4 Mole concept and stoichiometric calculations

Mass	Particles	Gas at STP	Solutions
$n = \frac{m}{M}$	$n = \frac{N}{N_A}$	$n = \frac{V}{V_m}$	$c = \frac{n}{V}$ or $c = \frac{m}{M\,V}$
m mass g M molar mass g.mol^{-1}	N_A = 6,02 $\times$ 10^{23} N number of particles	V_M = 22,4 dm^{3}mol^{-1} v volume dm^3	c concentration mol.dm^{-3} v volume dm^3

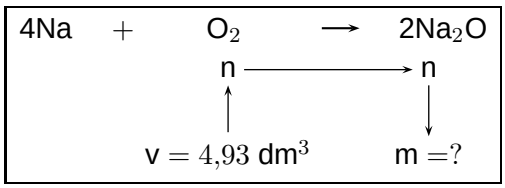
300 cm^3 solution contains 100 g NaCl. Calculate the solution concentration.	How many moles is 9,03 x 10^{24} NH_3 molecules?	How many mol CO_2(g) are there in 4,48 dm^3 at STP?
What is the volume of 2,7 mol N_2(g) at STP?	What is the mass of 3,6 mol potassium sulphate?	How many molecules are there in 4,2 mol ammonia?

Stoichiometry

When the substance given is not the substance asked, the ratio must be used. This step must be shown even if the ratio is 1:1

The amount of substance can be given/asked as volume/mass or concentration. It is converted to moles before/after working with the ratio.

Calculate the mass Na_2O that can be produced when 4,93 dm^3 oxygen gas (at STP) reacts with an excess of sodium. Na + O_2 ⟶ Na_2O



$$n = \frac{v}{V_m} = \frac{4{,}93}{22{,}4} = 0{,}22 \text{ mol } O_2$$

O_2	:	Na_2O
1	:	2
0,22	:	x
$1 \times x$	=	$2 \times 0{,}22$
x	=	0,44 mol Na_2O

$$n = \frac{m}{M}$$
$$0{,}44 = \frac{m}{62}$$
$$m = 27{,}28 \text{ g } Na_2O$$

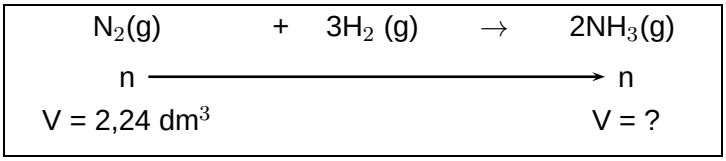
Exception: Gas volume to gas volume.

Avogadro's law:

Reagents are in the same container and therefore are at the same temperature and pressure. The **volume ratio is the same as the mole ratio**.

$N_2(g)$ + $3H_2(g)$ ⟶ $2NH_3(g)$

What volume ammonia gas will be produced when 2,24 dm^3 nitrogen gas reacts completely with an excess of hydrogen gas?



	N_3	:	NH_3
mole ratio	1	:	2
volume ratio	1	:	2
	2,24 dm^3	:	x

4,48 dm^3 NH_3 is produced

1. Calculate the volume of a 0,2 mol.dm^{-3} H$C\ell$-solution that is needed to produce 3,36 dm^3 $C\ell_2$(g) at STP.

   2KMnO_4 + 16H$C\ell \rightarrow$ 2K$C\ell$ + 2Mn$C\ell_2$ + 8H_2O + 5$C\ell_2$(g)

2. What mass of glucose will be produced when 100 g carbon dioxide reacts completely?

   6CO_2(g) + 6H_2O (ℓ) $\rightarrow$ $C_6H_{12}O_6$(s) + 6O_2(g)

3. Calculate the volume nitogen dioxide (at STP) that will be produced when $1{,}2 \times 10^{24}$ N_2O_5 molecule decompose.

   2N_2O_5(g) $\rightarrow$ 4NO_2(g) + O_2(g)

4 The following reaction take place in a container where CONDITIONS ARE NOT STP! Calculate the volume nitogen dioxide that will be produced when 4,86 dm^3 N_2O_5 decompose.

$$2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$$

5. The following reaction occurs under non-standard conditions:

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

What volume ammoniak gas is produced when 4,48 dm^3 hydogen gas reacts completely with an excess of nitrogen gas?

Neutralisation and stochiometry

Any question or part of a question involving a **titration** or where an acid **neutralises** a base implies that the reactants react in the ratio according to the balanced reaction. (No reactant in excess or limiting agent.)

