Using moles to balance equations (HT only)

The balancing numbers in a symbol equation can be calculated from the masses of reactants and products by converting the masses in grams to amounts in moles and converting the numbers of moles to simple whole number ratios.

Worked Example

Sodium nitrate, $NaNO_3$, decomposes on heating to give sodium nitrite, $NaNO_2$, and oxygen gas, O_2.

When 8.5g of sodium nitrate is heated in a test tube until its mass is constant, 6.9g of sodium nitrite is produced.

1. What is the mass of oxygen produced?
2. Find the ratio of reactants and products involved in the reaction and show how these can produce a balanced symbol equation

Step 1:	Calculate the mass of all the reactants and products.	Sodium nitrate → sodium nitrite + oxygen 8.5g = 6.9g + ? g Mass of oxygen = 8.5 – 6.9 = 1.6g
Step 2:	Using the masses from step 1, calculate the number of moles for each reactant and product.	M_r of $NaNO_3$ = 23 + 14 + (16 x 3) = 85 M_r of $NaNO_2$ = 23 + 14 + (16 x 2) = 69 M_r of O_2 = 16 x 2 = 32 Moles of $NaNO_3$ = 8.5 / 85 = 0.1 mol Moles of $NaNO_2$ = 6.9 / 69 = 0.1 mol Moles of O_2 = 1.6 / 32 = 0.05 mol
Step 3	Find the simplest whole number ratio of moles.	$NaNO_3$: $NaNO_2$: O_2 0.1 : 0.1 : 0.05 2 : 2 : 1
Step 4:	Use the ratio to write a balanced symbol equation.	$2NaNO_3 \rightarrow 2NaNO_2 + O_2$

Limiting reactants (HT only)

In a chemical reaction involving two reactants, it is common to use an excess of one of the reactants to ensure that all of the other reactant is used. A limiting reactant is the first reactant that is used up in a reaction. When the limiting reactant is all used up, no more product can form, so the reaction stops.

To identify the limiting reactant in a reaction you need to calculate the number of moles of each reactant to see which one is in excess.

2. A student carried out the reaction between copper(II) oxide and carbon.

Higher Tier only

The balanced symbol equation for the reaction is:

$2CuO + C \rightarrow 2Cu + CO_2$

Figure 2 shows the equipment they used.

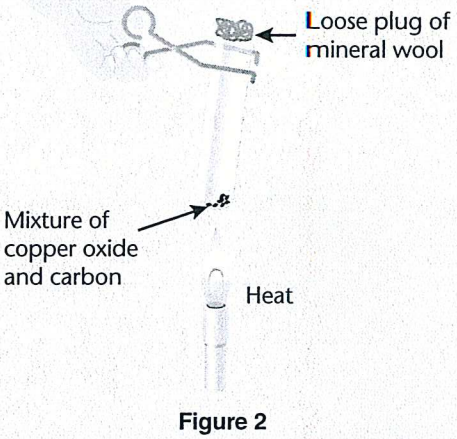


Figure 2

Practical

a Suggest the function of the mineral wool.

_____

_____ [2 marks]

b The student used 1.59 g of copper(II) oxide.

Calculate the expected mass of copper the student should make.

_____

_____

_____

_____

_____ g [3 marks]

Analyse the question

Use the same two steps as shown in question 2:

1. Calculate the moles of copper(II) oxide
2. The symbol equation shows that the number of moles of copper(II) oxide = moles of Cu
3. Calculate the mass of copper

Using moles to balance equations

1. How many moles are in 5.5 g of manganese (Mn)?

Higher Tier only

Maths

Tick **one** box

☐ 0.1 ☐ 0.22 ☐ 1 ☐ 2.2 [1 mark]

2. **Figure 3** shows the equipment used to react chlorine with iron.

