PEARSON

CHEMISTRY QUEENSLAND

UNITS 1 & 2

Elissa Huddart

2nd EDITION

Skills and Assessment

QCE 2025 Chemistry SYLLABUS

Contents

Pearson Chemistry Queensland Units 1 & 2 Skills and Assessment Book 2nd edition

Contents

UNIT 2: MOLECULAR INTERACTIONS AND REACTIONS

How to use this book

The *Pearson Chemistry Queensland Units 1 & 2 Skills and Assessment Book 2nd edition* takes an intuitive, self-paced approach to science education that ensures every student has opportunities to practise, apply and extend their learning through a range of supportive and challenging activities.

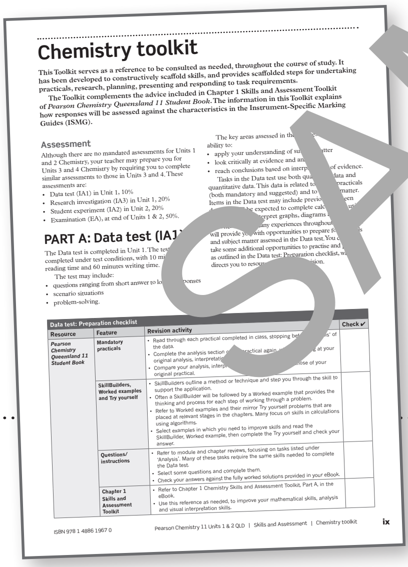
This resource has been developed by highly experienced and expert author teams, with lead Queensland specialists who have a working understanding of what teachers are looking for to support teaching and learning across the new Queensland Certificate of Education (QCE).

Fully written to the new QCE Units 1–4 Syllabus, the Skills and Assessment Book is organised by units and topics, and the **unit opener** outlines the unit objectives that are addressed. The Skills and Assessment Book is further organised into topics. Each **topic** addresses all of the subject matter and mandatory practicals, from the Syllabus.

All activities integrate into the Pearson *Chemistry 11 Units 1 & 2 Queensland Student Book* for a complete teaching, learning and assessment program, making integration of practice and rich learning activities a seamless inclusion. The resource has been designed so it can be used independently of the Student Book, providing flexibility in when and how the Skills and Assessment Book is engaged with.

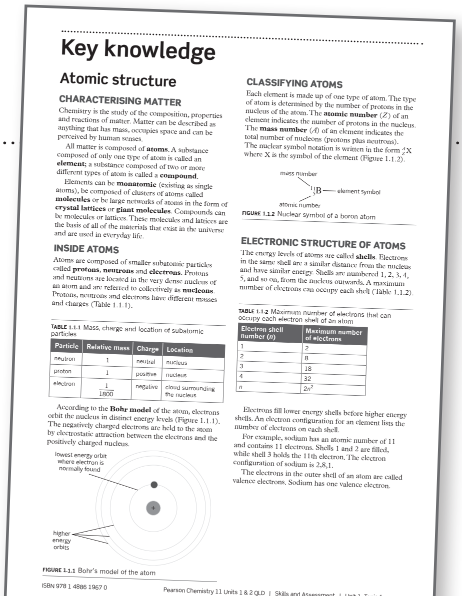
TOOLKIT

A complementary Toolkit supports development of the skills and techniques needed to undertake Practical investigations, the Data test, Student experiment and Research investigation, and also study skills. It also includes checklists and helpful hints to assist in fulfilling all assessment requirements.



KEY KNOWLEDGE

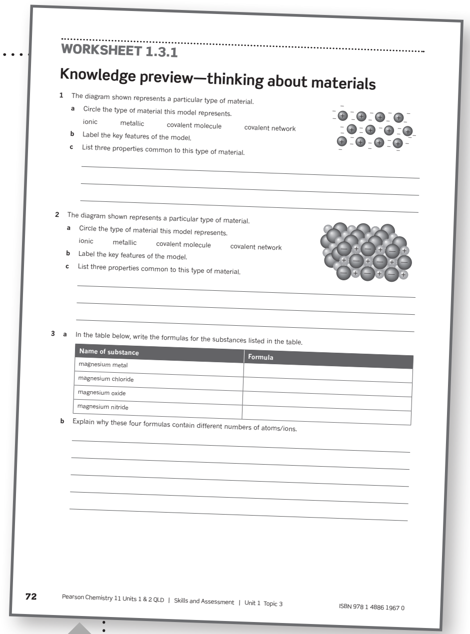
Each topic begins with a key knowledge section. Key knowledge consists of a set of succinct summary notes that cover the subject matter for each topic of the Syllabus. This section is highly illustrative and written in a straightforward style to assist students of all abilities in focusing on the salient points. Key terms are bolded for ease of navigation and are reflected in the Student Book glossary. The key knowledge also serves as a ready reference when completing worksheets and practical activities, and provides a handy set of revision and study notes.



WORKSHEETS

A diverse offering of instructive and self-contained worksheets is included in each topic. Common to all topics are the initial 'Knowledge preview' worksheets to activate prior knowledge; a 'Literacy review' worksheet to explicitly build language and application of scientific terminology; and finally, a 'Thinking about my learning' worksheet, which encourages students to reflect on their learning and identify areas for improvement. Other worksheets, with their range of activities and tasks, focus on application of subject matter to assist in the consolidation of learning and the making of connections between subject matter.

Worksheets may be used as formative assessment and are clearly aligned to the Syllabus. A range of questions provide scaffolded support in alignment with the revised Syllabus. These worksheets build students' proficiency in skills and knowledge required to respond effectively to assessment requirements.



WORKSHEET 1.3.1

Knowledge preview—thinking about materials

1 The diagram shown represents a particular type of material.
a Circle the type of material this model represents.
ionic metallic covalent molecule covalent network
b Label the key features of the model.
c List three properties common to this type of material.

2 The diagram shown represents a particular type of material.
a Circle the type of material this model represents.
ionic metallic covalent molecule covalent network
b Label the key features of the model.
c List three properties common to this type of material.

3 a In the table below, write the formulas for the substances listed in the table.

Name of substance	Formula
magnesium metal	
magnesium chloride	
magnesium oxide	
magnesium nitride	

b Explain why these four formulas contain different numbers of atoms/ions.

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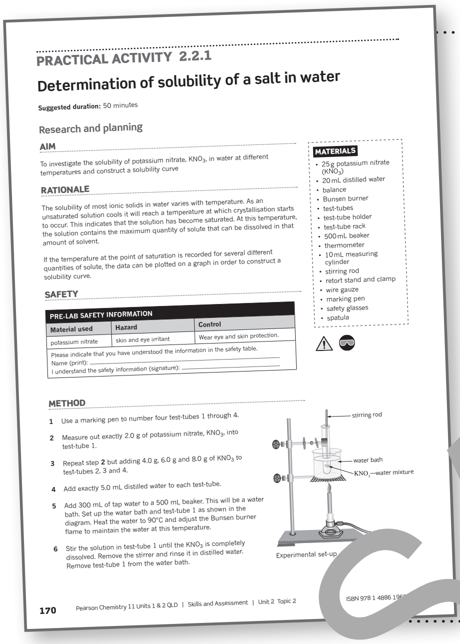

PRACTICAL ACTIVITY 2.2.1

Determination of solubility of a salt in water

Suggested duration: 50 minutes

Research and planning

AIM

To investigate the solubility of potassium nitrate, KNO_3, in water at different temperatures and construct a solubility curve

RATIONALE

The solubility of most ionic solids in water varies with temperature. As an unsaturated solution cools it will reach a temperature at which crystallisation starts to occur. This indicates that the solution has become saturated. At this temperature, the solution contains the maximum quantity of solute that can be dissolved in that amount of solvent.

If the temperature at the point of saturation is recorded for several different quantities of solute, the data can be plotted on a graph in order to construct a solubility curve.

MATERIALS
- 25 g potassium nitrate (KNO_3)
- 20 mL distilled water
- balance
- Bunsen burner
- test-tubes
- test-tube holder
- test-tube rack
- 500 mL beaker
- thermometer
- 10 mL measuring cylinder
- stirring rod
- retort stand and clamp
- wire gauze
- marking pen
- safety glasses
- spatula

SAFETY

PRE-LAB SAFETY INFORMATION

Material used	Hazard	Control
potassium nitrate	skin and eye irritant	Wear eye and skin protection.

Please indicate that you have understood the information in the safety table.
Name (print):
I understand the safety information (signature):

METHOD

1 Use a marking pen to number four test-tubes 1 through 4.
2 Measure out exactly 2.0 g of potassium nitrate, KNO_3, into test-tube 1.
3 Repeat step 2 but adding 4.0 g, 6.0 g and 8.0 g of KNO_3 to test-tubes 2, 3 and 4.
4 Add exactly 5.0 mL distilled water to each test-tube.
5 Add 300 mL of tap water to a 500 mL beaker. This will be a water bath. Set up the water bath and test-tube 1 as shown in the diagram. Heat the water to 90°C and adjust the Bunsen burner flame to maintain the water at this temperature.
6 Stir the solution in test-tube 1 until the KNO_3 is completely dissolved. Remove the stirrer and rinse it in distilled water. Remove test-tube 1 from the water bath.

