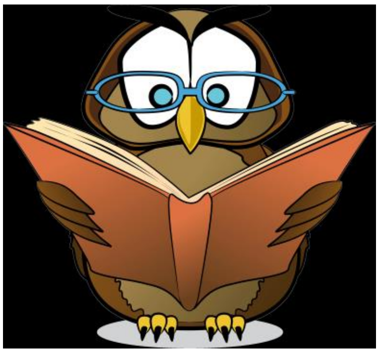


KNOWLEDGE

ST MARY'S SCIENCE DEPARTMENT: CHEMISTRY

A LEVEL CHEMISTRY

BRIDGING COURSE

ATOMS, IONS AND COMPOUNDS

WEEK 2

NAME	
CHEMISTRY CLASS	

VERSION 1.2

THIS MUST BE BROUGHT TO CHEMISTRY LESSONS AT THE START OF YEAR 12.

WEEK 1
Contents
2.1 Atoms and Isotopes
2.2 Ions

This bridging course will provide you with a mixture of information about A-level Chemistry's fundamental topics, and what to expect from the course, as well as key work to complete.

Students who are expecting to study Chemistry at A-level, and are likely to meet the entry requirements, must complete the bridging course fully and thoroughly, to the best of their ability. You should complete all work on paper and keep it in a file, in an ordered way. You will submit it to your teacher in September.

All of the work will be reviewed, and selected work will be formally assessed, and you will be given feedback on it. This work will be signalled to you. If you do not have access to the internet, please contact the school and appropriate resources will be sent to you.

If you are thinking about studying Chemistry at A-level you should attempt this work to see whether or not you think studying a subject like this is right for you. If you later decide to study Chemistry, you must ensure you complete this work in full. This work should be completed after you have read and completed the Study Skills work that all of Year 12 should complete.

Course outline

Assessment overview of A – level Chemistry

Content is in six modules:

Module 1 – Development of practical skills in chemistry
Module 2 – Foundations in chemistry
Module 3 – Periodic table and energy
Module 4 – Core organic chemistry
Module 5 – Physical chemistry and transition elements
Module 6 – Organic chemistry and analysis

Component	Marks	Duration	Weighting	
Periodic table, elements and physical chemistry (01)	**100**	2 hour 15 mins	37%	Assesses content from modules 1, 2, 3 and 5
Synthesis and analytical techniques (02)	**100**	2 hour 15 mins	37%	Assesses content from modules 1, 2, 4 and 6
Unified chemistry (03)	**70**	1 hour 30 minute	26%	Assesses content from all modules (1 to 6)
Practical endorsement in chemistry (04)	**-**	-	-	Non-exam assessment

All components include synoptic assessment.

Students must complete all components (01, 02, 03, and 04) to be awarded the OCR A Level in Chemistry A.

The course in Year 12 will follow Scheme of Work as set out below (this leads onto Y13 work):

Assessment overview Y12 Chemistry

Content is in four modules:

Module 1 – Development of practical skills in chemistry
Module 2 – Foundations in chemistry
Module 3 – Periodic table and energy
Module 4 – Core organic chemistry

Component	Marks	Duration	Weighting	
Breadth in chemistry (01)	70	1 hour 30 mins	50%	Assesses content from all four modules
Depth in chemistry (02)	70	1 hour 30 mins	50%	Assesses content from all four modules

Both components include synoptic assessment.

Students will complete the TWO exam papers in Chemistry at the end of Year 12 as a **MOCK EXAM** to gauge the students' progress in their first year of study.

Content overview

The four modules are each divided into key topics:

Module 1: Development of practical skills in chemistry

Practical skills assessed in a written examination

Module 2: Foundations in chemistry

Atoms, compounds, molecules and equations
Amount of substance
Acid–base and redox reactions
Electrons, bonding and structure

Module 3: Periodic table and energy

The periodic table and periodicity
Group 2 and the halogens
Qualitative analysis
Enthalpy changes
Reaction rates and equilibrium (qualitative)

Module 4: Core organic chemistry

Basic concepts
Hydrocarbons
Alcohols and haloalkanes
Organic synthesis
Analytical techniques (IR and MS)

Practical activities are embedded throughout the course to encourage practical activities in the laboratory, enhancing students' understanding of chemical theory and practical skills.

Aim

In this bridging course, we will outline the basic principles of key topics covered in Year 12 Chemistry.

In each topic, we will start by reviewing the understanding which you gained in GCSE Chemistry and apply it to more advanced applications found in A-Level Chemistry.

This is not a comprehensive overview of the A-Level Chemistry specification, rather a taster on what is covered throughout the course.

Important

Please remember to look after your own wellbeing as you work through this bridging course.

Please take regular breaks as you go through this work.

This work should take approximately 5 hours, so should not be completed in one sitting. Do not worry if you cannot complete all of the exercise's set. Use them, with the appropriate mark scheme provided, to judge how well you understand a topic

WEEK 2: ATOMS, IONS AND COMPOUNDS

Instructions

The content that will be covered in this part of the course is mainly an extension of GCSE Chemistry Atomic Structure work related to Topic 1 from the GCSE course.

There will be 1x PowerPoint booklet (see below) which will take you through Atoms, ions and compounds. There will be questions as you go that I suggest you complete (remember complete as required to aid in your understanding of the topic and file them to aid in your when we resume our studies in school) which are in the text, here the mark schemes will be supplied within the PowerPoints.

At the end of the atoms, ions and compound booklet (or power point) it directs you to answer some further **practice examination questions**

Attempt these questions after you have also completed this study guide.

THESE WILL BE REQUIRED TO BE HANDED IN UPON YOUR RETURN TO SCHOOL FOR FORMAL MARKING.

Power Points [should be attached or available for download]

- Ppt 2.1 + 2.2 + 2.3 Ch 2 ISOTOPES AND RELATIVE MASSES [remember there are suggested exercises to aid your understanding in these PowerPoints]

This information is also found in the attached PowerPoints in the form of directed questions.

The formally assessed questions are highlighted clearly in the appropriate PowerPoint 2.3.

RE-CAP IONIC AND COVALENT BONDING FROM WEEK 1

Complete the following questions to help re-cap the chemical content from last week's Bridging Course:

2 What is the formula of chromium(III) sulfate?

A Cr_3SO_4

B $Cr(SO_4)_3$

C $Cr_2(SO_4)_3$

D Cr_3SO_3

Your answer ☐

SPECIMEN

7 Which halogen most readily forms 1– ions?

A bromine

B chlorine

C fluorine

D iodine

Your answer ☐

18 A chemist determines some properties of two substances, C and D.

The results are shown in the table.

	C	D
Melting point / °C	660	801
Electrical conductivity when solid	Yes	No
Electrical conductivity when molten	Yes	Yes
Solubility in water	No	Yes

Which row correctly identifies the bonding and structure in C and D?

	C	D
A	giant ionic	giant metallic
B	giant ionic	giant ionic
C	giant metallic	giant metallic
D	giant metallic	giant ionic

Your answer ☐

[1]

In the next question don't worry if you cannot answer part a) but see if you can find out the answer (this will be covered when you come back to school)

Answer all the questions.

20 Bromine and mercury are the only two naturally occurring elements that are liquids at room temperature and pressure. Some physical properties of these two elements are given below.

	Appearance at room temperature	Melting point / °C	Boiling point / °C	Electrical conductivity of the liquid
Bromine	dark orange liquid	−7.2	58.8	very low
Mercury	shiny silver liquid	−38.8	356.7	good

(a) Complete the full electron configuration of a bromine atom.

$1s^2$ .... [1]

(b) Bromine and mercury react with many elements and compounds.