Higher Tier only

Synoptic

a Write the word equation for this reaction. [1 mark]

_____

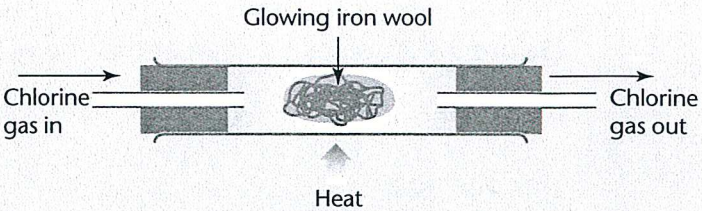


Figure 3

b 1.12 g of iron and 2.13 g of chlorine are used.

Calculate the number of moles of each

(A_r Fe = 56; A_r Cl = 35.5)

Moles of iron (Fe)

_____

Moles of chlorine (Cl_2)

_____ [2 marks]

Synoptic **c** The product of the reaction is iron(III) chloride, $FeCl_3$.

Use your answers from part **b** to write the balanced symbol equation.

_____ [2 marks]

Limiting reactants

1. Use the words in the box to complete the sentences. [3 marks]

Higher Tier only

chemical	excess	extreme	limiting	physical

In a _____ reaction involving two reactants the _____ reactant is the one that is all used up by the end of the reaction.

The reactant in _____ is still there at the end of the reaction.

2. **Figure 4** shows a piece of potassium in water.

Higher Tier only

Figure 5 shows what is seen at the end of the reaction.

Synoptic

What is the limiting reactant?

Tick **one** box. [1 mark]

- ☐ Potassium
- ☐ Water
- ☐ Potassium hydroxide
- ☐ Hydrogen

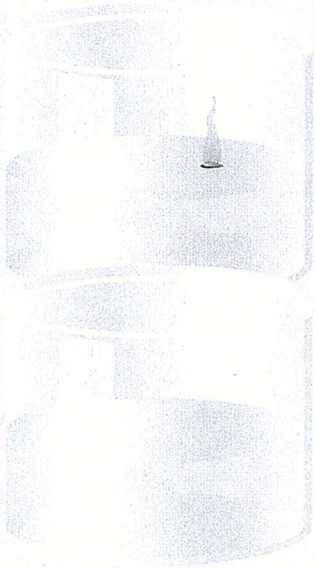


Figure 5

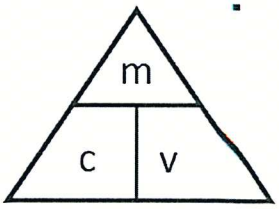
Concentration of solutions

Many chemical reactions take place in solutions.

The concentration of a solution can be measured in mass per given volume of solution, e.g. grams per dm^3 (g/dm^3).

To calculate the concentration of a solution the following formula can be used:

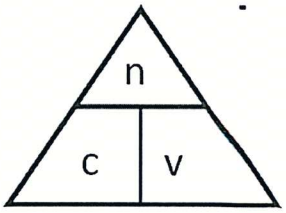
$$\text{Concentration } (g/dm^3) = \frac{\text{mass (g)}}{\text{volume } (dm^3)}$$



N.B. $1dm^3 = 1000cm^3$

(HT) If the amount of substance is expressed in moles, then the concentration of the solution is expressed in units of moles per dm^3 (mol/dm^3) and can be calculated using the equation:

$$\text{Concentration } (mol/dm^3) = \frac{\text{moles (mol)}}{\text{volume } (dm^3)}$$



3. A scientist carries out a reaction to make copper sulfate crystals.

Higher Tier only

Practical

Figure 6 shows the method they used.

a State one sign that a chemical reaction took place.

_____ [1 mark]

b Which reactant was in excess?

Explain the reason for your answer.

_____

_____ [2 marks]

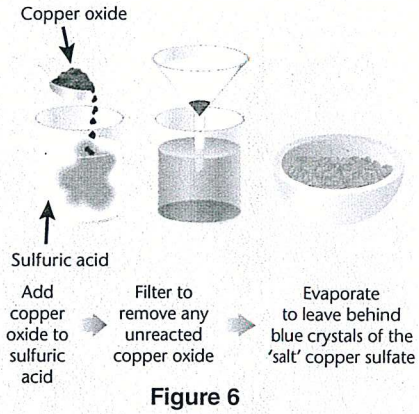


Figure 6

Concentration of solutions

1. How many cm^3 are in 1 dm^3?

Maths

Tick **one** box.