stirring rod
water bath
KNO_3—water mixture
Experimental set-up

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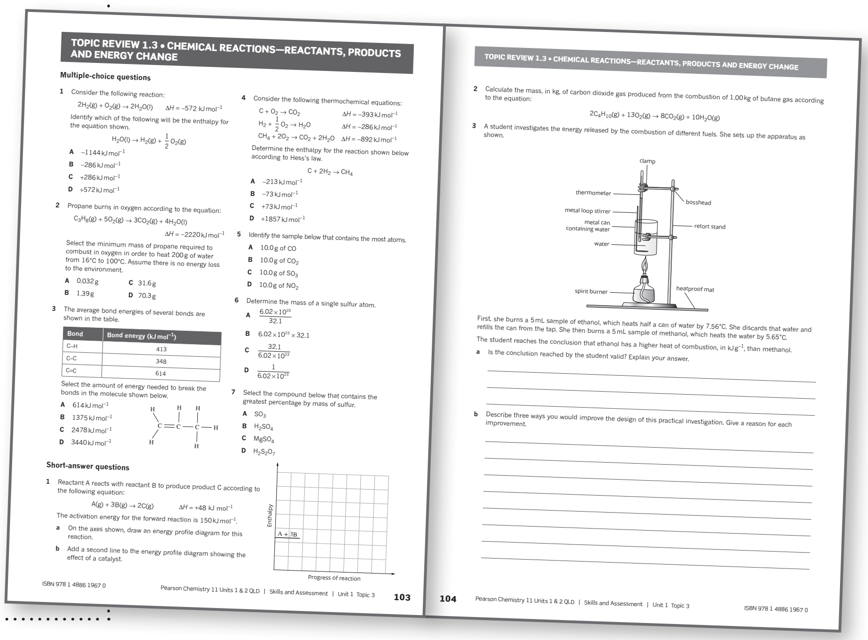
PRACTICAL ACTIVITIES

Practical activities take a highly scaffolded approach from beginning to completion and give students the opportunity to complete practical work related to the subject matter covered in the Syllabus. Practical activities include a rich assortment of tasks that maximise the learning opportunities and build experience in skill application to perform calculations and analysis of data, which are necessary for the Data test. A diverse range of high quality practical activities are included to provide depth and choice for teachers. Like the worksheets, a range of questions building from foundation to challenging are included, which are written to reflect the syllabus cognitions at the expected level.

TOPIC REVIEW QUESTIONS

Each topic concludes with a comprehensive set of question items consisting of multiple-choice and short-answer responses written in an exam style. This provides students with exposure to and the opportunity to practise drawing together subject matter and skills to respond to examination-style assessment.



TOPIC REVIEW 1.3 • CHEMICAL REACTIONS—REACTANTS, PRODUCTS AND ENERGY CHANGE

Multiple-choice questions

1 Consider the following reaction:
$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ $\Delta H = -572$ kJ mol^{-1}
Identify which of the following will be the enthalpy for the equation shown.
$H_2O(l) \rightarrow H_2(g) + \frac{1}{2}O_2(g)$
A −1144 kJ mol^{-1}
B −286 kJ mol^{-1}
C +286 kJ mol^{-1}
D +572 kJ mol^{-1}

2 Propane burns in oxygen according to the equation:
$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ $\Delta H = -2220$ kJ mol^{-1}
Select the minimum mass of propane required to combust in oxygen in order to heat 200 g of water from 16°C to 100°C. Assume there is no energy loss to the environment.
A 0.032 g C 31.6 g
B 1.39 g D 70.3 g

3 The average bond energies of several bonds are shown in the table.

Bond	Bond energy (kJ mol^{-1})
C–H	413
C–C	348
C=C	614

Select the amount of energy needed to break the bonds in the molecule shown below.
A 614 kJ mol^{-1}
B 1375 kJ mol^{-1}
C 2478 kJ mol^{-1}
D 3440 kJ mol^{-1}

4 Consider the following thermochemical equations:
$C + O_2 \rightarrow CO_2$ $\Delta H = -393$ kJ mol^{-1}
$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$ $\Delta H = -286$ kJ mol^{-1}
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ $\Delta H = -892$ kJ mol^{-1}
Determine the enthalpy for the reaction shown below according to Hess's law.
$C + 2H_2 \rightarrow CH_4$
A −213 kJ mol^{-1}
B −73 kJ mol^{-1}
C +73 kJ mol^{-1}
D +1857 kJ mol^{-1}

5 Identify the sample below that contains the most atoms.
A 10.0 g of CO
B 10.0 g of CO_2
C 10.0 g of SO_2
D 10.0 g of NO_2

6 Determine the mass of a single sulfur atom.
A $\frac{6.02\times10^{23}}{32.1}$
B $6.02\times10^{23}\times32.1$
C $\frac{32.1}{6.02\times10^{23}}$
D $\frac{1}{6.02\times10^{23}}$

7 Select the compound below that contains the greatest percentage by mass of sulfur.
A SO_2
B H_2SO_4
C $MgSO_4$
D $H_2S_2O_7$

Short-answer questions

1 Reactant A reacts with reactant B to produce product C according to the following equation:
$A(g) + 3B(g) \rightarrow 2C(g)$ $\Delta H = +48$ kJ mol^{-1}
The activation energy for the forward reaction is 150 kJ mol^{-1}.
a On the axes shown, draw an energy profile diagram for this reaction.
b Add a second line to the energy profile diagram showing the effect of a catalyst.

Enthalpy
A + 3B
Progress of reaction

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TOPIC REVIEW 1.3 • CHEMICAL REACTIONS—REACTANTS, PRODUCTS AND ENERGY CHANGE

2 Calculate the mass, in kg, of carbon dioxide gas produced from the combustion of 1.00 kg of butane gas according to the equation:
$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$

3 A student investigates the energy released by the combustion of different fuels. She sets up the apparatus as shown.

clamp
thermometer
bosshead
metal loop stirrer
metal can containing water
retort stand
water
spirit burner
heatproof mat

First, she burns a 5 mL sample of ethanol, which heats half a can of water by 7.56°C. She discards that water and refills the can from the tap. She then burns a 5 mL sample of methanol, which heats the water by 5.65°C.
The student reaches the conclusion that ethanol has a higher heat of combustion, in kJ g^{-1}, than methanol.
a Is the conclusion reached by the student valid? Explain your answer.
b Describe three ways you would improve the design of this practical investigation. Give a reason for each improvement.

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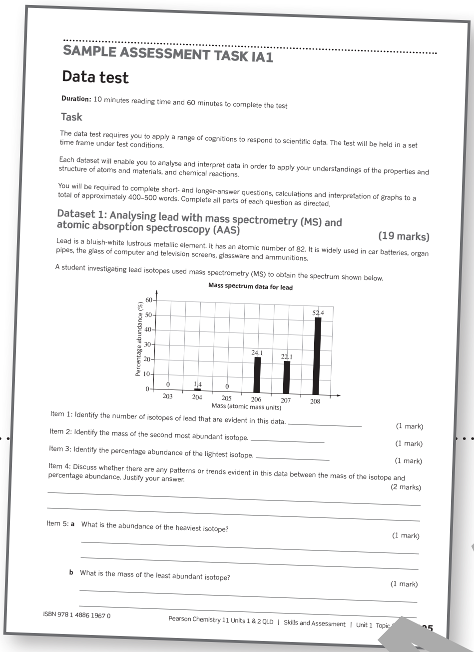
SAMPLE ASSESSMENT TASKS

Sample assessment tasks for the **Data Test**, **Student experiment** and **Research investigation** provide opportunities for students to practise responding to these assessment tasks. The activities are designed to support students by guiding and scaffolding them through each aspect of these assessments.


SAMPLE ASSESSMENT TASK IA1

Data test

Duration: 10 minutes reading time and 60 minutes to complete the test

Task

The data test requires you to apply a range of cognitions to respond to scientific data. The test will be held in a set time frame under test conditions.

Each dataset will enable you to analyse and interpret data in order to apply your understandings of the properties and structure of atoms and materials, and chemical reactions.

You will be required to complete short- and longer-answer questions, calculations and interpretation of graphs to a total of approximately 400–500 words. Complete all parts of each question as directed.

Dataset 1: Analysing lead with mass spectrometry (MS) and atomic absorption spectroscopy (AAS) (19 marks)

Lead is a bluish-white lustrous metallic element. It has an atomic number of 82. It is widely used in car batteries, organ pipes, the glass of computer and television screens, glassware and ammunitions.

A student investigating lead isotopes used mass spectrometry (MS) to obtain the spectrum shown below.

Item 1: Identify the number of isotopes of lead that are evident in this data. ______ (1 mark)

Item 2: Identify the mass of the second most abundant isotope. ______ (1 mark)

Item 3: Identify the percentage abundance of the lightest isotope. ______ (1 mark)

Item 4: Discuss whether there are any patterns or trends evident in this data between the mass of the isotope and percentage abundance. Justify your answer. (2 marks)

Item 5: **a** What is the abundance of the heaviest isotope? (1 mark)

b What is the mass of the least abundant isotope? (1 mark)

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ICONS AND FEATURES

Many of the Practical Activities are further supported by a complementary SPARKlab alternative practical.

Use the activities for practice, application and revision of subject matter.

The **safety icon** highlights significant hazards, indicating caution is needed.

The **safety glasses icon** highlights that protective eyewear is to be worn during the practical activity.

RATE MY LEARNING

This innovative feature appears at the end of most worksheets, all practical activities and sample assessment tasks. It provides students with the opportunity for self-reflection and self-assessment. Students are encouraged to consider how they can continue to improve, and identify areas of focus for further skill and subject matter development. This tool has been based on the syllabus requirements to provide teachers with a simple yet effective tool for gauging student needs.

RATE MY LEARNING	• I get it. • I can apply/teach it.	• I get it. • I can show I get it.	• I almost get it. • I might need help.	• I get some of it. • I need help.	• I don't get it. • I need lots of help.

Teacher support

Fully worked solutions, suggested answers and responses to sample assessment tasks, as well as practical activity support including full **risk assessments**, **expected results** and **handy hints**, are provided for teachers through the teacher support subscription.

Chemistry toolkit

This Toolkit serves as a reference to be consulted as needed, throughout the course of study. It has been developed to constructively scaffold skills, and provides scaffolded steps for undertaking practicals, research, planning, presenting and responding to task requirements.

The Toolkit complements the advice included in Chapter 1 Skills and Assessment Toolkit of *Pearson Chemistry Queensland Units 1 & 2 Student Book*. The information in this Toolkit explains how responses will be assessed against the characteristics in the Instrument-Specific Marking Guides (ISMG).

