Chemical calculations

First published 2005

Published by
The Chemical Bookstore, www.namedorganicreactions.co.uk

Q: Calculate the relative molecular masses of the following:

1. O_2	6. H_2SO_4
2. Cl_2	7. HCl
3. N_2	8. $Na_2S_2O_3$
4: H_2O	9. $C_6H_{12}O_6$
5. $NaOH$	10. CH_3COOH

Be careful with brackets.

e.g. $Ca(OH)_2$ means:

1 atom of calcium	1 x 40 =	40
2 atoms of oxygen	2 x 16 =	32
2 atoms of hydrogen	2 x 1 =	2
Total		74

You may find it easier to work out the inside of the bracket first.

40+2x(16+1) = 40-2x17 = 74 try these.

1. $Cu(OH)_2$, 2. $Cu(NO_3)_2$, 3. $Al(OH)_3$, 4. $(NH_3)_2SO_4$

Sometimes molecules of water are included in the formula. This is shown with a large number at the front of the molecule.

e.g. $CaSO_4.2H_2O$ means:

1 atom of calcium	1 x 40 = 40
1 atom of sulphur	1 x 32= 32
4 atoms of oxygen	4 x 16 = 64
4 atoms of hydrogen	4 x 1 = 4
2 atoms of oxygen	2 x 16 = 32
Total	172

You may find it easier to work out the molecule first.

E.g. $CaSO_4 \cdot 2H_2O$

40+32+4x16+2x(2x1+16) = 172

Q: Calculate the relative molecular masses of the following;

1. F_2
2. CO_2
3. KOH
4. Mg_2SO_4
5. $ZnCl_2$
6. C_2H_5OH
7. $FeCl_3$
8. HNO_3
9. SO_3
10. $CuSO_4.5H_2O$

Reacting Masses

The mass of a carbon atom is 12 times heavier than a hydrogen atom. This means that 1g of hydrogen and 12g of carbon will contain the same number of atoms. Any A_r in grams will contain the same number of atoms. If it follows that the M_r in grams will contain the same number of molecules. (The actual number of atoms or molecules is huge: 600 000 000 000 000 000 000 000) (T.A. only: chemists call the A_r or the M_r in grams one mole.)

e.g. There are the same numbers of particles in the fallowing masses:

56 g of Iron

32 g of Sulphur

88 g of Iron sulphide

This is very useful information to chemists. We can calculate the masses of substances which will react together. Look at the equation:

Iron + sulphur → iron sulphide

Fe + S → FeS

56 g of Iron + 32 g of Sulphur → 88 g of iron sulphide

Calculate the missing masses in the following equations:

1. $CaCO_3 \rightarrow CaO + CO_2$

    ? → 56g + ?

2. $CH_4 + 3\ O_2 \rightarrow CO_2 + 2\ H_2O$

    ? + 96g → ? + 36g

Look carefully at the last equation. In an equation the large numbers in front of the molecules multiply the whole molecule.

e.g. $2\ H_2O$ means $2 \times H_2O = 2 \times (2+16) = 36$

Now try the next equations.

3. $2\ Mg + O_2 \rightarrow 2\ MgO$

4. $Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$

    160g + ? → ? + ?

Equation 4 is the reaction which happens in the blast furnace when iron or (Fe_2O_3) is converted to iron. This has an important industrial application. Obviously in industry the quantities used are in tonnes. The proportion of each will be the same provided that the units are the same throughout.

Fe_2O_3	+	$3\ CO$	→	$2\ Fe$	+	$3\ CO_2$
160 tonnes	+	84 tonnes	→	112 tonnes	+	132 tonnes

How many tonnes of iron will be formed from 80 tonnes of iron oxide?

Not all the calculations are as simple as this. We need a method.

Step 1: write down the equation

Step 2: Circle the compounds you are interested in.

Step 3: Write in M_r values.

Step 4: Write the proportions.

Step 5: Write the ratio.

Step 6: Multiply by ratio.

Step 7: Check your answer.

Fe_2O_3 + 3 CO → 2 Fe + 3 CO_2

100 ?

160 112

160 tonnes of iron oxide give 112 tonnes of iron.

1 tonne of iron oxide give 112/160 tonnes of iron.

So 100 tonnes of iron oxide gives 112/160 * 100 tonnes of iron = 70 tonnes.

Now you try.

1) How many tonnes of iron will be formed from 65 tonnes of iron oxide?

2) How many tonnes of iron oxide will be needed to make 5 tonnes of iron?