☐ 10 ☐ 100

☐ 1000 ☐ 10 000 [1 mark]

2. Which salt solution is the most concentrated?

Tick **one** box

☐ 1 g of salt in 2 cm^3 of water

☐ 2 g of salt in 10 cm^3 of water

☐ 5 g of salt in 20 cm^3 of water

☐ 10 g of salt in 25 cm^3 of water [1 mark]

Maths

The units of concentration show you how to calculate it. If the unit is g/cm^3 then you just need to divide the mass of the solute in g by the volume of the solvent in cm^3. You might have to convert units – for example, from cm^3 to dm^3.

This formula can be rearranged to give you:

mass = volume × concentration

and

volume = mass/concentration

3. Calculate the:

Maths

a Concentration in g/cm^3 of a solution containing 15 g of copper sulfate in 100 cm^3 of water

_____ g/cm^3 [1 mark]

b Concentration in **g/dm^3** of a solution containing 0.2 g of sodium carbonate in 10 cm^3 of water

_____ g/dm^3 [2 marks]

c Mass of copper sulfate needed to make 50 cm^3 of a 10g/dm^3 solution

_____ g [2 marks]

Using concentrations of solutions in mol/dm^3

1. What is the concentration of a solution containing 0.2 moles of sodium chloride in 0.5 dm^3 of water?

Higher Tier only

Tick **one** box.

Maths

☐ 0.2 mol/dm^3 ☐ 0.4 mol/dm^3 ☐ 0.5 mol/dm^3 ☐ 1 mol/dm^3 [1 mark]

2. A student is asked to make 100 cm^3 of a 0.5 mol/dm^3 solution of copper sulfate ($CuSO_4$).

Higher Tier only

a Calculate the mass of 0.5 moles of copper sulfate.

Synoptic

Maths

_____ g [2 marks]

Maths **b** Use your answer from part **a** to calculate the mass of copper sulfate the student needs to add to 100 cm^3 of water to create a 0.5 mol/dm^3 solution.

_____ g [2 marks]

3. The student then reacted the copper sulfate solution with dilute sodium hydroxide.

Higher Tier only

The equation for the reaction is:

$CuSO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + Cu(OH)_2(s)$

Synoptic **a** Describe how the equation shows you that this is a precipitation reaction.

_____ [1 mark]

Maths **b** It took 45.3 cm^3 of dilute sodium hydroxide to completely react with 20 cm^3 of the 0.5 mol/dm^3 copper sulfate solution.

Calculate the concentration of the sodium hydroxide.

Give your answer to 1 decimal place.

_____

_____

_____

_____ [4 marks]

Analyse the question

There are several steps you need to follow:

1. Calculate the moles of copper sulfate. Use the equation moles = concentration × volume.
2. Use the symbol equation to work out how many moles of sodium hydroxide there must be. You can see that there are 2 moles of NaOH for every 1 mole of $CuSO_4$.
3. Calculate the concentration of sodium hydroxide. Rearrange the equation to give you concentration = moles × volume.

Section 3: Quantitative chemistry

Writing formulae

1. BF_3 [1 mark]
2. PbO_2 [1 mark]
3. **a** 3 [1 mark] **b** 4 [1 mark] **c** 11 [1 mark]
4. **a** Any one from: Use a gas syringe. Use a delivery tube into an upturned measuring cylinder/burette full of water. [1 mark]

   Accept a labelled diagram

   b Calcium carbonate – $CaCO_3$ [1 mark], Calcium chloride – $CaCl_2$[1 mark], Carbon dioxide – CO_2 [1 mark]

Conservation of mass and balanced chemical equations

1. lost [1 mark], chemical reaction [1 mark], equal to [1 mark]
2. 2.3 + 1.2 [1 mark] = 3.5 g [1 mark]
3. The product is not water. [1 mark]

   $2H_2 + O_2$[1 mark] → $2H_2O$ [1 mark]