Assessment

Although there are no mandated assessments for Units 1 and 2 Chemistry, your teacher may prepare you for Units 3 and 4 Chemistry by requiring you to complete similar assessments to those in Units 3 and 4. These assessments are:

- Data test (IA1) in Unit 1, 10%
- Research investigation (IA3) in Unit 1, 20%
- Student experiment (IA2) in Unit 2, 20%
- Examination (EA), at end of Units 1 & 2, 50%.

PART A: Data test (IA1)

The Data test is completed in Unit 1. The test is completed under test conditions, with 10 minutes reading time and 60 minutes writing time.

The test may include:

- scenario situations
- problem-solving.

The key areas assessed in the data test are your ability to:

- apply understanding of subject matter to process data
- look critically at evidence and analyse it.

Tasks in the data test use both qualitative data and quantitative data. This data is related to Unit 1 practicals and to subject matter. Items in the data test may include previously unseen data. You will be expected to complete calculations using algorithms, and interpret graphs, diagrams and tables.

There will be many experiences throughout Unit 1 that will provide you with opportunities to prepare for the skills and subject matter assessed in the data test. You can also take some additional opportunities to practise and prepare, as outlined in the Data Test: Preparation checklist, which directs you to resources to assist in revision.

Data test: Preparation checklist			
Resource	**Feature**	**Revision activity**	**Check ✔**
Pearson Chemistry Queensland 11 Student Book	**Practicals**	• Read through each practical completed. • Complete the analysis section of the practical again, without looking at your original analysis, interpretation and conclusion. • Compare your analysis, interpretation and conclusion with those of your original practical.	
	SkillBuilders, Worked examples and Try yourself	• SkillBuilders outline a method or technique and step you through the skill to support the application. • Often a SkillBuilder will be followed by a Worked example that provides the thinking and process for each step of working through a problem. • Refer to Worked examples and their mirror Try yourself problems that are placed at relevant stages in the chapters. Many focus on skills in calculations using algorithms. • Select examples in which you need to improve skills and read the SkillBuilder, Worked example, then complete the Try yourself and check your answer.	
	Questions/ instructions	• Refer to module and chapter reviews, focusing on tasks listed under 'Analysis'. Some of these tasks require the same skills needed to complete the Data test. • Select some questions and complete them. • Check your answers against the fully worked solutions provided in your eBook.	
	Chapter 1 Skills and Assessment Toolkit	• Refer to Chapter 1 Chemistry Skills and Assessment Toolkit, Part A, in the eBook. • Use this reference as needed, to improve your mathematical skills, analysis and visual interpretation skills.	

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Data test: Preparation checklist			
Resource	**Feature**	**Revision activity**	**Check ✔**
Pearson Chemistry Queensland 11 Skills and Assessment Book	**Practicals**	• See suggestions and support for practicals; these include working with data.	
	Topic review	• Refer to the topic review tasks for examples of the types of items on the Data test.	
	Practice data test	• Complete the practice Sample assessment task—Data test provided on page 101. • Complete these tasks under test conditions.	

PART B: Student experiment (IA2)

The Student experiment uses practical investigation methodology including a research question or hypothesis developed by the student, the collection of primary data, and then analysis and synthesis of that data.

The Research question developed must:

- relate back to a practical related to the subject matter.

CONDUCTING THE STUDENT EXPERIMENT

A great deal of preparation is needed before starting the experiment. Use the Student Experiment Checklist as a guide.

Refer to Pearson Chemistry 11 Units 1 & 2 Queensland Student Book, Chapter 1 ebook.

- Part A covers Scientific skills such as mathematical basics, representations in graphics, tables and graphs, data analysis.
- Part B covers all aspects of the student experiment and includes a sample student report.

Student Experiment Checklist				
Task		**Activity**	**Date due**	**Complete ✔**
Form ideas and develop the experiment question	**Initial practical**	• Identify the practical to be modified for your experiment.		
	Background	• Commence a journal to record all aspects of the assessment task. • Research relevant background information.		
	Variables	• Understand the data of original experiment. • Identify the dependent and independent variables of original experiment.		
	Modification	• Modify the original experiment. • Develop a new experiment question. • Identify the dependant and independent variables and check they can be measured to provide data.		
	Justification	• Justify/provide rationale for the modification for the new experiment question.		
Find the methodology and data	**Methodology**	• Plan the method to be followed for the experiment. • Write a statement of the aim that covers what the scientist wants to show, verify or find out in the experiment. - May be expressed as a statement or question. - May be one or two sentences. - Often written as 'To investigate the effect of … on …' or 'To investigate if a correlation exists between … and …'.		
	Risk assessment	• Identify and manage risks and potential dangers by completing the Risk Assessment Form on page xii–xiii.		
	Materials	• Make a list of all equipment, chemicals and materials used. • Include quantities (chemicals) and sizes (equipment).		

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	The experiment	• Conduct the experiment. • Collect the relevant data to answer the research question.		
	Results	• Record all measurements taken during the experiment as well as observations. • Collect sufficient and relevant data. • Observations may be recorded as text, diagrams, photos or videos. • Process data and present it correctly. • Most common records of primary data are tables with titles and units. • Most common records of processed data are tables, graphs and can include calculations. • Check for errors and mistakes in data collected. Take steps to reduce these.		
Analyse the evidence	**Organise data collected**	• Process the data using mathematical techniques and graphs. • Identify the trends, patterns or relationships. • Identify the uncertainties and limitations of the evidence. • Include the interpretation of results.		
Interpret and evaluate the evidence	**Work with data collected; relate back to the experiment question**	• Draw conclusion/s from the evidence that addresses the experiment question. • Evaluate the reliability and validity of the experimental process. • Provide suggestions to improve and/or extend the experiment. • Evaluate the method used. • Comment on whether results relate to the experiment question. • Provide suggestions for improvements and extensions to the experiment.		
The experiment report	**Presentation format**	• Decide on the presentation format; written or multi modal. • Check length requirements for your selected format.		
	Communication	• Communicate ideas in scientific language and representations. • Include in-text citations and reference list. • Write using your own words to avoid plagiarising. • Ensure length requirements are not exceeded.		

UNIT 1 Chemical fundamentals—structure, properties and reactions

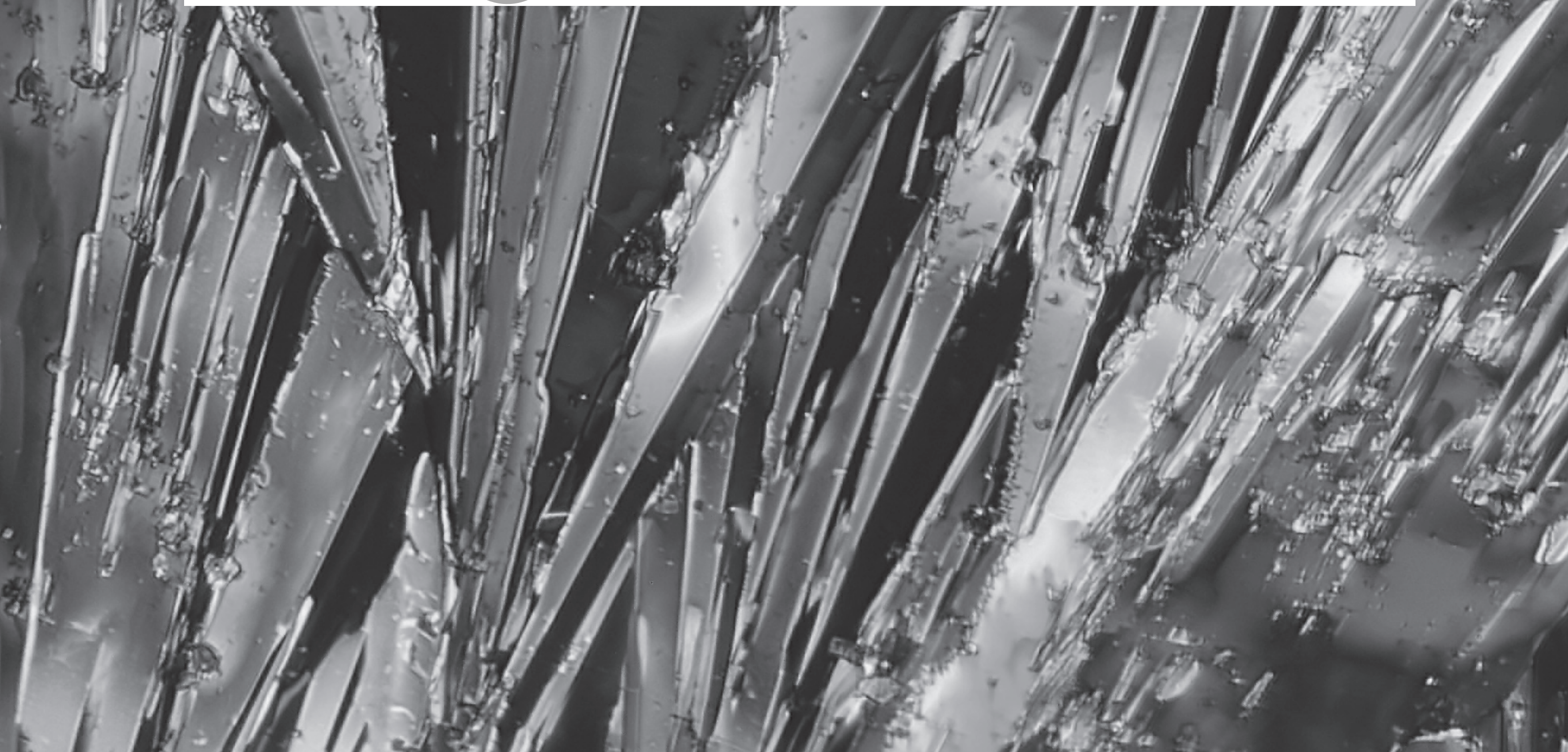
TOPIC 1 Properties and structure of atoms

TOPIC 2 Properties and structure of materials

TOPIC 3 Chemical reactions—reactants, products and energy change

Unit 1 objectives

- Describe ideas and findings about properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.
- Apply understanding of properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.
- Analyse data about properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.
- Interpret evidence about properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.
- Evaluate processes, claims and conclusions about properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.
- Investigate phenomena associated with properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.