In a titration experiment 35 cm^3 of a 0,5 $mol.dm^{-3}$ NaOH solution neutralises 25 cm^3 of a sulphuric acid solution. Calculate the concentration of the acid solution.

$$\underset{\text{n}}{H_2SO_4} + \underset{\text{n}}{2NaOH} \longrightarrow Na_2SO_4 + 2H_2O$$

$v = 35\ cm^3$, $c = ?$ $\qquad$ $v = 25\ cm^3$, $c = 0{,}5\ mol.dm^{-3}$

Three separate steps:

$$c = \frac{n}{V}$$
$$0{,}5 = \frac{n}{25 \times 10^{-3}}$$
$$n = 1{,}25 \times 10^{-2}\ mol\ NaOH$$

H_2SO_4 : NaOH
1 : 2
x : $1{,}25 \times 10^{-2}$
$6{,}25 \times 10^{-3}$ mol H_2SO_4

$$c = \frac{n}{V}$$
$$= \frac{6{,}25 \times 10^{-3}}{35 \times 10^{-3}}$$
$$= 0{,}179\ mol.dm^{-3}\ H_2SO_4$$

Or titration equation:

$$\frac{n_a}{n_b} = \frac{C_a.V_a}{C_b.V_b}$$
$$\frac{1}{2} = \frac{C_a.35}{0{,}5.25}$$
$$C_a = 0{,}179\ mol.dm^{-3}\ H_2SO_4$$

a. Sulphuric acid (concentration 0,01 $mol.dm^{-3}$) is neutralised by a ammonia solution. If 20 cm^3 of the base is used to neutralise 30 cm^3 of the acid, determine the concentration of the base.

Limiting agents

Sodium burns in oxygen according to the following equation:

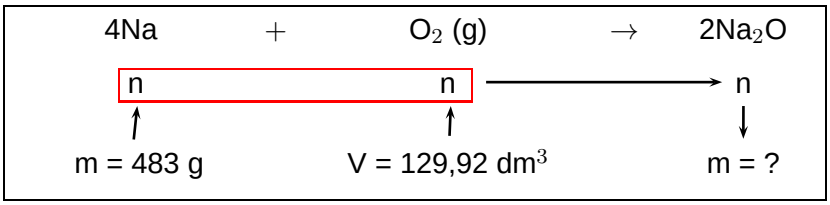
$$4Na + O_2 \rightarrow 2Na_2O$$

483 g sodium is placed in a container with 129,92 dm^3 oxygen gas.

a. Determine the limiting agent. Show all calculations.

b. Calculate the mass of sodium oxide that can be form.

c. Calculate the mass that remain of the reagent that is in excess.



a.

$$n = \frac{m}{M} = \frac{483}{23} = 21 \text{ mol Na available}$$

$$n = \frac{V}{V_m} = \frac{129,92}{22,4} = 5,8 \text{ mol } O_2 \text{ available}$$

$$Na : O_2$$
$$4 : 1$$
$$21 : x$$

5,25 mol O_2 required
O_2 available > O_2 required
$\therefore$ O_2 in excess
$\therefore$ Na limiting agent

b. Work with limiting agent

$$Na : Na_2O$$
$$4 : 2$$
$$21 : x$$

x = 10,5 mol Na_2O

$$n = \frac{m}{M}$$
$$10,5 = \frac{m}{62}$$
$$m = 651 \text{ g } Na_2O$$

c. O_2 remain = 5,8 - 5,25
= 0,55 mol

$$n = \frac{m}{M}$$
$$0,55 = \frac{m}{32}$$
$$m = 17,60 \text{ g } O_2$$

Limiting agents

1) 100 g nitrogen and 20 g hydrogen are available. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

a. Which reactant is the limiting agent?
b. What volume of ammonia can be produced at STP?
c. What mass of the reactant in excess will remain?

2) Calsium oxide reacts with hydrochloric acid: $CaO + 2HCl \rightarrow CaCl_2 + H_2O$

19,5 g CaO and 200 cm^3 of a 2 $mol.dm^{-3}$ HCl solution are mixed.

(a) Calculate the mass of $CaCl_2$ that can be produced.
(b) Calculate how many mol of the reactant in excess will remain unreacted.

3) During a titration 25 cm^3 of the 0,1 $mol.dm^{-3}$ sulphuric acid solution is added to an Erlenmeyer flask and titrated with a 0,1 $mol.dm^{-3}$ sodium hydroxide solution.

Calculate the pH of the solution in the flask after the addition of 30 cm^3 of sodium hydroxide. The endpoint of the titration is not yet reached at this point.

(IEB Calculate the hydronium ion concentration ...)DOE Mrt 2015 (8)

Reactant in excess and a second reaction

Some reagent is left over from the first reaction and then used in the second reaction. Remember that the **ratio** given by the balanced equation is the ratio in which the reagents **react**.