3) How many tonnes of iron oxide will be needed to make 8 tonnes of iron?

Classwork / Homework

1) Chemists obtain pure silicon from sand, which is silicon (IV) oxide (SiO_2). This is purified and heated with carbon at a high temperature. The reaction occurring is:

SiO_2 (s) + 2 C(s) → Si(s) + 2 CO(g)

a) Calculate the relative molecular mass of silicon(IV) oxide.

b) Calculate the mass of silicon(IV) oxide required to obtain 70 g of silicon.

2) Mg + Br_2 → $MgBr_2$

a) Calculate the relative molecular mass of magnesium bromide, M_r.

b) Calculate the mass of magnesium bromide obtained from 0.12 g of magnesium.

3) A lime kiln is used for the industrial production of quicklime (calcium oxide) from limestone (Calcium carbonate) in accordance with the equation: $CaCO_3$(s) → CaO(s) + CO_2(g)

a) Calculate the relative molecular masses of calcium carbonate and calcium oxide.

b) Using the above molecular masses and the equation calculate the mass of limestone required to produce 28000 kg of calcium oxide.

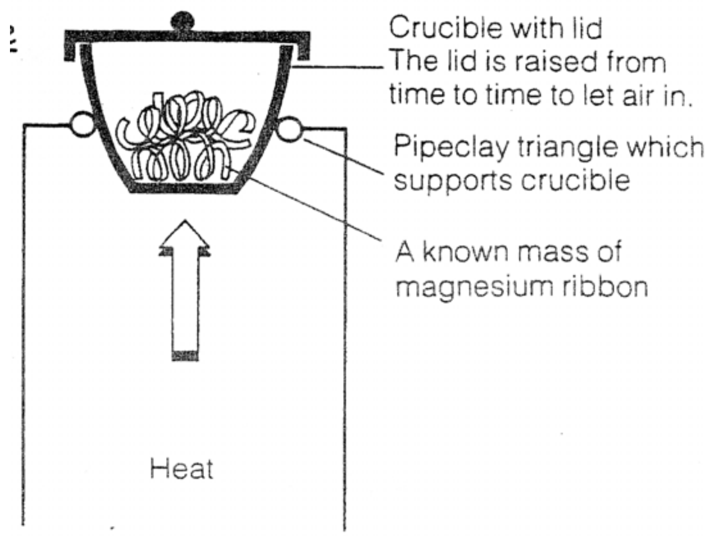
Finding Formulae

We have been using formulae throughout our Chemistry course. They tell us how many atoms combine together. All formulae have been confirmed by experiment. This section will show you how this is done.

Finding the formula of magnesium oxide

A known mass of magnesium is heated. When all the magnesium has been converted to magnesium oxide, the mass of magnesium oxide is found. By substraction the mass of oxygen which has combined with the magnesium can be found. Below are some perfect results and the method for calculating the formula.

1) Mass of the crucible	= 16.18 g
2) Mass of crucible + magnesium	= 17.24 g
3) Mass of magnesium = 2) - 1)	= 1.06 g
4) Mass of crucible + magnesium oxide	= 17.95 g
5) Mass of oxygen combined = 4) – 2)	= 0.71 g

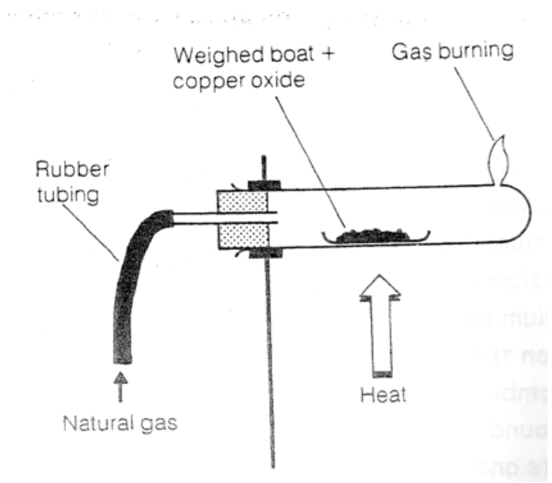


Steps in calculation	Magnesium	Oxygen
1) Write the masses of the elements	1.06	0.71
2) Write the A_r for each element	24	16
3) Divide the mass by A_r	1.06/24=0.044	0.71/16=0.044
4) Divide by the smallest number	0.044/0.044=1 in both cases	

You now have the ratio of atoms

5) Decide the simplest formula using whole numbers. Answer = MgO

Your teacher will show you a method for finding the formula of copper oxide.