Predict the formula of the compound formed when bromine reacts with aluminium.

.... [1]

(c) Explain how the structure and bonding in bromine account for its relatively low melting point.

....

....

....

.... [3]

SPECIMEN

(d) Mercury and bromine react together to form mercury(II) bromide, $HgBr_2$.

Describe and explain how electrical conductivity occurs in mercury(II) bromide and mercury, in both solid and molten states.

....

....

....

....

....

.... [5]

ANSWERS

Q2 C

Q7 C

Q18 D

Question			Answer	Marks	Guidance
20	(a)		$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5$ ✓	1	ALLOW ...$4s^2 3d^{10}$...
	(b)		$AlBr_3$ ✓	1	
	(c)		forces between (simple) molecules ... ✓ ... (which are) induced dipole–dipole forces OR London forces ... ✓ ... are weak, so (relatively easily) overcome by increased thermal motion/kinetic energy ✓	3	IGNORE any reference to covalent bonds ALLOW van der Waals' forces
	(d)		$HgBr_2$ conducts when molten but not when solid ✓ ... because ions are mobile in molten $HgBr_2$ ✓ ... but are fixed in a lattice in solid $HgBr_2$ ✓ Mercury conducts in both the solid and molten states ... ✓ ... because delocalised electrons move (in both solid and liquid state) ✓	5	Explanations must be included for 2nd and 3rd marks. IGNORE references to aqueous $HgBr_2$ IGNORE 'delocalised ions' OR 'free ions' for 'mobile ions' DO NOT ALLOW any mention of electrons moving DO NOT ALLOW any mention of + ions moving

SPECIMEN

2 Atoms, ions, and compounds

1. Introduction

The substances you see around you are all made up of tiny building blocks – atoms. In this chapter, you will develop your understanding of atoms, ions, and molecules, and how chemists describe them using symbols and chemical formulae. You will also look at how chemists obtain data about the masses of atoms and how chemical equations are used to describe chemical reactions.

The picture shows copper sulfate crystals, $CuSO_4$, which are commonly used as a fungicide. How many different elements do you think copper sulfate contains?

2. Prior Knowledge

This chapter covers some fundamental concepts in chemistry that you will need for your AS Chemistry course and builds on material you encountered at Key Stage 4.

You should make sure that you have a good understanding of:

The nuclear model of the atom

Use of chemical formulae to describe the number of atoms of each element in a compound

The use of balanced chemical equations to describe what happens in a chemical reaction

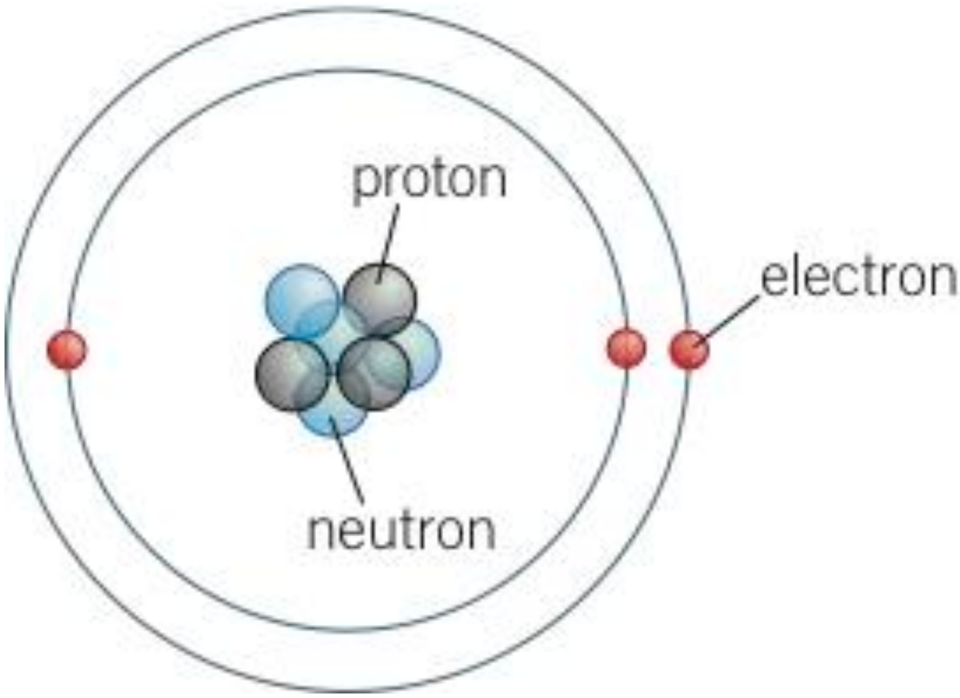
The formation of positive and negative ions, as a result of atoms losing or gaining electrons.

Revise these concepts at BBC Bitesize website: Atomic number, mass number, and isotopes. Then test your knowledge with this quiz about atomic structure on Educational Quizzes.

2.1 Atomic structure and isotopes – introduction

An atom contains a nucleus composed of protons and neutrons. Surrounding this nucleus are electrons arranged in shells. The three types of subatomic particle – protons, neutrons, and electrons – have different properties.

Many elements exist as different isotopes. The number of protons, neutrons, and electrons in these isotopes can be calculated if the atomic number and mass number is known.



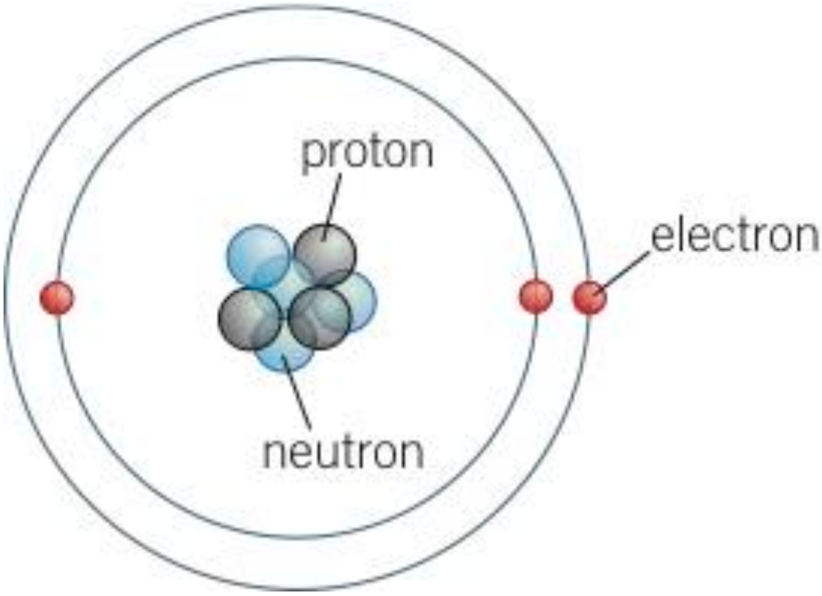
2.1 Atomic structure and isotopes – atomic structure

Demonstrate knowledge of atomic structure.

You can review ideas about the nuclear model of the atom, and the properties of the subatomic particles in '2.1 Revision podcast: Atomic structure'.

You need to be able to calculate the numbers of protons, neutrons, and electrons in an atom or ion, using the atomic number and mass number, or vice versa. '2.1 Support: Subatomic particles' helps you practise.

What is the atomic number and mass number of the atom shown in the diagram?



2.1 Atomic structure and isotopes – isotopes

Understand the nature of isotopes.

Isotopes are atoms of the same element with different numbers of neutrons and different masses. You need to be able to use isotope notation to work out the numbers of protons, neutrons, and electrons from the symbol for an atom or ion.