TOPIC 1

Properties and structure of atoms

- ☐ Worksheet 1.1.1 Knowledge preview—atoms and reactions

ATOMIC STRUCTURE

- ☐ Worksheet 1.1.2 Writing electron configurations—shells and subshells
- ☐ Practical activity 1.1.1 Science as a Human Endeavour—Simulating Geiger–Marsden's gold foil experiments

ISOTOPES

- ☐ Worksheet 1.1.4 Interpreting mass spectrometry

ANALYTICAL TECHNIQUES

- ☐ Worksheet 1.1.4 Interpreting mass spectrometry
- ☐ Worksheet 1.1.5 Analysis with light—atomic absorption spectroscopy
- ☐ Practical activity 1.1.2 Flame colours of selected metals

PERIODIC TABLE AND TRENDS

- ☐ Worksheet 1.1.3 Tracking trends—patterns in properties in the periodic table
- ☐ Practical activity 1.1.3 Investigating periodic trends, patterns and relationships—data analysis

INTRODUCTION TO BONDING

- ☐ Worksheet 1.1.6 Writing ionic formulas
- ☐ Worksheet 1.1.7 Comparing simple molecules

- ☐ Worksheet 1.1.8 Literacy review—comparing similar terms
- ☐ Worksheet 1.1.9 Thinking about my learning
- ☐ **Topic review 1.1**

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Key knowledge

Atomic structure

CHARACTERISING MATTER

Chemistry is the study of the composition, properties and reactions of matter. Matter can be described as anything that has mass, occupies space and can be perceived by human senses. All matter is composed of **atoms**.

INSIDE ATOMS

Atoms are composed of smaller subatomic particles called **protons**, **neutrons** and **electrons**. Protons, neutrons and electrons have different masses and charges (Table 1.1.1).

TABLE 1.1.1 Mass, charge and location of subatomic particles

Particle	Relative mass	Charge	Location
neutron	1	neutral	nucleus
proton	1	positive	nucleus
electron	$\frac{1}{1800}$	negative	cloud surrounding the nucleus

Atoms can be modelled as a nucleus surrounded by electrons located in distinct energy levels (Figure 1.1.1). Protons and neutrons are located in the nucleus. The negatively charged electrons are held to the atom by electrostatic attraction between the electrons and the positively charged nucleus.

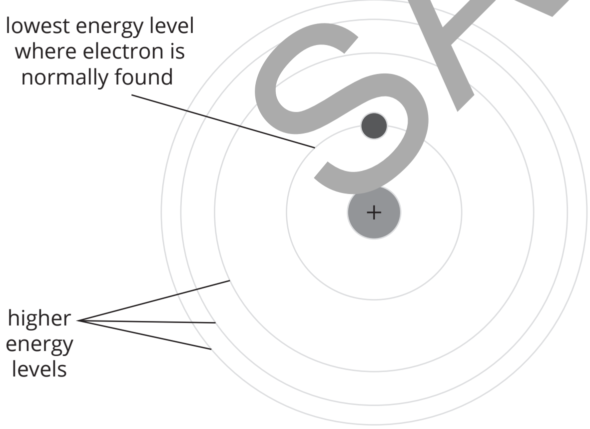

FIGURE 1.1.1 A model of the atom

CLASSIFYING ATOMS

Each element is made up of one type of atom. The type of atom is determined by the number of protons in the nucleus of the atom. The **atomic number** (Z) of an element indicates the number of protons in the nucleus. The **mass number** (A) of an element indicates the total number of nucleons (protons plus neutrons). The nuclear symbol notation for an atom, ion or isotope is written in the form ${}^{A}_{Z}X$ where X is the symbol of the element (Figure 1.1.2).

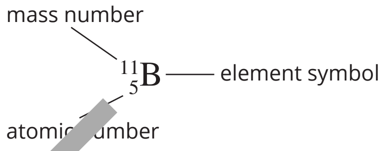

FIGURE 1.1.2 Nuclear symbol of a boron atom

ELECTRONIC STRUCTURE OF ATOMS

The energy levels of atoms are called **shells**. Electrons in the same shell are a similar distance from the nucleus and have similar energy. Shells are numbered 1, 2, 3, 4, 5, and so on, from the nucleus outwards. A maximum number of electrons can occupy each shell (Table 1.1.2).

TABLE 1.1.2 Maximum number of electrons that can occupy each electron shell of an atom

Electron shell number (n)	Maximum number of electrons
1	2
2	8
3	18
4	32
n	$2n^2$

Electrons fill lower energy shells before higher energy shells. An electron configuration for an element lists the number of electrons on each shell.

For example, sodium has an atomic number of 11 and contains 11 electrons. Shells 1 and 2 are filled, while shell 3 holds the 11th electron. The electron configuration of sodium is 2,8,1.

The electrons in the outer shell of an atom are called valence electrons. Sodium has one valence electron.

QUANTUM MECHANICAL MODEL OF THE ATOM

Erwin Schrödinger proposed a new model of the atom using quantum mechanics. His model proposed that electrons should be regarded as having wave-like properties. According to his model, electrons are not restricted to a specific orbit but behave as negative clouds of charge found in regions of space called **orbitals** (Figure 1.1.3).

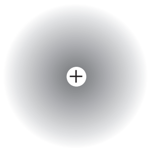

FIGURE 1.1.3 Electron cloud around a nucleus

Electrons make up most of the volume of an atom. The 'negative clouds' of electrons are organised into orbitals in subshells within shells (Table 1.1.3).

TABLE 1.1.3 Different levels of organisation of electrons

Level of organisation	Definition	Label
shell	major energy levels within an atom	1, 2, 3, 4, 5, etc.
subshell	energy levels within a shell	*s*, *p*, *d*, *f*
orbital	regions in subshells in which electrons move	

The **Pauli exclusion principle** states that each orbital may hold a maximum of two electrons.

- An *s*-subshell has 1 orbital and can hold up to 2 electrons.
- A *p*-subshell has 3 orbitals and can hold up to 6 electrons.
- A *d*-subshell has 5 orbitals and can hold up to 10 electrons.
- An *f*-subshell has 7 orbitals and can hold up to 14 electrons.

The subshells closest to the nucleus have the lowest energy and are filled first. This is known as the **Aufbau principle**. However, some subshells are higher in energy than subshells of the next shell (Figure 1.1.4).

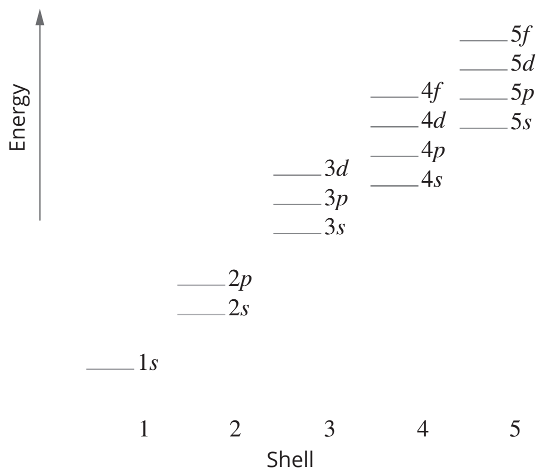

FIGURE 1.1.4 Energy levels in an atom

For instance, the unfilled 3*d* subshell is higher in energy than the unfilled 4*s*-subshell. Therefore, the 4*s* subshell is filled before the 3*d*.

The electron configurations of lithium, nitrogen, potassium and nickel using the quantum mechanical model are shown in Table 1.1.4.

TABLE 1.1.4 Electron configurations of some elements using the quantum mechanical model

Element	Atomic number	Electron configuration
lithium	3	$1s^2 2s^1$
nitrogen	7	$1s^2 2s^2 2p^3$
potassium	19	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
nickel	28	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$

Chromium and copper are exceptions to the usual order of filling. In these cases there is increased stability in having a half or completely full *d*-subshell, so an electron from the 4*s*-subshell is promoted to a 3*d*-orbital. Their electron configurations are:

Cr: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$

Cu: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$

Valence electrons occupy the shell furthest from the nucleus. The valence electrons determine an element's chemical properties. Atoms lose or gain the valence electrons to form **ions**.

Condensed electron configuration

Condensed electron configuration is an abbreviated version of the full configuration. The symbol of a noble gas, enclosed in square brackets, is used in the electron configuration to represent the inner-shell electrons. Only the valence electrons are shown in their shells or subshells, as seen in Table 1.1.5.

Orbital diagrams

Orbital diagrams represent individual electrons in the orbitals of an atom. Electrons have **spin** that can be characterised as being in either the up or down direction. The pair of electrons in a single orbital must have opposite spin (Figure 1.1.5).

FIGURE 1.1.5 Diagrammatic representation of a pair of electrons in an orbital. The arrows show the opposite spin.

Hund's rule states that every orbital in a subshell must contain a single electron before any orbital contains two electrons. The first electron in each orbital is always written with an upward spin as shown in Table 1.1.5.