Below are some perfect results:

1) Mass off 'boat'	= 21.04 g
2) Mass of 'boat' + copper oxide	= 23.76 g
3) Mass of 'boat' + copper	= 23.21 g
4) Mass of copper = 3) – 1)	= 2.17 g
5) Mass of oxygen = 2) – 3)	= 0.55 g

Steps in calculation	Copper	Oxygen
1) Write the masses of the elements		
2) Write the A_r for each element		
3) Divide the mass by A_r		
4) Divide by the smallest number		

You now have the ratio of atoms

5) Decide the simplest formula using whole numbers. Answer =

Classwork / Homework

1) An experiment was carried out to find the equation for the reaction between magnesium and oxygen.

1) Mass of the crucible	= 3.00 g
2) Mass of crucible + magnesium	= 3.24 g
3) Mass of magnesium = 2) - 1)	= g
4) Mass of crucible + magnesium oxide	= 3.40 g
5) Mass of oxygen combined = 4) – 2)	= g

Steps in calculation	Magnesium	Oxygen
1) Write the masses of the elements		
2) Write the A_r for each element		
3) Divide the mass by A_r		
4) Divide by the smallest number		
You now have the ratio of atoms		

5) Decide the simplest formula using whole numbers. Answer =

2) 14.4 g of iron oxide was found to contain 11.2 g of iron. Calculate the simplest formula for this oxide of iron. Show your working.

3) 4.82 g of an oxide of cobalt was found to contain 3.54 g of cobalt. Deduce the simplest empirical formula of the oxide.

a) Find the mass of oxygen in 4.82 g of the oxide.

b) Find the relative number of atoms of cobalt and oxygen and hence deduce the empirical formula of the oxide.

<u>The Mole **Separate Science only**</u>

The relative molecular mass (Mr) of a compound in grams is equal one mole of that substance. It is often called the molar mass given the symbol – (M).

One mole of any substance contains the same number of particles e.g. atoms, molecules or ions.

1) Calculate the molar mass of the following:

a) Ar

b) H_2

c) NaOH

d) HCl

We may not use these exact quantities for our experiments and we need to calculate the number of moles we are using. Use this equation for solids:

Number of moles = mass of substance / molar mass (M)

2) Calculate the number of moles in the following masses, show your working:

a) 20 g Calcium

b) 54 g Aluminium

c) 10 g Sodium hydroxide

d) 19.6g of sulphuric acid

e) 5.3g of sodium carbonate

3) Calculate the masses for the following number of moles; Show your working.

a) 0.5 moles of calcium carbonate $CaCO_3$

b) 0.2 moles of iron(III)oxide Fe_2O_3

c) 0.1 moles of potassium hydroxide KOH

d) 1.5 moles of aluminium oxide Al_2O_3

e) 0.05 moles of sulphuric acid H_2SO_4

4) Calculate the moles for the following number of masses; Show your working.

a) 100 g of $CaCO_3$

b) 120 g SiO_2

c) 115 g PbI_2

<u>More Problems - Solutions?</u> **<u>Separate Science Only</u>**

Many experiments are carried out in solution. We measure out a certain volume of solution and we need to know how many moles this contains.

The concentration of a solution is the number of moles dissolved in 1 dm^3 (=1000 cm^3 = 1000 ml = 1 liter) of solution.

You need to use a new equation for solutions.

Number of moles dissolved = volume (dm^3) * concentration (moles/dm^3)

Calculate the number of moles dissolved in the following and then the mass needed to make up the solutions:

a) 100 cm^3 of 0.2 mol/dm^3 sodium hydroxide NaOH

b) 250 cm^3 of 0.25 mol/dm^3 sodium carbonate Na_2CO_3

c) 10 cm^3 of 0.1 mol/dm^3 potassium hydroxide KOH

d) 20 cm^3 of 0.1 mol/dm^3 sulphuric acid H_2SO_4

e) 100 cm^3 of 0.2 mol/dm^3 sodium carbonate Na_2CO_3

f) 20 cm^3 of 0.5 mol/dm^3 hydrochloric acid HCl

g) 25 cm^3 of 0.05 mol/dm^3 Copper sulphate CuSO4

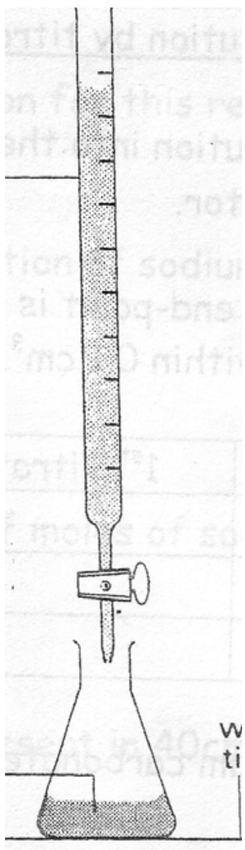
Making a solution

You are going to make up $250cm^3$ of 0,1 mol/dm^3 sodium carbonate solution in a graduated flask.