2.2 Relative mass – introduction

Chemists use a mass system based on relative mass to compare the masses of atoms. They compare the masses of isotopes to a standard mass, the atomic mass unit, u, which is 1/12th of the mass of a carbon-12 atom. The term relative isotopic mass is used to describe the mass of an isotope.

The masses of isotopes are found experimentally using a mass spectrometer. Data from this instrument is also used to find the weighted mean of all the isotopic masses of an element. This is known as the relative atomic mass of that element.

2.2 Relative mass – relative isotopic mass and relative atomic mass

Define the terms relative atomic mass and relative isotopic mass.

You need to be able to define the terms 'relative atomic mass' and 'relative isotopic mass' in a very precise way. Look at the definitions in the student book on pages 12 and 13, and make sure you learn the wording carefully.

Although chemists find accurate values for relative atomic masses using mass spectrometry, you can carry out much simpler investigations in the laboratory, using ideas about moles (you will do this in Chapter 3). You can determine the relative atomic mass of a metal in '2.2 Practical: Determining the relative atomic mass of a metal'.

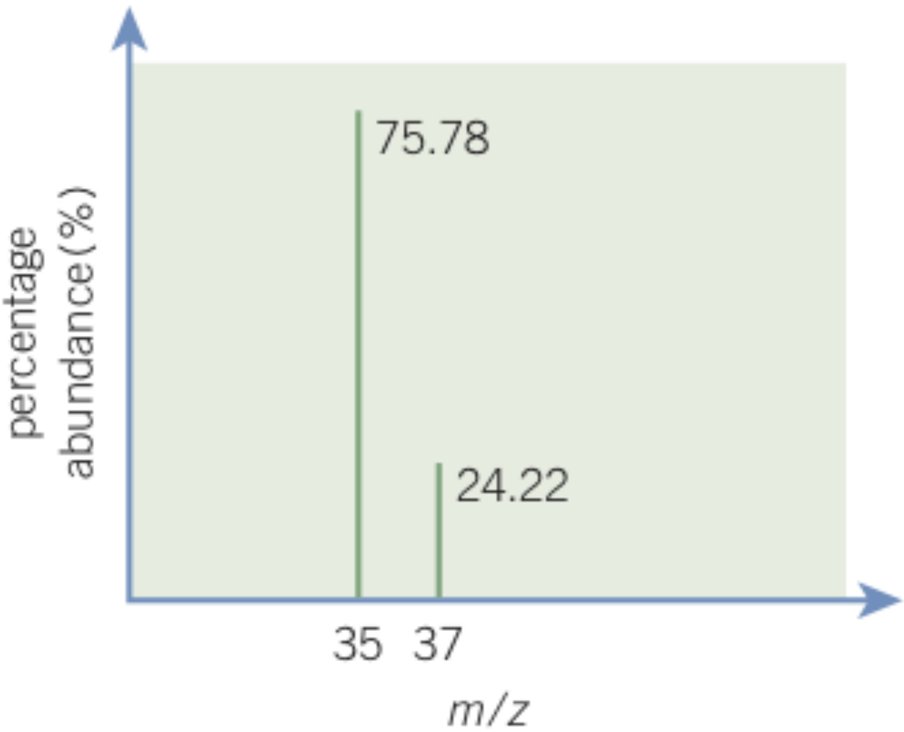
2.2 Relative mass – calculating relative atomic mass from percentage abundances

Understand the use of mass spectrometry to find the relative abundances of isotopes.

Calculate the relative atomic mass from the relative abundances of isotopes.

You do not need to know how a mass spectrometer works. However, you do need to be able to understand the data that is displayed in a mass spectrum and use it to calculate a weighted mean of the isotopic masses. You can learn more about mass spectrometry and its applications in '2.2 Application sheet: Isotopic abundance'.

The relative atomic mass of chlorine is shown as 35.5 on many periodic tables. Use the data from the mass spectrum of chlorine below to calculate a more precise value, to four significant figures.



2.3 Formulae and equations – introduction

Atoms combine together in fixed whole number ratios when they form compounds. Chemical formulae show the number of atoms of each element that combine together. For ionic compounds it is often possible to predict the chemical formula using ideas about the charges on the ions formed from each element.

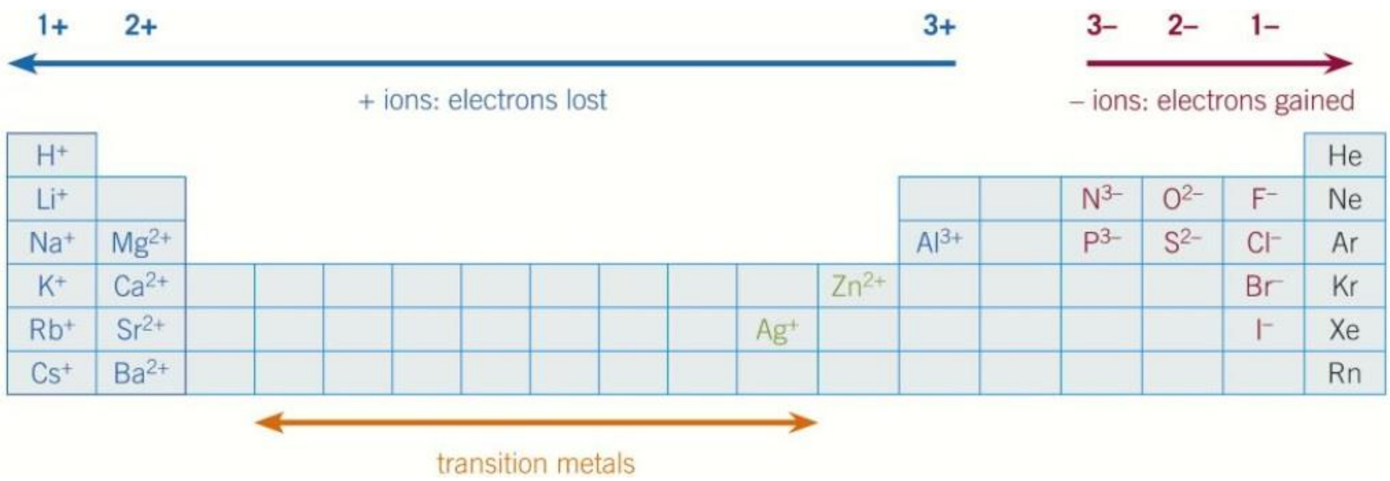
Balanced chemical equations are written to show the relative number of each type of particle that react together in chemical reactions.

2.3 Formulae and equations – ions

Predict ionic charges from the position of an element in the periodic table.

Recall the names and formulae of some common ions.

You need to be able to predict the charges of simple ions that form from elements in Groups 1–3 and 15–17 (5–7) of the periodic table.



Some ions, called polyatomic ions, contain atoms of more than one element. You need to learn the names, formulae, and charges of these ions. Use Table 1 on page 16 of the student book to revise these.

2.3 Formulae and equations – ionic compounds

Write the formulae of ionic compounds from ionic charges.

You need to be able to combine ionic charges in a suitable ratio to write down the formula of an uncharged compound. Look at the worked example on page 16 of the student book (found in the power point).

What is the formula of calcium fluoride?

2.3 Formulae and equations – balancing equations

Construct balanced equations, including state symbols.

You learnt how to write and balance equations to describe reactions at Key Stage 4. By the end of this course you should be able to write balanced equations for all the reactions you have studied and also for some unfamiliar reactions.

Use '2.3 Support: Balancing equations' to practise this important skill and look at some of the common errors that can occur.

To try writing formulae and equations in unfamiliar contexts, you might like to attempt the activities in '2.3 Stretch and challenge: High-temperature superconductors', which looks at reactions involving some unusual ionic compounds.