Mass changes when a reactant or product is a gas

1. 4.2 – 3 = 1.2 g [1 mark]
2. **a** Thermal decomposition [1 mark]

   b Worked example – full answer given in workbook.

   c i Worked example – full answer given in workbook.

   ii (0.8 + 0.5 + 0.9 + 0.4 + 0.6)/5 = 0.64 [1 mark]
   (0.5/0.64) × 100 [1 mark] = 78.1% [1 mark]

Relative formula mass

1. 32 [1 mark]
2. From top, lines to: 81 [1 mark], 44 [1 mark], 98 [1 mark], 18 [1 mark]
3. M_r of 2KI = 2 × (39 + 127) = 332 [1 mark]

   M_r of $Pb(NO_3)_2$ = 207 + (14 × 2) + (16 × 6) = 331 [1 mark]

   Total M_r of reactants = 332 + 331 = 663 [1 mark]

   M_r of PbI_2 = 207 + (2 × 127) = 461 [1 mark]

   M_r of $2KNO_3$ = 2 x (39 + 14 + (16 × 3)) = 202 [1 mark]

   Total M_r of products = 461 + 202 = 663 [1 mark]

Moles

1. 46 g [1 mark]
2. 1.5 [1 mark]
3. **a** 4 × 12 = 48 g [1 mark]

   b Worked example – full answer given in workbook.

   c 1 + 80 = 81 [1 mark]

   283.5/81 = 3.5 moles [1 mark]
4. 6.02×10^{23} [1 mark]

Amounts of substances in equations

1. **a** M_r calcium carbonate = 40 + 12 + (16 × 3) = 100 [1 mark]

   200/100 = 2 (moles) [1 mark]

   b M_r calcium oxide = 40 + 16 = 56 [1 mark]

   56 × 2 (moles) = 112 (kg) [1 mark]
2. **a** To prevent the mixture coming out of the test tube [1 mark] and causing burns. [1 mark]

   b M_r copper oxide = 2 × (63.5 + 16) = 159 [1 mark]

   Moles copper oxide = 1.59/159 = 0.01 [1 mark]

   Mass copper = (63.5 x 2) × 0.01 [1 mark]

   = 1.27 (g)

Using moles to balance equations

1. 0.1 [1 mark]
2. **a** Iron + chlorine → iron chloride [1 mark]

   b 1.12/56 = 0.02 [1 mark]

   2.13/(35.5 × 2) = 0.03 [1 mark]

   c 2Fe + $3Cl_2$[1 mark] → $2FeCl_3$[1 mark]

Limiting reactants

1. Answers in order: chemical, limiting, excess [3 marks]
2. Potassium [1 mark]
3. **a** A colour change/some of the copper oxide was used up [1 mark]

   b Copper oxide [1 mark] because there was some left over after the reaction had finished [1 mark]

Concentration of solutions

1. 1000 [1 mark]
2. 1 g of salt in 2 cm^3 of water [1 mark]
3. **a** 15/100 = 0.15 (g/cm^3) [1 mark]

   b 10 cm^3/1000 = 0.01 dm^3 [1 mark]

   0.2/0.01 = 20 (g/dm^3) [1 mark]

   c 50 cm^3/1000 = 0.05 dm^3 [1 mark]

   0.05 × 10 = 0.5 g [1 mark]

Answers

Using concentrations of solutions in mol/dm³

1. 0.4 mol/dm³ [1 mark]

2. **a** $M_r CuSO_4 = 63.5 + 32 + (16 \times 4) = 159.5$ [1 mark]

0.5 moles × 159.5 = 79.75 (g) [1 mark]

b 100/1000 = 0.1 [1 mark]

79.75 × 0.1 = 7.975 (g) [1 mark]

(allow error to be carried over from **a**)

3. **a** A solid is formed. [1 mark]

b Moles of $CuSO_4$ = 0.5 mol/dm³ × (20/1000) [1 mark] = 0.01 [1 mark]

1 mole $CuSO_4$ = 2 moles NaOH

0.01 × 2 = 0.02 moles of NaOH [1 mark]

0.02/(45.3/1000) = 0.4 mol/dm³ [1 mark]