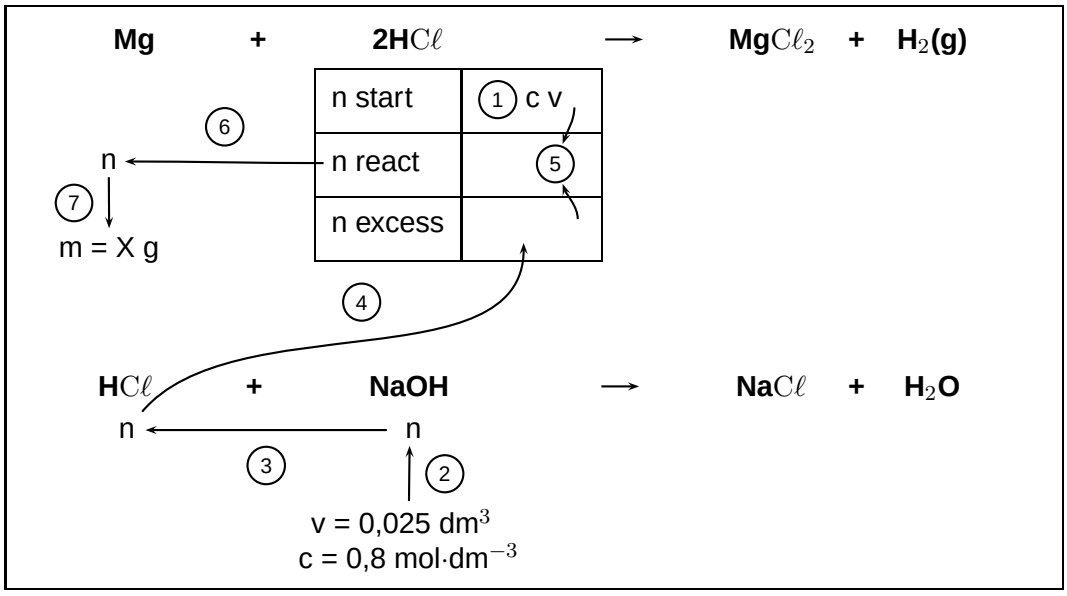
X g magnesium reacts with 200 cm^3 of a 0,15 $mol{\cdot}dm^{-3}$ HCl solution. The acid is in **excess**.

$$Mg + 2HC\ell \longrightarrow MgC\ell_2 + H_2(g)$$

The acid that is in excess is titrated with a 0,8 $mol{\cdot}dm^{-3}$ NaOH solution. 25 cm^3 of the NaOH is needed to neutralise the acid:

$$HC\ell + NaOH \longrightarrow NaC\ell + H_2O$$

Calculate mass X.



(1) $HC\ell$ added:

$$c = \frac{n}{V}$$
$$0{,}15 = \frac{m}{0{,}2}$$
$$n = 0{,}03 \text{ mol}$$

(2) NaOH react:

$$c = \frac{n}{V}$$
$$0{,}8 = \frac{m}{0{,}025}$$
$$n = 0{,}02 \text{ mol}$$

(3) $HC\ell$: NaOH
1 : 1
0,02 mol $HC\ell$ reacts in 2nd reaction

(4) 0,02 mol $HC\ell$ excess in 1st reaction

(5) $n_{HC\ell}$ react = $n_{HC\ell}$ added - $n_{HC\ell}$ excess
= 0,03 - 0,02
= 0,01 mol

(6) Mg : $HC\ell$
1 : 2
x : 0,01
0,005 mol Mg

(7) $n = \frac{m}{M}$
$0{,}005 = \frac{m}{24}$
$m = 0{,}12$ g

1. A learner adds a sample of calcium carbonate to 50,0 cm^3 of hydrochloric acid of concentration 1,0 $mol \cdot dm^{-3}$. The hydrochloric acid is in excess.

   $$CaCO_3 + 2HCl \longrightarrow CaCl_2 + CO_2 + H_2O$$

   The excess hydrochloric acid is now neutralised by 28,0 cm^3 of a 0,5 $mol \cdot dm^{-3}$ sodium hydroxide solution. The balanced equation for this reaction is:

   $$HCl + NaOH \longrightarrow NaCl + H_2O$$

   Calculate the mass of calcium carbonate in the sample.

Percentage yield and percentage purity

$$\% \text{ purity} = \frac{\text{mass of compound(theoretical)}}{\text{mass of sample}} \times 100\%$$

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield(possible)}} \times 100\%$$

1) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

21 g H_2 reacts and produces 90 g ammonia. Calculate the percentage yield.

2) 12 g unpure copper reacts with HNO_3 according to the following equation and 2,24 dm^3 NO(g) is produced at STP.

$$3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO(g) + 4H_2O$$

Prove that the copper is 79,38 % pure.