Summary

In this chapter you have developed and practised some important skills that will lay the foundations for your further study of chemistry.

You should now check how well you can apply your skills and knowledge from Chapter 2, using the following resources:

2 Atoms, ions, and compounds: Checklist

SUPPORT 2.1 SUBATOMIC PARTICLES

Specification reference

- *2.1.1 a) b)*

Learning outcomes

After completing this activity you should be able to:

- recall the definitions for key terms about atomic structure
- state the relative mass and relative charge of subatomic particles
- deduce the numbers of protons, neutrons and electrons in a variety of atoms and ions
- analyse data from some isotopes.

Questions

1. Define the term atomic number. *(1 mark)*

2. Define the term mass number. *(1 mark)*

3. Copy and complete the Table 1 to show the relative mass and relative charge of the subatomic particles. *(3 marks)*

Table 1 *Subatomic particles*

Sub-atomic particle	Relative mass	Relative charge
proton		
	1	

4. Copy and complete the Table 2 to show the mass number, atomic number and number of each sub-atomic particle for each of the atoms and ions listed.

(5 marks)

Table 2 *Numbers of subatomic particles in some elements*

Atom or ion	Mass number	Atomic number	Number of protons	Number of neutrons	Number of electrons
Li	7	3			
Na	23	11			
N	14		7		
Ne	20		10		
F		9		10	
K				20	19
Na^{+}	23	11			
Mg^{+}	24		12		
Al^{3+}	27				10
F^{-}			9	10	
O^{2}			8	8	

5. Define the term isotope. *(1 mark)*

6. Copy and complete the Table 3 to show the number of protons, neutrons and electrons in each atom of lithium. Lithium has an atomic number of 3. *(3 marks)*

Table 3 *Numbers of subatomic particles in lithium*

Isotope	Number of protons	Number of neutrons	Number of electrons
^{6}Li			
^{7}Li			
^{8}Li			

ANSWERS

1. The atomic number is the number of protons in the nucleus of an atom. *(1 mark)*

2. The mass number is the total number of protons plus neutrons in the nucleus of an atom (or the total number of nucleons). *(1 mark)*

3. Award one mark for each correct complete row. *(3 marks)*

Sub-atomic particle	Relative mass	Relative charge
proton	**1**	**+1**
neutron	1	**0**
electron	**1/1840 (negligible)**	**-1**

4. Award one mark for each correct complete column. *(5 marks)*

Atom or ion	Mass number	Atomic number	Number of protons	Number of neutrons	Number of electrons
Li	7	3	**3**	**4**	**3**
Na	23	11	**11**	**12**	**11**
N	14	**7**	7	**7**	**7**
Ne	20	**10**	10	**10**	**10**
F	**19**	9	**9**	10	**9**
K	**39**	**19**	**19**	20	19
Na^{+}	23	11	**11**	**12**	**10**
Mg^{+}	24	**12**	12	**12**	**10**
Al^{3+}	27	**13**	**13**	**14**	10
F^{-}	**19**	**9**	9	10	**10**
O^{2}	**16**	**8**	8	8	**10**

5. Isotopes are atoms with the same number of protons in their nucleus *(1 mark)*

but a different number of neutrons *(1 mark)*

OR the same atomic number and a different mass number.

6. Award one mark for each correct complete row. *(3 marks)*

Isotope	Number of protons	Number of neutrons	Number of electrons
^{6}Li	**3**	**3**	**3**
^{7}Li	**3**	**4**	**3**
^{8}Li	**3**	**5**	**3**

2.2 PRACTICAL DETERMINING THE RELATIVE ATOMIC MASS OF A METAL

METHOD

Learning outcomes

After completing the practical you should be able to:

- carry out calculations using stoichiometric relationships
- measure the volume of gas collected over water using a delivery tube and measuring cylinder
- determine the relative atomic mass of a metal by using experimental data.

Background

One mole of any gas, at room temperature and pressure (RTP), occupies a volume of 24.0 dm^3 or 24 000 cm^3. We can use this information, alongside the stoichiometric ratio in an equation, to work out the relative atomic mass of a metal. When a Group 1 metal reacts with water, the following reaction takes place.

$$2M(s) + 2H_2O(l) \rightarrow 2MOH(aq) + H_2(g)$$

The hydrogen gas produced can be collected over water as it is not very soluble. As soon as it is formed, it is bubbled through a trough and into a measuring cylinder where it displaces water. This allows the volume of gas evolved to be measured. Your task is to carry out an experiment using an unknown Group 1 metal, and determine its identity by calculating its relative atomic mass.

Safety

- Unknown Group 1 metal is HIGHLY FLAMMABLE and CORROSIVE.
- Eye protection should be worn.

Equipment and materials

- 250 cm^3 measuring cylinder
- 100 cm^3 measuring cylinder
- trough or large plastic container
- 250 cm^3 conical flask with delivery tube
- clamp stand
- boss and clamp
- balance (accurate to at least 2 decimal places)
- distilled water
- beehive shelf
- unknown Group 1 metal
- filter paper
- tweezers

USE VOLUME OF 1 MOLE OF GAS = 24800 cm^3 just for this question

Method

1 Set up your apparatus as shown in Figure 1. Ensure that you use the clamp and clamp stand to stabilise the delivery tube as it passes from the conical flask to the trough. The 250 cm^3 measuring cylinder needs to contain water so that the hydrogen produced can displace it.

2 Record the volume of gas in the measuring cylinder; if it is full of water then the volume is 0 cm^3.

3 Using the 100 cm^3 measuring cylinder, measure out 100 cm^3 of distilled water and pour into the conical flask.

4 Remove the Group 1 metal from the container using a pair of tweezers and, using a filter paper, remove as much oil as possible.

5 Weigh the metal and add it to the water in the conical flask, replacing the bung as quickly as possible.

6 Hydrogen gas will be produced and will bubble into the measuring cylinder. Wait until the volume of hydrogen remains constant and record this volume.

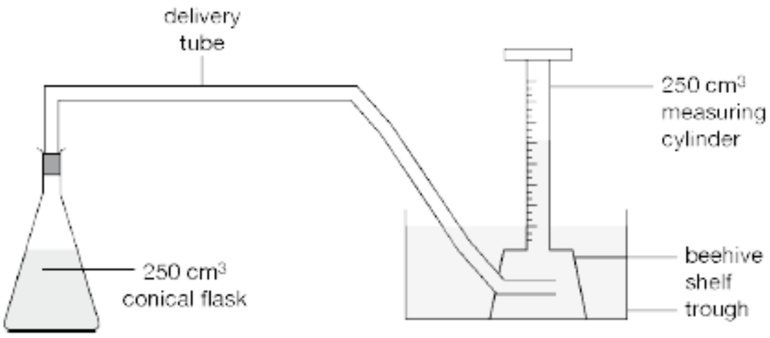


Figure 1 *Experimental set-up*

Results

Construct a table, such as Table 1, in which you can record your readings.

Table 1 *Example results table*

Mass of Group 1 metal used / g	
Final volume / cm^3	
Initial volume / cm^3	
Volume of hydrogen / cm^3	

Example data

Mass of lithium used is 0.10 g

Volume of hydrogen collected is 150 cm^3

Questions

1 Using the volume of hydrogen collected, calculate the number of moles of hydrogen formed during the experiment. (*2 marks*)

2 From the equation given in the background information, determine the number of moles of metal that reacted. (*2 marks*)

3 Using both the number of moles and your recorded mass of metal, calculate its relative atomic mass to one decimal place. Use your periodic table to determine which Group 1 metal you have used. (*3 marks*)

4 Steps **4** and **5** in the method should be carried out as quickly as possible. Suggest two reasons why this is. (*2 marks*)

5 Suggest the pH value of the solution in the conical flask after the reaction has taken place, and explain your reasoning. (*4 marks*)

6 Compare the relative atomic mass derived from your calculations in questions **1**-**3** with the accurate relative atomic mass of the metal you were given, as stated in the periodic table. Discuss the reason for any difference in the values. (*6 marks*)

In your answer you should:

- evaluate any errors in your experimental method
- suggest how these errors have affected your result
- outline any ways in which you could change the experimental procedure in order to gain a more precise and accurate result.

