_4}$$

So, to prepare this solution, weigh out 35.5 grams of sodium sulfate, add to a 500 mL volumetric flask, and dilute to 500 mL with 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)

② Take a previously prepared solution of known concentration and DILUTE it with solvent to form a new solution

"stock 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)

$$M_1 V_1 = M_2 V_2$$

before
dilution

after
dilution

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

$$M_1 V_1 = M_2 V_2 \quad \dots \text{the "DILUTION EQUATION"}$$

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?

$$M_1 = 0.500 \text{ M}$$

$$M_2 = 0.333 \text{ M}$$

$$M_1 V_1 = M_2 V_2$$

$$V_1 = ?$$

$$V_2 = 150. \text{ mL}$$

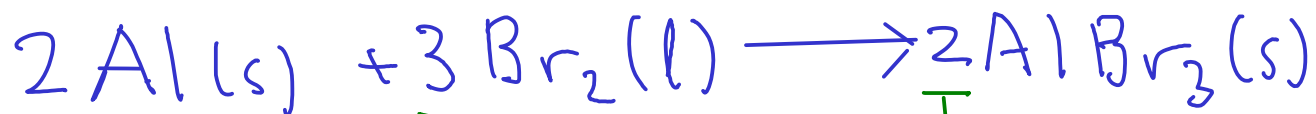
$$(0.500 \text{ M}) \times V_1 = (0.333 \text{ M}) \times (150. \text{ mL})$$

$$V_1 = \boxed{99.9 \text{ mL of } 0.500 \text{ M Na}_2\text{SO}_4}$$

So, to prepare the new solution, we measure out 99.9 mL of the 0.500 M stock, then add enough water to make 150 mL of solution. (Ideally, we'd use a 150 mL volumetric flask to contain the solution...)

CHEMICAL CALCULATIONS CONTINUED: REACTIONS

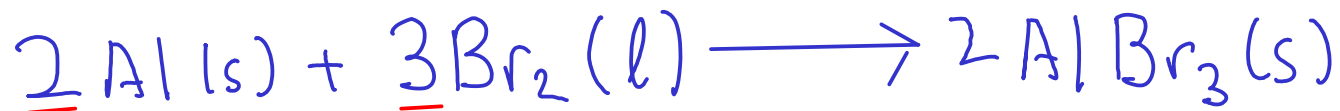
- Chemical reactions proceed on an ATOMIC basis, NOT a mass basis!
- To calculate with chemical reactions (i.e. use chemical equations), we need everything in terms of ATOMS ... which means MOLES of atoms



coefficients are in terms of atoms and molecules!



- 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



* 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? How many grams of aluminum bromide would be produced?

① Convert grams of bromine to moles: Need formula weight Br_2 : $\frac{2 \times 79.90}{159.80}$

$$159.80 \text{ g Br}_2 = 1 \text{ mol Br}_2$$

$$25.0 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.80 \text{ g Br}_2} = 0.15645 \text{ mol Br}_2$$

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

$$2 \text{ mol Al} = 3 \text{ mol Br}_2$$

$$0.15645 \text{ mol Br}_2 \times \frac{2 \text{ mol Al}}{3 \text{ mol Br}_2} = 0.10430 \text{ mol Al}$$

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

$$26.98 \text{ g Al} = 1 \text{ mol Al}$$

$$0.10430 \text{ mol Al} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = \boxed{2.81 \text{ g Al}}$$

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

$$25.0 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.80 \text{ g Br}_2} \times \frac{2 \text{ mol Al}}{3 \text{ mol Br}_2} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = 2.81 \text{ g Al}$$

①
②
③

You can solve the second part of the question using CONSERVATION OF MASS - since there's only a single product and you already know the mass of all reactants.

$$\begin{array}{r} 25.0 \text{ g Br}_2 \\ + 2.81 \text{ g Al} \\ \hline 27.8 \text{ g AlBr}_3 \end{array}$$

But ...

...what would you have done to calculate the mass of aluminum bromide IF you had NOT been asked to calculate the mass of aluminum FIRST?

$$25.0 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.80 \text{ g Br}_2} \times \frac{2 \text{ mol AlBr}_3}{3 \text{ mol Br}_2} \times \frac{266.694 \text{ g AlBr}_3}{1 \text{ mol AlBr}_3} = 27.8 \text{ g AlBr}_3$$

①
②
③

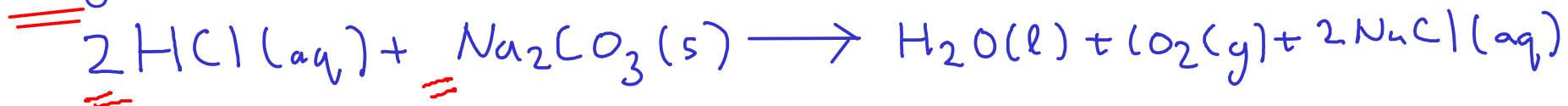
convert mass
bromine
to moles

convert moles
bromine to
moles aluminum
bromide

convert moles
aluminum
bromide
to mass

Example:

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



- 1 - Convert 25.0g sodium carbonate to moles. Use FORMULA WEIGHT of sodium carbonate.
- 2 - Convert moles sodium carbonate to moles HCl. Use CHEMICAL EQUATION.
- 3 - Convert moles HCl to volume. Use MOLAR CONCENTRATION of HCl (and L → mL conversion)