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TABLE 1.1.5 Different types of electron configurations and orbital representations

Element	Electron configuration	Electron configuration using quantum mechanical model	Condensed electron configuration using quantum mechanical model	Orbital diagram
$^{31}_{15}P$	2,8,5	$1s^2 2s^2 2p^6 3s^2 3p^3$	$[Ne]3s^2 3p^3$	1s [↑↓] 2s [↑↓] 2p [↑↓][↑↓][↑↓] 3s [↑↓] 3p [↑][↑][↑]
$^{59}_{28}Ni$	2,8,16,2	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$	$[Ar]3d^8 4s^2$	1s [↑↓] 2s [↑↓] 2p [↑↓][↑↓][↑↓] 3s [↑↓] 3p [↑↓][↑↓][↑↓] 4s [↑↓] 3d [↑↓][↑↓][↑↓][↑][↑] 4s [↑↓]

IONISATION ENERGIES AND ELECTRON CONFIGURATION

Ionisation energy is the energy required to remove an electron from an atom or ion. The ionisation energy required to remove each successive electron from an atom can be measured. Successive ionisation energies relate to the electron configuration of an atom. The grouping of electrons with similar ionisation energy reflects the number of electrons that can fit on each shell. The final two electrons to be removed are always a group of two electrons (on the first shell). The second group of electrons always contains no more than eight electrons (Figure 1.1.6).

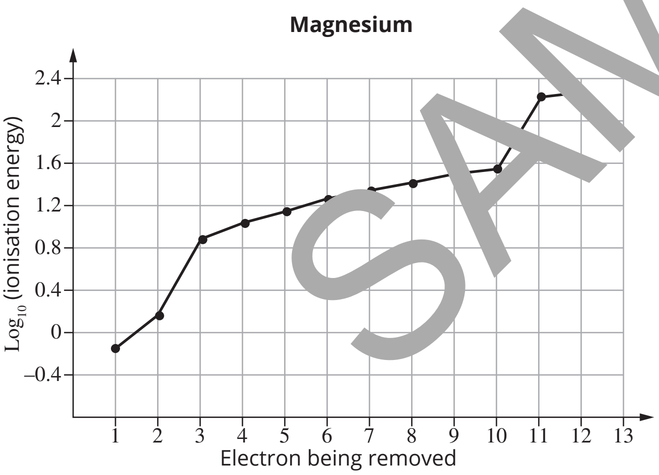

FIGURE 1.1.6 Successive ionisation energies for magnesium. There are three groups of energies, indicating that the electrons occupy three energy levels (shells).

Isotopes

All atoms of the same element have identical atomic numbers. However, atoms of the same element can have different mass numbers; that is, they can have different numbers of neutrons. Atoms of the same element with different numbers of neutrons are called **isotopes** (Figure 1.1.7).

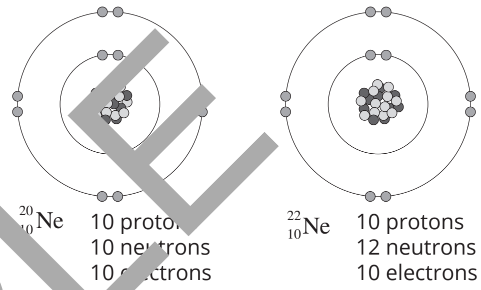

FIGURE 1.1.7 Isotopes of neon

The isotopes in Figure 1.1.7 are represented by the symbols ^{20}Ne and ^{22}Ne or 20-Ne and 22-Ne. These are in the form ^{A}X or X-A where A is the atomic number and X is the symbol of the element. Isotopes have the same number of electrons, and therefore the same electron configuration, which gives them similar chemical properties.

The physical properties of isotopes differ because the different number of neutrons changes the mass of the atom and the nuclear structure. Properties such as density, thermal conductivity, viscosity and the existence of radioactivity can all differ between isotopes.

MASSES OF PARTICLES

Masses used in chemistry are *relative* masses. They are relative to the standard of the common isotope **carbon-12** (^{12}C) being given a mass of exactly 12 units.

The **relative atomic mass** of an element is the ratio of the weighted average mass per atom of the naturally occurring form of the element to $\frac{1}{12}$ the mass of an atom of carbon-12.

Analytical techniques

Different analytical techniques are used to determine the relative atomic mass of elements and to determine the presence and concentration of elements in a sample.

MASS SPECTROMETRY

Samples of most elements contain a mixture of isotopes. A **mass spectrometer** can be used to identify the existence of isotopes of an element and their **relative isotopic abundances** so that relative atomic masses can be determined.

When a substance is analysed in a mass spectrometer, it is first ionised to form positive ions. The resulting ions are then separated according to their mass-to-charge ratio and their abundance is detected.

Analysis of data from a mass spectrometer

The data from a mass spectrometer is in the form of a **mass spectrum** (Figure 1.1.8).

Each peak on a spectrum represents one isotope. The position of each peak indicates the relative mass of the isotope through its mass-to-charge ratio (m/z) and the height of the peak indicates its percentage abundance. The masses and abundances of isotopes of a particular element allow the calculation of relative atomic mass.

The mass spectrum data for a sample of copper represented in Figure 1.1.8 shows that:

- one copper isotope has a relative mass of 62.9 and relative isotopic abundance of 69.1%
- one copper isotope has a relative mass of 64.9 and relative isotopic abundance of 30.9%.

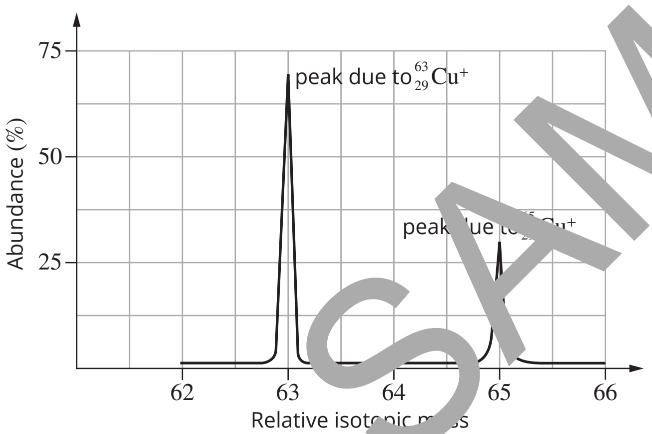

FIGURE 1.1.8 Mass spectrum of copper

The average relative mass of a copper atom can be calculated:

$$A_r(\text{Cu}) = \frac{(\%\text{ abundance} \times \text{relative isotopic mass}) + (\%\text{ abundance} \times \text{relative atomic mass})}{100}$$

$$= \frac{(62.9 \times 69.1) + (64.9 \times 30.9)}{100}$$

$$= 63.5$$

SPECTROSCOPY

Spectroscopy uses the interaction between light and matter to provide information about different materials.

Flame tests

Some metals produce characteristic colours when heated in a Bunsen burner flame. These flame tests can allow the identification of an unknown metal ion present in a sample based on its flame colour. For example, sodium produces a yellow colour and copper produces a green colour. This is a limited type of analysis as not all metals produce a colour and some metals produce very similar colours.

Emission line spectra are produced when the light released by heated atoms is passed through a prism. Each coloured line in an emission line spectrum corresponds to a photon, or light of different energy. Emission spectra are unique to each element and are related to the electronic structure of atoms.

The emission spectrum of hydrogen provides evidence for Bohr's model of the atom, in which electrons exist in discrete energy levels. The spectrum shown in Figure 1.1.9 is produced based on the following characteristics.

- Electrons are able to absorb energies to move from lower to higher energy levels, causing the atom to move into an excited state.
- An excited atom is unstable so the promoted electrons immediately return to the lower energy levels. The atom returns to its ground state.
- The extra energies that the electrons had absorbed are then emitted as photons of light.
- These photons, which represent fixed energy 'jumps', appear in emission spectra and are unique to each element.

FIGURE 1.1.9 The emission spectrum of hydrogen contains lines representing photons of light.

Specific recognisable series have been observed in the hydrogen spectrum. Each series of lines represent different types of electron jumps as excited electrons in a sample return to their original shell in the atom. Jumps down can occur in a stepwise fashion.

An absorption line spectrum (Figure 1.1.10) can be considered as the inverse of an emission spectrum. Absorption line spectra have black lines in a coloured spectrum background. The black lines represent the energy absorbed from light by an electron jumping to a higher energy level.

FIGURE 1.1.10 Absorption spectrum for hydrogen. The energy levels of the black lines on what would be a coloured background correspond to the energy levels of the coloured lines on the background of the emission spectrum.

Atomic absorption spectroscopy

Atomic absorption spectroscopy (AAS) is another spectroscopic technique used to detect the presence of metals and determine their concentration. Rather than looking at emitted light, AAS measures the light energy absorbed by a sample. It is based on the understanding that light of specific wavelengths causes electrons in atoms to jump to a higher energy level.

A hollow cathode lamp containing the metal to be analysed is fitted to an atomic absorption spectrometer. The lamp strongly emits the specific wavelengths that the sample atoms can absorb. The amount of light absorbed by the element is measured. It indicates the quantity of the metal element present in the sample.

Calibration curve

The exact concentration of a component in a sample is determined using a **calibration curve** (Figure 1.1.11). A calibration curve establishes a relationship between concentration and absorbance by using the following steps.

1 Standard solutions are prepared and a fixed volume of each is analysed. The absorption of light of the selected colour or wavelength by each standard solution is measured.

2 A calibration graph is plotted using the results obtained by the standard solutions.

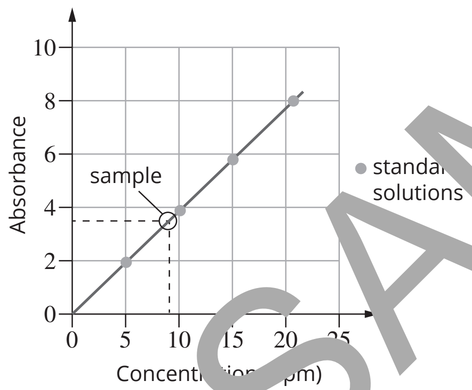

FIGURE 1.1.11 Calibration curve of concentration versus absorbance

The concentration of an unknown solution can then be determined.

3 The sample is analysed for its absorbance.

4 The sample's concentration is determined by plotting its absorbance on the calibration curve and reading off the concentration.