FOLLOW UP

Questions

1 a State what is meant by the term 'relative atomic mass'. (*1 mark*)

b Use your periodic table to give the relative atomic mass of the following metals: (*3 marks*)

- lithium (Li)
- magnesium (Mg)
- chromium (Cr)
- beryllium (Be)
- silver (Ag)
- potassium (K).

2 A student carried out an experiment to determine the relative atomic mass of calcium. She added 0.40 g of calcium to 100 cm^3 of distilled water and collected the hydrogen formed. On completion of the reaction, she found she had collected 202 cm^3 of hydrogen.

a Construct an equation for this reaction. (*1 mark*)

b Calculate the number of moles of hydrogen formed. (*1 mark*)

c Calculate the relative atomic mass of the metal. Quote your answer to **one** decimal place. (*3 marks*)

3 To check her results, the student decided to titrate the solution formed with hydrochloric acid. She placed 25 cm^3 of the solution into a conical flask and added some phenolphthalein indicator. The solution required 24.20 cm^3 of 0.2 mol dm^{-3} of hydrochloric acid for neutralisation.

a Construct an equation for this reaction. (*1 mark*)

b Calculate the number of moles of hydrochloric acid used. (*2 marks*)

c Calculate the number of moles of calcium hydroxide in 25 cm^3 of the solution. (*1 mark*)

d Calculate the number of moles of calcium hydroxide in 100 cm^3 of the solution, and so, calculate the moles of calcium that reacted. (*2 marks*)

e Use the moles and the mass of the calcium to calculate the relative atomic mass of calcium to one decimal place. (*1 mark*)

4 Compare the calculated relative atomic masses for both experiments. Discuss which method you think is the most accurate and state the reasons for your decision. (*4 marks*)

Example data

Mass of lithium used is 0.10 g

Volume of hydrogen collected is 150 cm^3

ANSWERS

Answers for method sheet

1 Moles of hydrogen $= \frac{\text{volume}}{24\,800}$

$= \frac{150}{24\,800}$ (*1 mark*)

$= 6.05 \times 10^{-3}$ (*1 mark*)

2 Moles metal $= 6.05 \times 10^{-3} \times 2$ (*1 mark*)

$= 0.0121$ (*1 mark*)

3 Molar mass of metal $= \frac{\text{mass}}{\text{moles}}$

$= \frac{0.10}{0.0121}$ (*1 mark*)

$= 8.3$ (*1 mark*)

The metal is therefore lithium. (*1 mark*)

4 Step 4 to prevent oxidation of the Group 1 metal in air (although this would be minimal). (*1 mark*)

Step 5 to prevent hydrogen from escaping. (*1 mark*)

5 Metal hydroxide is produced, and hence hydroxide (OH^-) ions in the solution increase in concentration. (*1 mark*)

Concentration of hydrogen (H^+) ions does not increase, since the hydrogen bubbles off as a gas. (*1 mark*)

The pH goes up from pH 7 (neutral, pH of water) (*1 mark*)

It is therefore likely to be greater than pH 8. (*1 mark*)

6

Question	Answer	Marks	Guidance
6	**Level 3 (5-6 marks)** At least 3 errors are identified, with a detailed explanation as to how the results are affected. AND A detailed suggestion of how each source of error could be improved. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Two errors are identified with some explanation as to how the results are affected. AND Some explanation of how the experimental procedure could be changed for each source of error. *There is a line of reasoning presented with some structure.* *The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1-2 marks)** One error is identified with some explanation of how the results are affected. AND There is an attempt to explain how the experimental procedure could be change to minimise this error but is lacking in detail. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** *No response or no response worthy of credit*	6	*Error 1* Oil not removed properly. Effect: Will make the mass of metal appear greater. Less hydrogen than expected is produced making the relative atomic mass appear greater. Improvement: Use of a non-polar solvent to remove the oil. *Error 2* Hydrogen could escape before the bung is replaced. Effect: Volume of hydrogen is less than it should be so moles appear less and relative atomic mass of metal appears to be greater. Improvement: Adapt how the metal is added to the water, for example, place the metal in an ignition tube and shake to mix after bung has been replaced or use a split-bottomed conical flask to separate the reactants. *Error 3* Metal could get oxidised by the oxygen in the air. Effect: Measured mass of metal is greater than the actual mass. Less hydrogen will be produced so relative atomic mass of metal appears to be greater. Improvement: Carry out the experiment in an inert atmosphere. *Error 4* Gas volume is imprecise as only measured to the nearest whole number. Effect: Will lead to the wrong number of moles of lithium being calculated. Improvement: Use an upturned burette or a more accurate measuring cylinder. *Error 5* Amount of metal used is very small. Effect: Large % error. Improvement: Use a larger amount of metal.

Answers for follow up sheet

1 **a** The weighted mean mass of an atom of an element relative to one-twelfth of the mass of an atom of carbon-12. *(1 mark)*

b Award 1 mark for each two correct elements, up to a total of 3 marks. *(3 marks)*

Relative atomic masses:

- lithium (Li) = 6.9
- magnesium (Mg) = 24.3
- chromium (Cr) = 52.0
- beryllium (Be) = 9.0
- silver (Ag) = 107.9
- potassium (K) = 39.1.

2 **a** $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$ *(1 mark)*

b Moles of hydrogen $= \frac{202}{24\,800}$ *(1 mark)*

$= 8.145 \times 10^{-3}$

c Moles Ca $= 8.145 \times 10^{-3}$ *(1 mark)*

Molar mass of metal $= \frac{\text{mass}}{\text{moles}}$ *(1 mark)*

$= \frac{0.4}{8.145 \times 10^{-3}}$ *(1 mark)*

$= 49.1$

3 **a** $Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$ *(1 mark)*

b Moles hydrochloric acid = concentration × volume *(1 mark)*

$= 0.2 \times \frac{24.20}{1000}$ *(1 mark)*

$= 4.84 \times 10^{-3}$

c Moles of calcium hydroxide $Ca(OH)_2 = \frac{4.84 \times 10^{-3}}{2}$ *(1 mark)*

$= 2.42 \times 10^{-3}$

d Moles in 100 cm^3 $= 2.42 \times 10^{-3} \times 4$ *(1 mark)*

$= 9.68 \times 10^{-3}$

Moles of calcium reacted = moles of $Ca(OH)_2$

$= 9.68 \times 10^{-3}$ *(1 mark)*

e Relative atomic mass of calcium $= \frac{\text{mass}}{\text{moles}}$

$= \frac{0.4}{9.68 \times 10^{-3}}$

$= 41.3$ *(1 mark)*

4 Any four points from:

- Value obtained by titration is more accurate, as the calculated relative atomic mass is closest to the actual relative atomic mass. *(1 mark)*
- In the gas collection method, hydrogen can be lost if the bung is not replaced quickly. *(1 mark)*

- In the gas collection method, measurement of volume of gas collected in measuring cylinder is not very precise. *(1 mark)*
- Volume reading in a burette is more precise than in a measuring cylinder. *(1 mark)*
- However, both methods are likely to produce inaccurate results due to the calcium being impure. *(1 mark)*

2.2 APPLICATION ISOTOPIC ABUNDANCE

Introduction

Mass spectrometry is one of the most useful analytical techniques available to the analytical chemist. It can compare the masses of elements relative to one another and work out the relative molecular mass of compounds. Chemists can use this information to work out the composition of the sample being tested.