① Na_2CO_3 : Na : 2×22.99
 C : 1×12.01
 O : 3×16.00
↓ Formula weight of sodium carbonate.
 $105.99 \text{ g Na}_2\text{CO}_3 = 1 \text{ mol Na}_2\text{CO}_3$

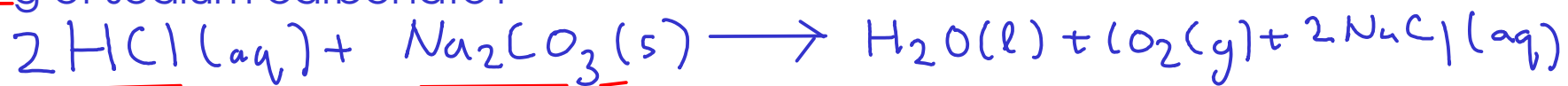
$$25.0 \text{ g Na}_2\text{CO}_3 \times \frac{1 \text{ mol Na}_2\text{CO}_3}{105.99 \text{ g Na}_2\text{CO}_3} = 0.2358713086 \text{ mol Na}_2\text{CO}_3$$

② $2 \text{ mol HCl} = 1 \text{ mol Na}_2\text{CO}_3$

$$0.2358713086 \text{ mol Na}_2\text{CO}_3 \times \frac{2 \text{ mol HCl}}{1 \text{ mol Na}_2\text{CO}_3} = 0.4717426172 \text{ mol HCl}$$

Example:

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



- 1 - Convert 25.0g sodium carbonate to moles. Use FORMULA WEIGHT of sodium carbonate.
- 2 - Convert moles sodium carbonate to moles HCl. Use CHEMICAL EQUATION.
- 3 - Convert moles HCl to volume. Use MOLAR CONCENTRATION of HCl (and L → mL conversion)

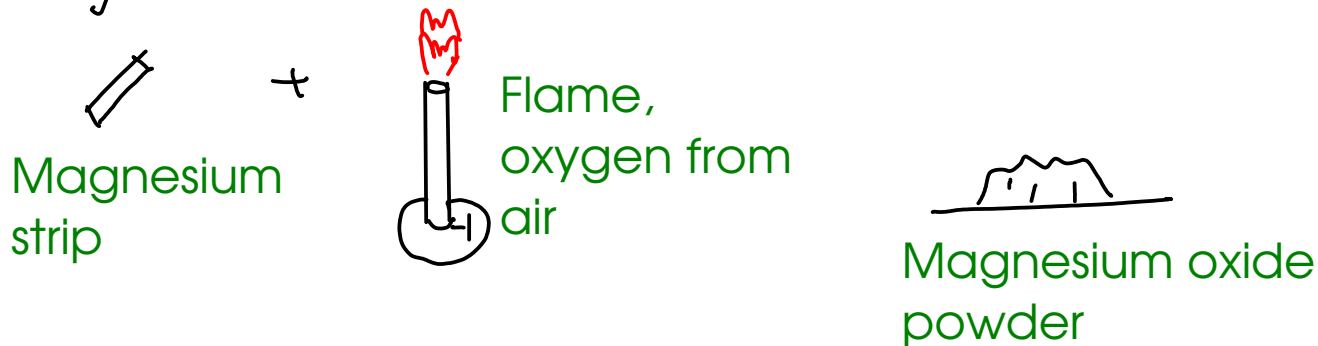
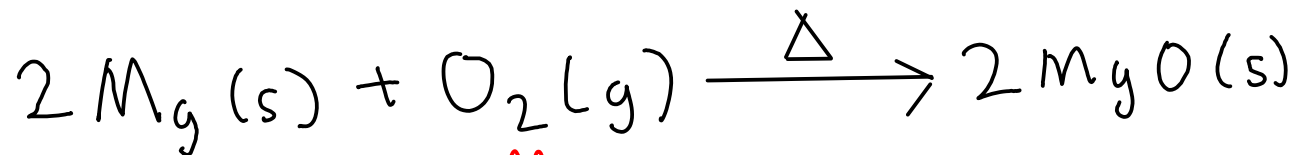
$$\textcircled{3} \quad 6.00 \text{ mol HCl} = 1 \text{ L} \quad \text{mL} = 10^{-3} \text{ L}$$

$$0.4717426172 \text{ mol HCl} \times \frac{1 \text{ L}}{6.00 \text{ mol HCl}} \times \frac{\text{mL}}{10^{-3} \text{ L}} = 78.6 \text{ mL of } \underline{6.00 \text{ M HCl}}$$

The problem asked us for the volume in mL, so we added this unit conversion to our third step.

CONCEPT OF LIMITING REACTANT

- When does a chemical reaction STOP?



- When does this reaction stop? When burned in open air, this reaction stops when all the MAGNESIUM STRIP is gone. We say that the magnesium is LIMITING.

- This reaction is controlled by the amount of available magnesium

- At the end of a chemical reaction, the LIMITING REACTANT will be completely consumed, but there may be amount of OTHER reactants remaining. We do chemical calculations in part to minimize these "leftovers".

These are often called "excess" reactants, or reactants present "in excess"