Periodic table and trends

ELEMENTS AND THE PERIODIC TABLE

The **periodic table** is an extremely useful organisational tool for chemists. It can be used to identify patterns, trends and relationships between the structures and properties of elements. All 118 known elements are listed on the table using the symbol of the element, in order of increasing atomic number, and elements that share chemical properties are grouped together. A full version of the periodic table can be found on page 201.

The modern periodic table has the following features.

- Each individual box of the periodic table contains one element and information about it (Figure 1.1.12).
- Horizontal rows are called **periods**. Periods are numbered 1–7.
- Vertical columns are called **groups**. Groups are numbered 1–18. Elements in the same group have similar chemical properties. Some groups in the periodic table have particular names. Some examples are given in Table 1.1.6.

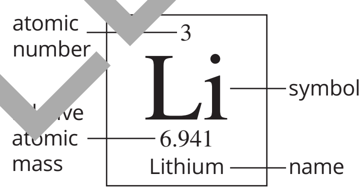

FIGURE 1.1.12 Periodic table information for lithium. Different periodic tables may contain different information.

TABLE 1.1.6 Names of some different groups in the periodic table

Group number	Name
1	alkali metals
2	alkaline earth metals
17	halogens
18	noble gases

Metals, non-metals and metalloids

The elements in the periodic table can be described as metals, non-metals or metalloids according to their metallic and non-metallic behaviours (Table 1.1.7). Metallic elements and non-metallic elements share properties.

Going down a group there is a trend of increasing metallic behaviour. Going left to right across a period, the behaviour becomes less metallic (Figure 1.1.13).

TABLE 1.1.7 Typical properties of metals, metalloids and non-metals

Metals	Metalloids	Non-metals
• lustrous (shiny) • malleable • ductile (can be drawn into a wire) • silvery colour • dense • high melting and boiling points • good conductors of electricity • good conductors of heat	Metalloids have some metallic and some non-metallic properties.	• dull • not malleable • not ductile • not dense • lower melting and boiling points than metals • poor conductors of electricity • poor conductors of heat

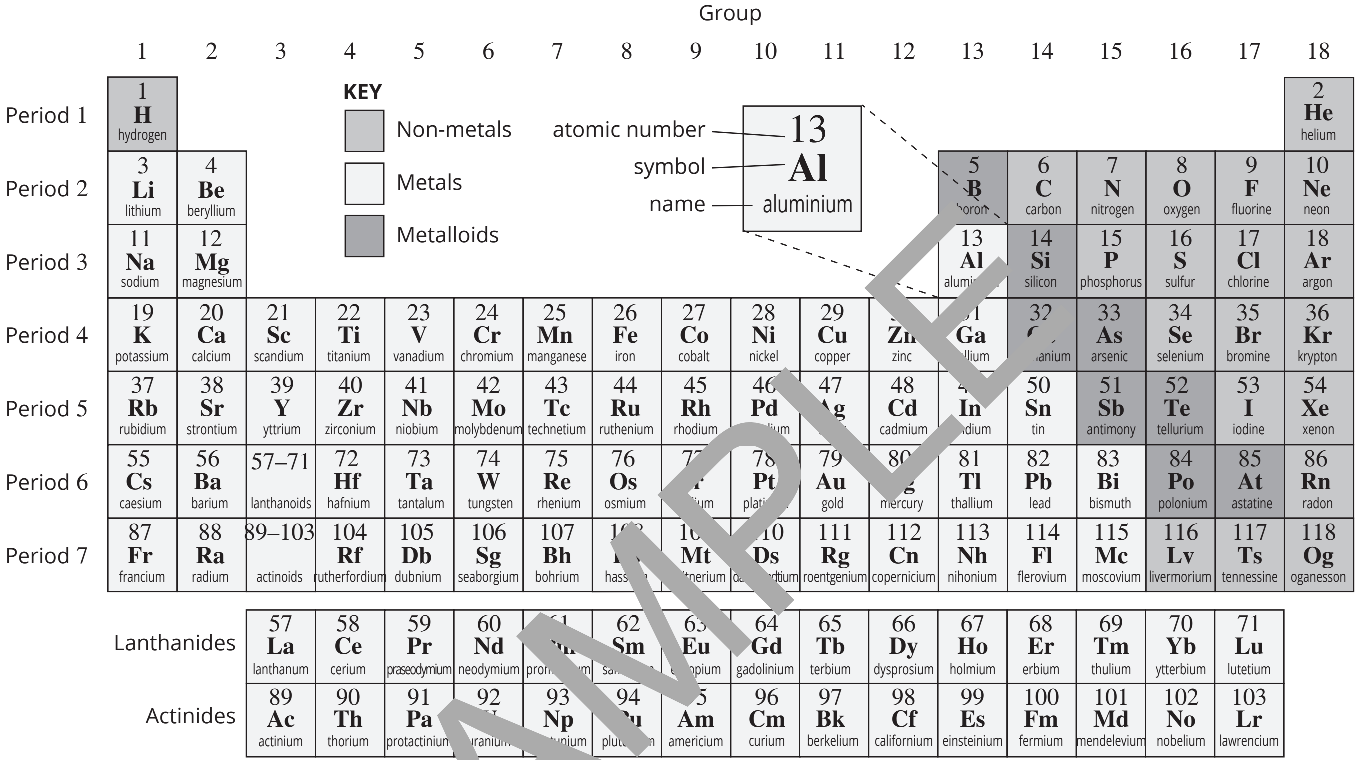

FIGURE 1.1.13 Elements are classified as metals, non-metals or metalloids in the periodic table.

In addition to being classified as metals or non-metals, elements are placed in specific groups (columns) in the periodic table. In general, elements in the same group have similar physical and chemical properties (Table 1.1.8). There are also trends in reactivity within groups, Alkali metals (Li–Cs) become more reactive going down the group. The non-metal halogens (F–I) become less reactive.

TABLE 1.1.8 Properties of elements in some groups of the periodic table

Group number	Elements in the group	Physical and chemical properties shared by elements in that group
1 (alkali metals)	lithium (Li), sodium (Na), potassium (K), rubidium (Rb), caesium (Cs), francium (Fr)	low melting and boiling points, soft, low density, highly reactive with reactivity increasing going down the group.
17 (halogens)	fluorine (F), chlorine (Cl), bromine (Br), iodine (I)	coloured, highly reactive gases that become less reactive going down the group.

ELECTRON CONFIGURATION AND THE PERIODIC TABLE

In terms of electron configuration, the periodic table has the following features.

- Elements in the same period of the periodic table have the same number of occupied electron shells.
- Elements in the same group have the same outer-shell electron configuration, so the same number of valence electrons.

The periodic table is arranged into four large blocks based on the level of the last subshell being filled in the electron configuration of the element (Table 1.1.9) on the following page.

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TABLE 1.1.9 *s*-, *p*-, *d*- and *f*-blocks in the periodic table

Block	Part of periodic table	Shell being filled
s	groups 1 and 2	*s*-subshell
p	groups 13–18	*p*-subshell
d	transition metals, groups 3–12	*d*-subshell
f	lanthanides and actinides	*f*-subshell

TRENDS IN THE PERIODIC TABLE

Trends in properties observed in the periodic table (Table 1.1.10) are a reflection of changing numbers of protons and electrons.

- Going down a group, the number of occupied electron shells increases by one each row, so atomic radius is increasing. Valence electrons become further from the nucleus and there is an increased **shielding effect**. This makes the valence electrons less tightly held, meaning they are more easily removed.
- Going across a period, the **effective nuclear charge** of successive elements increases by one each element (effective nuclear charge = no. of protons – no. of inner-shell electrons). As the effective nuclear charge increases, the valence electrons experience a greater attraction to the nucleus and are held more tightly. They become more difficult to remove.

TABLE 1.1.10 Trends in the periodic table

Property	What it indicates	Trend going down a group	Trend going from left to right across a period
electron configuration	number of electrons in each shell (Bohr) or subshell written in order of increasing energy	The number of occupied shells increases.	The number of valence electrons increases.
effective nuclear charge	effective nuclear charge = no. of protons – no. of inner-shell electrons	The effective nuclear charge does not change.	Effective nuclear charge increases.
valency	charge on an ion of the atom due to electrons lost or gained	The valency does not change.	Groups 1, 2 and 13 have valencies of +1, +2 and +3, respectively. Groups 15, 16 and 17 have valencies of –3, –2 and –1, respectively. Elements in groups 14 and 18 do not form ions.
atomic radius	radius of an atom	Atomic radius increases.	Atomic radius decreases.
ionic radius	radius of an atom's ion	Ionic radius increases.	Ionic radius decreases then increases.
first ionisation energy	minimum amount of energy required to remove the highest energy electron from an atom or ion	First ionisation energy decreases.	First ionisation energy increases.
electronegativity	ability of an atom to attract shared electrons in a molecule	Electronegativity decreases.	Electronegativity increases.

Reactivity of metals and non-metals

The more readily a metal loses its electrons, the more reactive it will be. Going down group 1, the alkali metals become more reactive as increasing shielding means the electrostatic attraction between valence electrons and the nucleus decreases. Going across a period, the reactivity of metals decreases as the increasing effective nuclear charge means valence electrons are held more tightly.

The reactivity of a non-metal is based on how readily the atom can gain electrons. Going down group 17, the halogens become less reactive as the valence shell becomes further from the nucleus and therefore less able to attract electrons. Going across a period, the reactivity of non-metals increases as there is a greater effective nuclear charge to attract electrons.

Oxides

Oxygen is a highly electronegative element and forms compounds with many other elements. These compounds are called oxides. There is a trend in the acidic nature of oxides going from left to right across a period. The trend that occurs in period 3 oxides when added to water is demonstrated in Table 1.1.11.