1. Calculate the number of moles dissolved in this solution.
2. Calculate the mass of sodium carbonate dissolved in this solution.

It is very difficult to weigh out exactly this amount and also very difficult to ensure that all of this is transferred into the flask.

Using the sodium carbonate solution to find the concentration of approximately 0.1 M sulphuric acid solution by titration. **Separate science only**



1. Use the pipette and filler to place 25cm^3 of sodium carbonate solution into the flask.

2. Add 3 drops of methyl orange indicator.

3. Fill the burette with acid.

4. Add acid from the burette until the end-point is reached.

5. Repeat until two readings agree to within 0.1 cm^3.

Our teacher will demonstrate the technique. Use the teacher's results as a rough titration.

	Rough Titration	1st Titration	2nd Titration
Initial reading			
Final reading			
Volume used (cm^3)			

Calculate the number of moles of sodium carbonate in 25 cm^3 of solution:

Na_2CO_3 + H_2SO_4 → Na_2SO_4 + H_2O + CO_2

1 mole + 1 mole

At the neutral point the number of moles of sodium carbonate is equal to the number of moles of sulphuric acid. Calculate the concentration of the sulphuric acid solution.

Using the sodium carbonate solution to find the concentration of an approximately 0.2 hydrochloric acid solution by titration. **Separate science only**

1. Place 25cm^3 of sodium carbonate solution into the flask.
2. Add 3 drops of methyl orange indicator.
3. Fill the burette with acid.
4. Add acid from the burette until the end-point is reached.
5. Repeat until two readings agree to within 0.1 cm^3.

	Rough Titration	1st Titration	2nd Titration
Initial reading			
Final reading			
Volume used (cm)			

Calculate the number of moles of sodium carbonate in 25 cm^3 of solution.

Na_2CO_3 + 2 HCl → 2 NaCl + H_2O + CO_2

1 mole + 2 moles

The number of moles of sodium carbonate is not equal to the number of moles hydrochloric acid. 2 X the number of moles of sodium carbonate is equal to the number of moles of hydrochloric acid.

Calculate the concentration of the hydrochloric acid solution:

1) In a titration it was found that 25 cm^3 of sodium carbonate solution containing 5.3 g in 500 cm^3 needed 40 cm^3 of hydrochloric add for neutralisation.

a) Write a balanced equation for this reaction.

b) Calculate the concentration of sodium carbonate solution.

c) How many moles are present in 40cm^3 of hydrochloric acid solution.

d) Calculate the concentration of hydrochloric acid solution.

2) A_r(Na) = 23; A_r(O) = 16; A_r(H) = 1.

a) Calculate the molar mass of sodium hydroxide (NaOH).

b) 4 g of sodium hydroxide was dissolved to make 250 cm^3 of solution. What is the concentration of the solution in mol dm^{-3}?

Classwork / Homework

1) Sodium hydroxide solution reacts with hydrochloric acid according to the following equation: NaOH (aq) + HCl (aq) → NaCl (aq) + H_2O (l)
It was found that 20 cm^3 od sodium hydroxide solution containing 2 g in 250 cm^3 of solution was needed to neutralise 25 cm^3 dilute hydrochloric acid.

a) Calculate the concentration of the sodium hydroxide in mol dm^{-3}.

b) Calculate the number of moles of sodium hydroxide in 20 cm^3.

c) How many moles of hydrochloric acid are present in 25 cm^3?

d) Calculate the concentration of the hydrochloric acid in mol dm^{-3}.

2) In a laboratory experiment it was found that 50 cm^3 of a different sodium hydroxide solution was exactly neutralised by 35 cm^3 of a 0.5 mol dm^{-3} solution of hydrochloric acid.

a) Sketch and label the apparatus that would be needed to carry out the experiment.

b) How would you know when the mixture was exactly neutral?

c) Write a balanced symbol equation for the reaction.

d) Calculate the concentration of the sodium hydroxide solution in mol dm^{-3}.

e) What mass of sodium hydroxide would be present in 1 dm^3 of this solution?