Learning outcomes

After completing the worksheet you should be able to:

- interpret simple mass spectra
- construct mass spectra from given experimental data of isotopic abundance, using ICT skills
- calculate the relative atomic mass of an element from experimental data.

Background and data

- A trace called a 'mass spectrum' is produced by the mass spectrometer. This spectrum shows a trace of mass number versus abundance (peak height). In this worksheet you will work out the percentage isotopic abundance of the isotopes of mercury and lead and use this data to calculate the relative atomic mass of these elements.
- For this exercise you will need access to a PC running a program such as Microsoft Excel, that will enable you to produce graphs and charts.
- Figure 1 shows the mass spectrum of zirconium. It shows peaks occurring at mass numbers 90, 91, 92, 94 and 96, which are the five naturally occurring isotopes of zirconium.

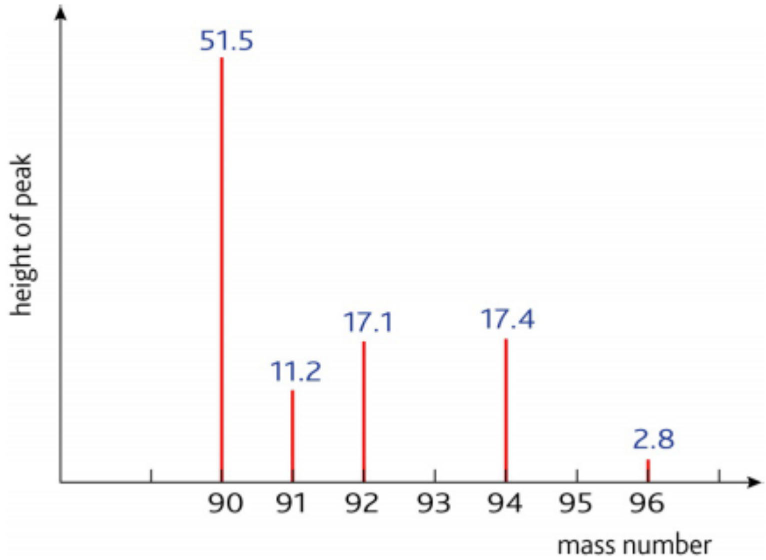


Figure 1 *Mass spectrum of zirconium*

- The spectrum in Figure 1 shows the height of each peak and this gives an indication of how much of that isotope there is in this sample. This is called its 'abundance'. When you add up all the heights of each peak this corresponds to the total amount of substance put into the mass spectrometer. You would then be able to calculate the relative atomic mass of zirconium.
- You are now going to do this for mercury and lead.

Task

1 The table below provides mass spectrometer data for mercury. For each line of data, work out the percentage isotopic abundance by using the following formula:

$$\%\ \text{abundance} = \frac{\text{peak height}}{\text{total height of all the peaks}} \times 100$$

2 Work out the relative atomic mass of mercury by multiplying the mass number by the percentage isotopic abundance for each isotope.

3 Add them together to get the final mass.

Mass number	Peak height /mm	% abundance	Mass of isotope in sample
196	0.6		
198	40.1		
199	67.4		
200	92.5		
201	52.8		
202	119.2		
204	27.4		
Total peak height	400.0		
M_r of mercury			

4 Use Excel or a similar program to present the data graphically, as with the zirconium spectrum above.

5 Repeat the exercise for lead using the table below

Mass number	Peak height /mm	% abundance	Mass of isotope in sample
204	6.1		
206	94.4		
207	90.4		
208	209.4		
Total peak height	400.3		
M_r of lead			

Questions

1 From your data, state the relative atomic mass of mercury.

2 From your data, state the relative atomic mass of lead.

3 The following isotopes of barium have the percentage abundances given in brackets: 130 (0.101%), 132 (0.097%), 134 (2.42%), 135 (6.59%), 136 (7.81%), 137 (11.32%), 138 (71.66%)
Calculate the atomic mass of barium.

ANSWERS

- The concept of mass spectrometry is difficult to convey as the students don't see the machinery very often.
- When students are working out the percentage abundance they may differ slightly to the results below because of rounding up errors, but this gives an idea of what results the student should be getting.

Table 1 *Results for mercury*

Mass number	Peak height /mm	% abundance	Mass of isotope in sample
196	0.6	0.15	0.29
198	40.1	10.02	19.84
199	67.4	16.84	33.51
200	92.5	23.13	46.26
201	52.8	13.22	26.57
202	119.2	29.80	60.19
204	27.4	6.85	13.97
Total peak height	400		
M_r of mercury	200.6		

Table 2 *Results for lead*

Mass number	Peak height /mm	% abundance	Mass of isotope in sample
204	6.1	1.52	3.06
206	94.4	23.61	48.61
207	90.4	22.60	46.78
208	209.4	52.34	108.78
Total peak height	400.3		
M_r of lead	207.2		

Answers

Students' answers should match those recorded in their tables. Where the answer given is wrong, guidance should be given on where the error occurred in data handling.

1 200.6

2 207.2

3 137.4

2.3 STRETCH AND CHALLENGE HIGH TEMPERATURE SUPERCONDUCTORS

Introduction

In this activity, you will look at some unusual ionic compounds which have important applications. The formulae of these compounds are rather more complicated than most of those that you have met so far, giving you some practice in applying what you have learnt about formulae and equations to more challenging situations!

Learning outcomes

After completing this worksheet you should be able to:

- predict ionic charge from the position of an element in the periodic table
- recall the names and formulae for some polyatomic ions
- construct formulae for unfamiliar ionic compounds
- construct balanced chemical equations, including state symbols, for unfamiliar reactions.

Background

Superconductors are a class of substance that, when cooled below a certain temperature, have no electrical resistance at all. Most superconducting materials need to be cooled to extremely low temperatures – only a few degrees above absolute zero (–273 °C) to take on these remarkable properties.

However, chemists have discovered a new class of materials, called *high- temperature superconductors*, that become superconducting at much higher temperatures (around −150 °C). These temperatures can easily be achieved by cooling the material in liquid nitrogen, meaning that these superconductors are much easier and cheaper to use in a range of different applications. They are used to make powerful magnets in particle accelerators and even the futuristic ultra-high speed trains known as *maglevs*.

High-temperature superconductors are often based on ionic compounds containing oxide ions bonded in an ionic lattice with several different metal ions. Examples include yttrium–barium–copper oxides (YBCOs) and bismuth–strontium–calcium–copper oxides (BSCCOs).

Questions

1 This question is about bismuth–strontium–calcium–copper oxides (BSCCOs).

a Use your periodic table to write down the charge on:

i a strontium ion

ii a calcium ion

iii an oxide ion. (*3 marks*)

b One of the BSCCO compounds used to form high-temperature superconductors has the formula $Bi_2Sr_2CaCu_2O_8$. In this compound, the copper ion has a charge of +2.

i Deduce the charge on a bismuth (Bi) ion in this compound. (*1 mark*)

ii Comment on whether this is the charge you would expect for bismuth, from its position in the periodic table. (*2 marks*)

c A simpler oxide based on bismuth contains only bismuth, strontium, and copper ions and has a formula that can be represented as $Bi_2Sr_2CuO_x$.