AQA

The Periodic Table of Elements

1	2											3	4	5	6	7	0
							1 **H** hydrogen 1										4 **He** helium 2
7 **Li** lithium 3	9 **Be** beryllium 4											11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9	20 **Ne** neon 10
23 **Na** sodium 11	24 **Mg** magnesium 12											27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17	40 **Ar** argon 18
39 **K** potassium 19	40 **Ca** calcium 20	45 **Sc** scandium 21	48 **Ti** titanium 22	51 **V** vanadium 23	52 **Cr** chromium 24	55 **Mn** manganese 25	56 **Fe** iron 26	59 **Co** cobalt 27	59 **Ni** nickel 28	63.5 **Cu** copper 29	65 **Zn** zinc 30	70 **Ga** gallium 31	73 **Ge** germanium 32	75 **As** arsenic 33	79 **Se** selenium 34	80 **Br** bromine 35	84 **Kr** krypton 36
85 **Rb** rubidium 37	88 **Sr** strontium 38	89 **Y** yttrium 39	91 **Zr** zirconium 40	93 **Nb** niobium 41	96 **Mo** molybdenum 42	[97] **Tc** technetium 43	101 **Ru** ruthenium 44	103 **Rh** rhodium 45	106 **Pd** palladium 46	108 **Ag** silver 47	112 **Cd** cadmium 48	115 **In** indium 49	119 **Sn** tin 50	122 **Sb** antimony 51	128 **Te** tellurium 52	127 **I** iodine 53	131 **Xe** xenon 54
133 **Cs** caesium 55	137 **Ba** barium 56	139 **La*** lanthanum 57	178 **Hf** hafnium 72	181 **Ta** tantalum 73	184 **W** tungsten 74	186 **Re** rhenium 75	190 **Os** osmium 76	192 **Ir** iridium 77	195 **Pt** platinum 78	197 **Au** gold 79	201 **Hg** mercury 80	204 **Tl** thallium 81	207 **Pb** lead 82	209 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[267] **Rf** rutherfordium 104	[270] **Db** dubnium 105	[269] **Sg** seaborgium 106	[270] **Bh** bohrium 107	[270] **Hs** hassium 108	[278] **Mt** meitnerium 109	[281] **Ds** darmstadtium 110	[281] **Rg** roentgenium 111	[285] **Cn** copernicium 112	[286] **Nh** nihonium 113	[289] **Fl** flerovium 114	[289] **Mc** moscovium 115	[293] **Lv** livermorium 116	[293] **Ts** tennessine 117	[294] **Og** oganesson 118

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

* The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Relative atomic masses for **Cu** and **Cl** have not been rounded to the nearest whole number.

*create a mind map to summarise this topic *

Topic 3 – Quantitative Chemistry Glossary

Key Word	Definition
Avogadro constant	The number of atoms or molecules in 1 mole of a substance. 6.02×10^{23}.
Chemical reaction	A process that involves the rearrangement of atoms to form a new substance – usually resulting in an energy change.
Concentration	The amount of a particular substance contained within a solution in a particular volume.
Conservation of mass	The mass of reactants must equal the mass of the products in a chemical reaction.
Excess	When a reactant is in excess there is a greater amount than necessary to fully react with the limiting reactant.
Limiting reactant	The first reactant that is used up in a reaction.
Moles	The number of atoms/molecules in a particular amount of substance. The mass of 1 mole of a substance is its relative formula mass in grams.
Percentage composition	A numerical way to describe what proportions of the different elements there are in a compound.
Product	The substance that is produced in a chemical reaction.
Reactant	The substance that reacts in a chemical reaction.
Relative formula mass	The sum of the relative atomic masses of the atoms in the numbers shown in the formula.
Solution	A liquid mixture in which a soluble solid has dissolved and spread out in the solvent.
Symbol equation	A representation of a chemical reaction in the form of symbols and formulae which show reactants on the right hand side of the arrow and products on the left hand side of the arrow.
Word equation	A representation of a chemical reaction in the form of words (names of the substances) which show reactants on the right hand side of the arrow and products on the left hand side of the arrow.