TABLE 1.1.11 Reactions of period 3 oxides with water

Group	1	2	13	14	15	16	17
Name and formula of oxide	sodium oxide, Na_2O	magnesium oxide, MgO	aluminium oxide, Al_2O_3	silicon dioxide, SiO_2	diphosphorus pentoxide, P_2O_5	sulfur dioxide, SO_2, or trioxide, SO_3	chlorine monoxide, Cl_2O
Reaction with water	• dissolves to form strongly basic solution	• dissolves to form strongly basic solution	• does not dissolve in water • **amphoteric** (reacts with both acids and bases)	• does not dissolve in water • reacts with very strong bases	• reacts with water to form strongly acidic solutions	• reacts with water to form strong acids	• reacts with water to form very strong acids

Introduction to bonding

TYPES OF BONDS

Bonds between atoms or ions hold matter together. There are different types of bonds present in different types of materials.

Metallic elements exist as lattices, which contain vast numbers of metal ions held together by **metallic bonds**.

Apart from the noble gases, non-metallic elements exist as molecules in which two or more atoms are **covalently** bonded together.

In compounds, the type of bond is determined by the difference in the electronegativity of the two atoms involved in the bond.

- If the difference in electronegativity between the two atoms is great, an electron can be completely transferred from one atom to the other, forming an **ionic bond** and making an ionic compound.
- If the difference in electronegativity between the two atoms is small, the electrons are shared between the two atoms, forming a **covalent bond** in a molecule.

Electrostatic attractions

All types of chemical bonding are due to **electrostatic attractions**. Electrostatic attraction is the attraction that occurs between opposite charges. Examples of different types of opposite charges that cause bonds are:

- anions and cations (ionic bonds)
- a cation and negatively charged electrons (metallic bonds)
- a positively charged nucleus and negatively charged electrons (covalent bonds).

Other bonds that occur between different molecules are also based on electrostatic attraction. All of these types of bonds will be covered further in Topics 2 and 3.

ATOMS AND STABILITY

The **octet rule** states that the most stable electron configuration is when an atom has eight valence electrons. This explains why the noble gases, which are located in group 18 of the periodic table, are so stable. Other elements achieve a stable electron configuration by losing, gaining or sharing valence electrons with other atoms in order to gain a total of eight valence electrons.

It is the pursuit of stability that causes atoms to lose, gain or share electrons, which can lead to the formation of charged ions that then bond by electrostatic attraction.

Charges on ions

An ion is an atom or group of atoms that are electrically charged. The positive or negative charge is due to an imbalance in the number of electrons and protons in the ion and indicates whether the atom has lost or gained electrons as well as how many (Table 1.1.12). Metal atoms, which have one, two or three electrons in their valence shell, tend to lose electrons and form cations. Non-metal atoms, which have five, six or seven electrons in their valence shell, tend to gain electrons and form negative anions. The size of the positive or negative charge indicates the number of electrons removed or gained. The charge on an ion is called its **valency**.

TABLE 1.1.12 Charges on some common ions

Element	Electrons in outer shell	Tendency	Valency	Ion
sodium	1	lose one electron	+1	Na^{+}
aluminium	3	lose three electrons	+3	Al^{3+}
oxygen	6	gain two electrons	–2	O^{2-}
chlorine	7	gain one electron	–1	Cl^{-}

Many transitional elements, which are located in the *d*-block of the periodic table, form more than one stable ion. For example, iron can form two ions because the 4*s* and 3*d* orbitals have very similar energies (Table 1.1.13). A half-filled *d*-subshell is a stable configuration.

TABLE 1.1.13 Different valencies of iron ions

Species	Number of electrons lost	Condensed electron configuration
Fe	0	$[Ar]3d^6 4s^2$
Fe^{2+}	2	$[Ar]3d^6$
Fe^{3+}	3	$[Ar]3d^5$

Ionic formulas

Anions and cations are formed when electrons are transferred from metal atoms to non-metal atoms during the formation of ionic compounds (Figure 1.1.14).

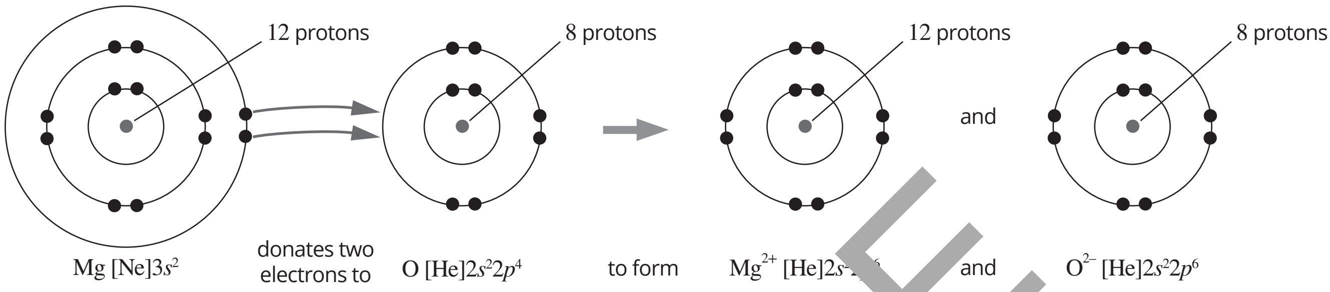

FIGURE 1.1.14 Transfer of electrons when magnesium reacts with oxygen

The ratio of metal to non-metal atoms in the compound is written in the ionic formula and depends on the valencies of the ions involved (Table 1.1.14). The overall charge must be balanced.

TABLE 1.1.14 Formation of ionic compounds from ions of different valencies

Cation	Anion	Formula	Name
Na^+	Cl^-	NaCl	sodium chloride
Mg^{2+}	Cl^-	$MgCl_2$	magnesium chloride
Ca^{2+}	NO_3^-	$Ca(NO_3)_2$	calcium nitrate
Al^{3+}	O^{2-}	Al_2O_3	aluminium oxide

Sharing electrons

A non-metal atom generally has five, six or seven electrons in its outer shell. When non-metal atoms bond with other non-metal atoms, their relatively similar electronegativities result in them sharing their valence electrons. Discrete **molecules** are formed containing fixed numbers of atoms.

In general, electrons are shared between non-metal atoms so that each atom ends up with eight electrons in its outer shell. A bond forms because the shared electrons are attracted to the positive nuclei of both atoms. Each pair of shared electrons constitutes a **covalent bond**, which is extremely strong.

- One pair of shared electrons constitutes a single covalent bond.
- Two pairs of shared electrons constitute a double covalent bond.
- Three pairs of shared electrons constitute a triple covalent bond.

The atom will form as many covalent bonds as it needs to achieve eight electrons in its outer shell. The valency of an atom can be used to determine the number of bonds an atom can make (Table 1.1.15).

TABLE 1.1.15 Determining the number of bonds an atom can make

Element	Number of valence electrons	Number of bonds made
carbon	4	= 8 – 4 = 4 bonds
nitrogen	5	= 8 – 5 = 3 bonds
fluorine	7	= 8 – 7 = 1 bond

The structures of molecules are often represented by **Lewis (electron dot) structures** in which dots represent each valence electron up to four electron pairs for each atom (Figure 1.1.15). Lewis structures are helpful in identifying the numbers of bonding electrons and any lone pairs of electrons (Figure 1.1.16).

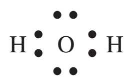

FIGURE 1.1.15 Lewis structure of a water molecule

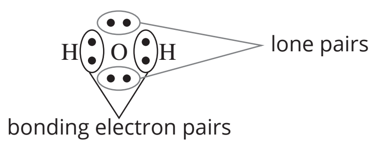

FIGURE 1.1.16 In a water molecule, there are two bonding electron pairs and oxygen contains two pairs of lone electrons.

NAMING IONIC AND COVALENT COMPOUNDS

Chemists use a set of common rules to name covalent and ionic compounds, including the following.

- The least electronegative element is named first in covalent compounds; the cation is named first in ionic compounds.
- The name of the second element in covalent compounds and the anion in ionic compounds is modified by adding or altering the end of its name to 'ide'.
- Covalent compounds use the prefixes *mono, di, tri, tetra,* and so on, which means 1, 2, 3, 4 etc. to indicate the number of atoms of each element.
- For ionic compounds that include metals that have ions of variable electrovalencies, the charge on the ion is specified when naming the compound by placing a Roman numeral in brackets immediately after the metal in the compound.

Different formulas can be used to indicate the number and type of elements in a compound (Table 1.1.16):

- **empirical formula** is the simplest whole number ratio of atoms contributed by each element
- **molecular formula** is the actual number of atoms of each element present in the compound.

The molecular formula and empirical formula can be the same or different (Table 1.1.16). When different, the empirical formula becomes a **formula unit**. The molecular formula will be a multiple of this formula unit.

TABLE 1.1.16 Some molecular and empirical formulas of organic compounds

Molecule	Molecular formula	Empirical formula
Ethane	C_2H_6	CH_3
Propanol	C_3H_8O	C_3H_8O
Glucose	$C_6H_{12}O_6$	CH_2O

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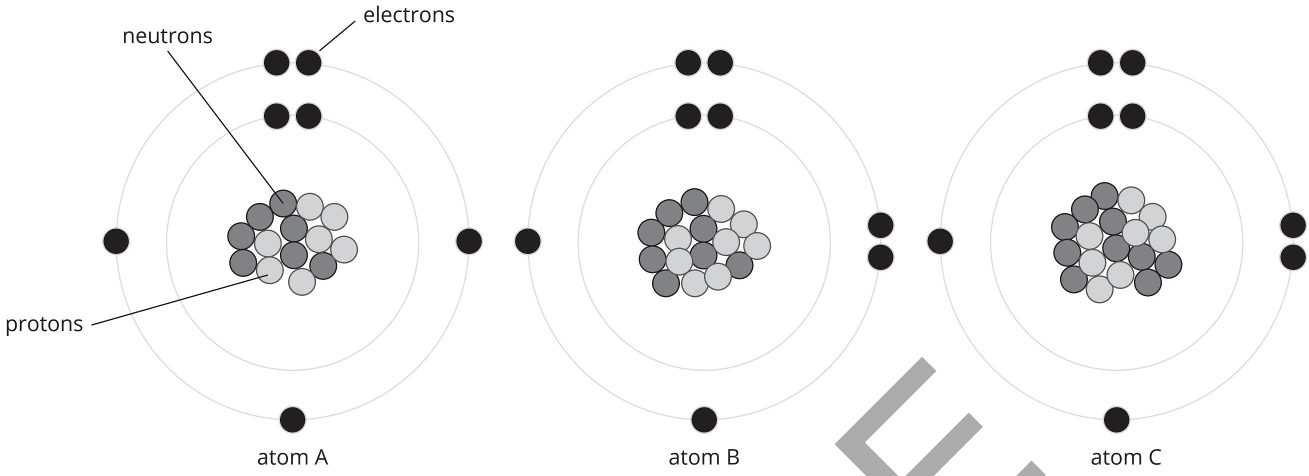
WORKSHEET 1.1.1

Knowledge preview—atoms and reactions

Examine the three atoms represented by these shell models.