Calculate the value of *x* (assume that the charges on the metal ions are identical to those in the first BSCCO compound). (*2 marks*)

2 The BSCCO superconductor with formula $Bi_2Sr_2CaCu_2O_8$ can be made by heating a mixture of Bi_2O_3, $SrCO_3$, $CaCO_3$, and CuO in suitable ratios at 700 °C. Carbon dioxide is also released during the process. All the oxides and carbonates used in this reaction have a melting point above 700 °C.

a Write a balanced equation, including state symbols, for this reaction. (*3 marks*)

b Calculate the relative formula mass, M_r, of this BSCCO superconductor. (*1 mark*)

3 This question is about yttrium–barium–copper oxides (YBCOs).One of these compounds has the formula $YBa_2Cu_3O_7$. It was first made by chemists in 1986 by heating several simpler compounds together. Part of the equation is shown below.

$$4\ BaCO_3 + Z + 6\ CuCO_3 + \frac{1}{2}O_2 \rightarrow 2\ YBa_2Cu_3O_7 + 13\ CO_2$$

a Name the following substances in this equation.

i $BaCO_3$

ii $CuCO_3$ (*2 marks*)

b Deduce the formula of compound Z and give the formula of the ions that it contains. (*3 marks*)

c Modern methods of making these compounds use metal nitrates as the starting materials. Write down the formula of the nitrates that would be used in the modern process. (*3 marks*)

4 In order to create superconductors from these oxides, they are treated chemically to form compounds with a slightly altered formula. For example, $YBa_2Cu_3O_7$ is converted into a compound which is represented by the formula $YBa_2Cu_3O_{6.85}$.

a Describe what has happened to the oxide during this conversion. (*1 mark*)

b Identify what is unusual about the formula of the new compound and suggest why the formula needs to be written in this way. (*2 marks*)

ANSWERS

1 **a** **i** Sr^{2+} *(1 mark)*

ii Ca^{2+} *(1 mark)*

iii O^{2-} *(1 mark)*

b **i** The eight O^{2-} ions make up a total negative charge of 16-, the strontium, calcium, and copper ions make up a total positive charge of 10+. Thus the two bismuth ions have a total charge of 6+, implying Bi^{3+} as the charge on the bismuth ion. *(1 mark)*

ii This is not the expected charge; bismuth is in Group 5 *(1 mark)*

and so might be expected to have a charge of 3-. *(1 mark)*

c Charges on bismuth, strontium, and copper add up to 12+, *(1 mark)*

so if O = 2-, then *x* = 6. *(1 mark)*

2 **a** $Bi_2O_3\,(s) + 2SrCO_3(s) + CaCO_3(s) + 2CuO(s) \rightarrow Bi_2Sr_2CaCu_2O_8\,(s) + 3CO_2\,(g)$

(1 mark all formulae correct)
(1 mark for balancing)
(1 mark for state symbols)

b 888.3 *(1 mark)*

3 **a** **i** barium carbonate *(1 mark)*

ii copper carbonate OR copper(II) carbonate (if systematic naming has been introduced) *(1 mark)*

b On the RHS of the equation:

Y	Ba	Cu	C	O
2	4	6	13	40

On the LHS of the equation:

Y	Ba	Cu	C	O
0	4	6	10	31

So Z = $Y_2C_3O_9$ or $Y_2(CO_3)_3$ *(1 mark)*

Yttrium(III) carbonate *(1 mark)*

Y^{3+} and CO_3^{2-} *(1 mark)*

c Method would use:

Barium nitrate, $Ba(NO_3)_2$ *(1 mark)*

Yttrium(III) nitrate, $Y(NO_3)_3$ *(1 mark)*

Copper(II) nitrate, $Cu(NO_3)_2$ *(1 mark)*

4 **a** Some oxygen atoms have been removed. *(1 mark)*

b The formula is not written with whole number ratios. *(1 mark)*

Some of the oxygen atoms have been removed from the structure, but only a very small proportion, so it would be very difficult to write the formula in terms of whole numbers. *(1 mark)*

2.3 SUPPORT BALANCING EQUATIONS

Introduction

Writing balanced equations is something that you will be asked to do throughout your chemistry course. A balanced equation is a way of summarising and visualising what happens in a chemical reaction, and it allows chemists to calculate the quantities of substance that react.

Even experienced students can make mistakes in balancing chemical equations. This support sheet provides you with some activities to help avoid making these mistakes when you balance equations.

Learning outcomes

After completing the worksheet you should be able to:

- construct formulae of ionic compounds from ionic charges
- construct balanced chemical equations including state symbols for familiar and unfamiliar reactions.

Background

You can read about balancing equations in Topic 2.3: 'Formulae and equations'. If you are finding it difficult to balance equations, you may find the flow chart in Figure 1 helpful. The flow chart takes you through the process of balancing equations and also reminds you of things to be careful about at each stage. There are also some useful tips for successful balancing.

You may not always need to write an equation from scratch – sometimes you will be given the word equation or the formulae of the substances involved. In these cases, just start at the appropriate point on the flow chart.

Remember that, in exam questions, you may also be asked to add state symbols to your equation. There will always be some useful clues in the question to help you to do this, but students often lose marks by forgetting about this final step in the question.

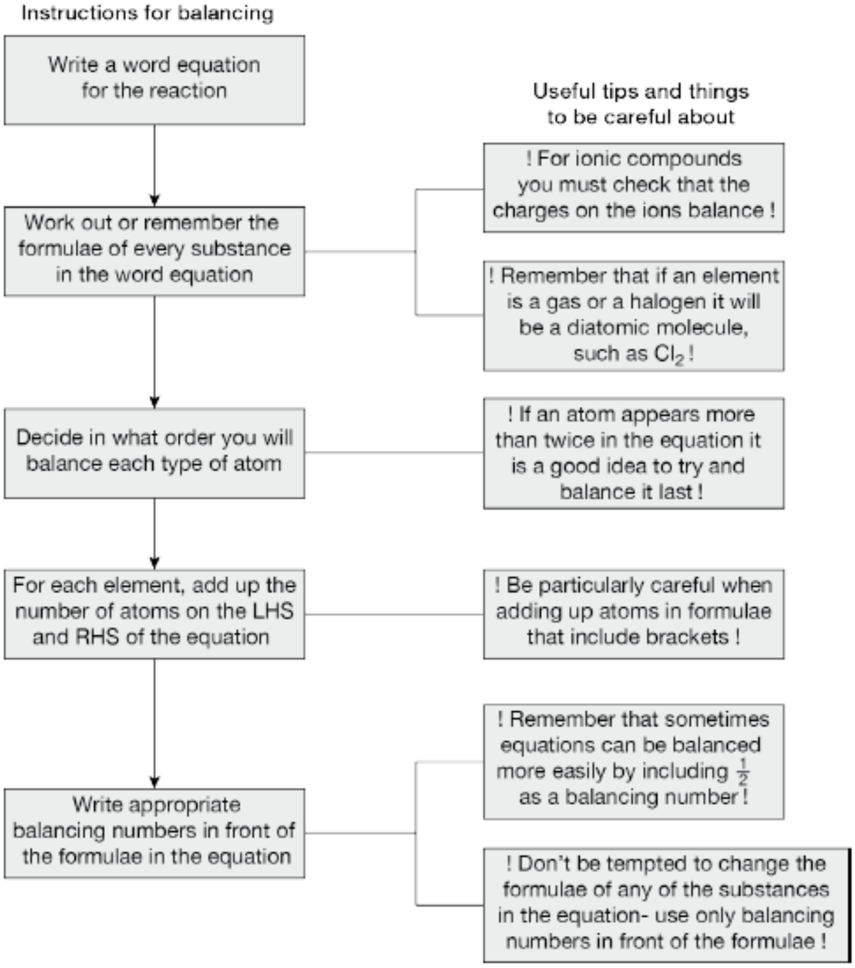


Figure 1 *Flow chart of steps for balancing chemical equations*

Task

Some students tried to balance equations. Each of them found themselves stuck and unable to write a balanced equation.

Use the hints and tips in the flow chart in Figure 1 to decide where they are going wrong, and then write a correct balanced equation.

1 Adam tried to balance an equation for the reaction between magnesium hydroxide and sulfuric acid. He got as far as writing the formulae of the substances involved, constructing the equation below.

$$MgOH + H_2SO_4 \rightarrow MgSO_4 + H_2O$$

Adam then could not find a way of balancing the equation. Suggest what he has done wrong. Construct the correct balanced equation. (*2 marks*)

2 Becky is given an equation to balance, as below.

$$NO + CO \rightarrow N_2 + CO_2$$

She balances it by rewriting it as

$$NO + CO \rightarrow N + CO_2$$

Suggest what she has done wrong. Construct the correct balanced equation. (*2 marks*)

3 Claire has got as far as writing the formulae for an equation showing the decomposition of lead(II) nitrate, as below.

$$Pb(NO_3)_2 \rightarrow PbO + NO_2 + O_2$$

She adds up the number of atoms on each side, using Table 1.

Table 1 *Number of atoms in the equation of the decomposition of lead(II) nitrate*

Atom	No. on left hand side	No. on right hand side
Pb	1	1
N	1	1
O	6	5

She then balances the equation in this way

$$Pb(NO_3)_2 \rightarrow PbO + NO_2 + 1\frac{1}{2}O_2$$

Suggest what she has done wrong. Construct the correct balanced equation. (*2 marks*)

4 Dinesh is balancing a combustion reaction:

$$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$$

He decides to balance the oxygen first:

$$C_3H_8 + 1\frac{1}{2}O_2 \rightarrow CO_2 + H_2O$$

He then balances the hydrogen and carbon:

$$C_3H_8 + 1\frac{1}{2}O_2 \rightarrow 3CO_2 + 4H_2O$$

Suggest what he has done wrong. Construct the correct balanced equation. (*2 marks*)

Exam-style question

1 Strontium is a metal in Group 2 of the periodic table. It reacts fairly rapidly with water to produce an alkaline solution. This solution can then react with acids to produce a range of salts. Other metals may behave in a similar way.

a **i** Construct a balanced equation for the reaction of strontium with water, based on the unbalanced equation: (*2 marks*)

$$Sr + H_2O \rightarrow Sr(OH)_2 + H_2$$

ii A student notices that when a piece of lithium, a Group 1 metal, is added to water, it behaves in a similar way to strontium. Name the two substances that will be formed in this reaction. (*2 marks*)

b When solid strontium hydroxide reacts with hydrochloric acid, a neutralisation reaction occurs, forming a salt and water.

i Construct a word equation for this neutralisation reaction. (*2 marks*)

ii State the formula of the salt that is formed. (*1 mark*)

c Another salt of strontium is strontium nitrate, $Sr(NO_3)_2$. If a solid sample of this nitrate is heated it decomposes to form strontium oxide. Nitrogen dioxide and oxygen gases are given off. Construct a balanced equation for this reaction, including state symbols. *(3 marks)*

ANSWERS

Tasks

1 Adam has written an incorrect formula for magnesium hydroxide. (*1 mark*)

Using the charges on the ions (Mg^{2+} and OH^-) the correct formula is $Mg(OH)_2$

A correct balanced equation is: $Mg(OH)_2 + H_2SO_4 \rightarrow MgSO_4 + 2H_2O$ (*1 mark*)

2 Becky has changed the formula of nitrogen from N_2 to N. (*1 mark*)

Keeping the formula as N_2, the equation can easily be balanced by using a $\frac{1}{2}$:

$NO + CO \rightarrow \frac{1}{2}N_2 + CO_2$ (*1 mark*)

Alternatively, the numbers can be doubled up, to give the same ratios:

$2NO + 2CO \rightarrow N_2 + 2CO_2$

3 Claire has added up the number of atoms in the brackets incorrectly. The correct figures for the left hand side are nitrogen: 2 and oxygen: 6. She has also put the incorrect number of oxygen atoms on the right hand side. There are 5, not 6 oxygen atoms on the right-hand side. (*1 mark*)

This means that a 2 must be placed before the N in nitrogen dioxide to balance the nitrogen atoms, and then the oxygen atoms must be added up again.

The correct balanced equation is: $Pb(NO_3)_2 \rightarrow PbO + 2NO_2 + \frac{1}{2}O_2$ (*1 mark*)

Alternatively, the numbers can be doubled up, to give the same ratios:

$2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$

4 Dinesh has not successfully balanced the oxygen on both sides of the equation. He should have balanced the oxygen last of all, since it appears more than twice in the equation. (*1 mark*)

A good order to balance these atoms would be: carbon, hydrogen and then oxygen.

There are three carbon atoms in C_3H_8 so there will be three carbon dioxide molecules on the right hand side.

There are eight hydrogen atoms in C_3H_8 so there will be four water molecules on the right hand side.

That now makes ten oxygen atoms on the right hand side, so there must be five oxygen molecules on the left hand side. The balanced equation is therefore:

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ (*1 mark*)

Exam-style question

1 **a** **i** $Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$

Left hand side correct. (*1 mark*)

Right hand side correct. (*1 mark*)

ii lithium hydroxide (*1 mark*)

hydrogen (*1 mark*)

b **i** strontium hydroxide + hydrochloric acid → strontium chloride + water (*1 mark for each product*)

ii $SrCl_2$ (*1 mark*)

c $2Sr(NO_3)_2(s) \rightarrow 2SrO(s) + 4NO_2(g) + O_2(g)$

OR $Sr(NO_3)_2(s) \rightarrow SrO(s) + 2NO_2(g) + \frac{1}{2}O_2(g)$

NO_2 balancing correct. *(1 mark)*

SrO and O_2 balancing correct. *(1 mark)*

State symbols correct. *(1 mark)*

CHECKLIST

Atoms, ions, and compounds

Specification reference	**Checklist questions**	
2.1.1a	Can you describe isotopes as atoms of the same element with different numbers of neutrons and different masses?	☐
2.1.1 b	Can you describe atomic structure in terms of the numbers of protons, neutrons and electrons for atoms and ions, given the atomic number, mass number and any ionic charge?	☐
2.1.1 c	Can you explain the terms *relative isotopic mass* (mass compared with 1/12th mass of carbon-12) and *relative atomic mass* (weighted mean mass compared with 1/12th mass of carbon-12), based on the mass of a ^{12}C atom, the standard for atomic masses?	☐
2.1.1 d	Can you use mass spectrometry?	☐
2.1.1 d i	Can you use mass spectrometry to determine relative isotopic masses and relative abundances of the isotope?	☐
2.1.1 d ii	Can you use mass spectrometry to calculate the relative atomic mass of an element from the relative abundances of its isotopes?	☐
2.1.2 a	Can you write formulae of ionic compounds from ionic charges?	☐
2.1.2 a i	Can you predict ionic charge from the position of an element in the periodic table?	☐
2.1.2 a ii	Can you recall the names and formulae for the following ions: NO_3^{-}, CO_3^{2}, SO_4^{2-}, OH–, NH_4^{+}, Zn^{2+}, and Ag^{+}?	☐
2.1.2 b	Can you construct balanced chemical equations (including ionic equations), including state symbols, for reactions studied and for unfamiliar reactions given appropriate information?	☐