1 Complete the information for each atom.

	Atom A	Atom B	Atom C
atomic number			
mass number			
name of element			

2 Three types of subatomic particles are labelled in atom A.

a Identify the subatomic particle that has a negative charge. ______

b Identify the subatomic particle that has a positive charge. ______

c Identify the two subatomic particles that are assigned a mass of 1. ______

3 The diagrams above are representations of the structure of atoms. Describe two limitations of these diagrams.

______

______

______

4 When a chemical reaction occurs, the atoms in the reactants are rearranged to become the products. Identify each statement below about chemical reactions as true or false.

Statement about chemical reactions	True or False
Mass is always conserved in a chemical reaction.	
The rate of a chemical reaction will change with changes in temperature.	
The total mass of the products may be slightly less or greater than the starting mass of the reactants.	
The number of protons in a particular atom might change during a chemical reaction.	
If there are six carbon atoms in the reactants of a chemical reaction, there must also be six carbon atoms in the products.	

WORKSHEET 1.1.8

Literacy review—comparing similar terms

In Topic 1, you learnt a number of new terms that are alike in some way. Demonstrate your understanding of some of these terms by comparing the meaning of each pair of terms. Include examples wherever possible.

1 atomic number and mass number

2 electronegativity and electrostatic attraction

3 atomic radius and ionic radius

4 first ionisation energy and second ionisation energy

5 electron configuration and condensed electron configuration

6 anion and cation

7 absorption spectrum and emission spectrum

8 ionic bond and covalent bond

9 acidic and amphoteric

RATE MY LEARNING	• I get it. • I can apply/teach it.	• I get it. • I can show I get it.	• I almost get it. • I might need help.	• I get some of it. • I need help.	• I don't get it. • I need lots of help.

WORKSHEET 1.1.9

Thinking about my learning

On completion of Unit 1 Topic 1, Properties and structure of atoms, you should be able to describe, explain and apply the relevant scientific ideas. You should be able to interpret, analyse and evaluate data. Consider how aware you are of how you learn. Consider how much control you take for your own learning. Thinking about how you learn is called metacognition and includes:

- being aware of your learning goals
- knowing the best ways for you to learn
- identifying your learning strengths and weaknesses
- planning how to tackle difficult tasks
- monitoring your own progress
- working out how to correct your own errors.

1 Refer to page 1 of the *Skills and Assessment Book* to read the content outline for this topic.

Read each dot point. Reflect on how well you understand each concept. Indicate your level of understanding by using highlighters
to colour code each point:

- green – very confident
- yellow – in the middle
- red – starting to get the idea.

2 Describe two concepts you learned and one skill you developed or improved during this topic.

Two concepts I learned:

One skill I developed:

3 List any concepts that you are still unsure of and need to improve. Next to each, note what strategies you could use to improve in these areas.

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PRACTICAL ACTIVITY 1.1.1

Science as a Human Endeavour—Simulating Geiger–Marsden's gold foil experiments

Suggested duration: 30 minutes

RESEARCH QUESTION

Can a simulation of Geiger–Marsden's gold foil experiments provide reliable evidence for Rutherford's nuclear model of the atom?

MATERIALS

- tape
- metre ruler
- modelling dough
- marble
- piece of card 10 cm × 50 cm

RATIONALE

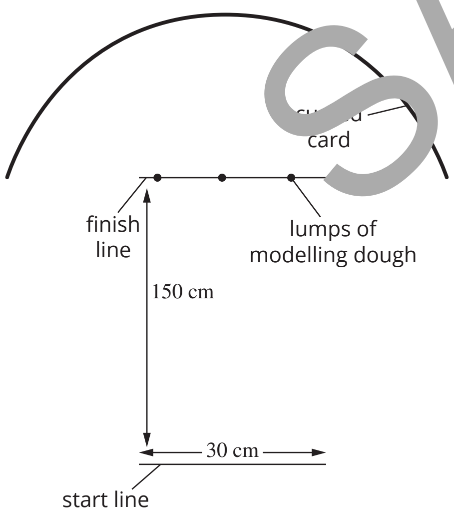
Early in the twentieth century, Geiger and Marsden carried out an experiment that led Rutherford to develop the first nuclear model of an atom. Prior to this model, the atom was thought of as resembling a plum pudding, i.e. a dense, solid object that carries a positive charge but has negatively charged electrons distributed throughout. Geiger and Marsden fired helium nuclei (also known as alpha particles) at a sheet of gold foil. This simulation using cardboard, modelling dough and marbles will model the collection of data on a visible scale in order to answer the research question.

RISK MANAGEMENT

There are no particular safety precautions required for this activity.

METHOD

1 As shown in the figure below, use a 30 cm piece of tape to mark a start line on a large flat surface (table or floor). Mark a finish line 150 cm away using another 30 cm piece of tape, as shown. Curve the piece of card and tape it to the floor approximately 20 cm behind and around the finish line. Place three small round lumps of modelling dough along the finish line, as shown.



Set-up of the gold foil simulation

2 Working in pairs, place the marble somewhere along the starting line. Close your eyes and roll the marble towards the finish line at least 80 times. Count how many times the marble hits a piece of modelling dough.

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VARIABLES

i Identify the independent variable: ____________________

ii Identify the dependent variable: ____________________

iii Identify any controlled variables: ____________________

RESULTS

1 Record your results in Table 1.

TABLE 1 Number of times modelling dough was hit by the marble

Total number of rolls	
Number of rolls that hit modelling dough	

2 Calculate the percentage of your rolls that hit the modelling dough.

____

3 Collect from all class groups the percentage of rolls that hit the modelling dough. Create a table for recording the data below.

ANALYSING

4 Calculate the mean percentage rolls that hit the modelling dough.

____

5 Calculate the measurement uncertainty for the mean percentage rolls that hit the modelling dough.

____

____

____

6 Describe the reliability of the results.

INTERPRETING

7 Interpret the results to explain how Geiger–Marsden's gold foil experiments enabled Rutherford to develop the nuclear model of the atom.

EVALUATING

8 Interpret what the calculated measurement of uncertainty means for this investigation.

9 Explain why it was important that you rolled the marbles randomly.

10 Justify why it was necessary to roll the marble so many times in the simulation.

11 Discuss the likely impact of any sources of bias in the way you carried out the method.

12 Discuss the validity of the data obtained in this simulation.

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13 Propose improvements you would make to this activity to improve the validity of the data for modelling Geiger–Marsden's gold foil experiments.

CONCLUSION

14 Provide a conclusion to the research question and justify your conclusion with specific reference to the results of this activity.

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Multiple-choice questions

1 Identify the particles in the isotope of iodine that are represented by the symbol $^{131}_{53}I$.

A The isotope has 53 protons and 78 neutrons.

B The isotope has 53 neutrons and 78 protons.

C The isotope has 53 neutrons and 131 protons.

D The isotope has 53 protons and 131 neutrons.

2 Recall the rules for writing electron configuration to identify the electron configuration of a $^{52}_{24}Cr$ atom in an excited state.

A $1s^22s^22p^63s^23p^63d^4$

B $1s^22s^22p^63s^23p^63d^44s^2$

C $1s^22s^22p^63s^23d^63d^24s^2$

D $1s^22s^22p^63s^23p^63d^54s^1$

3 Select the development that best describes how the shell model contributed to atomic theory.

A Electrons exist as regions of negative cloud surrounding the nucleus.

B Electrons orbit a central dense core called a nucleus. The atom is mostly empty space.

C Electrons are located in orbitals, which are regions of space in which electrons are located.

D Electrons orbit the nucleus in fixed energy levels. The lowest energy levels are closest to the nucleus.

4 Identify the best description of the formation of a calcium ion from a calcium atom.

A The calcium atom gains two electrons to form a calcium ion with a charge of 0.

B The calcium atom loses two electrons to form a calcium ion with a charge of –2.

C The calcium atom gains two electrons to form a calcium ion with a charge of –2.

D The calcium atom loses two electrons to form a calcium ion with a charge of +2.

5 Identify the correct formula of the ionic compound made from strontium and chlorine.

A SrCl

B $SrCl_2$

C Sr_2Cl

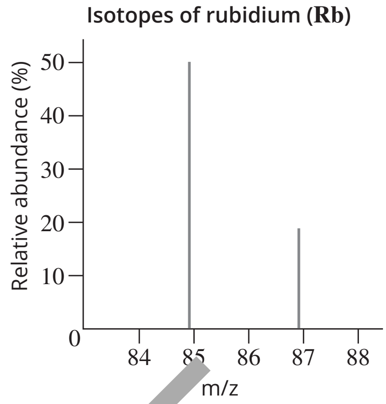
D Sr_2Cl_2

6 Select the number of lone electron pairs in a molecule of methane, CH_4.

A 0 **B** 1 **C** 2 **D** 4

Short-answer questions

1 The following mass spectrum shows the isotopic pattern of a particular sample of rubidium.

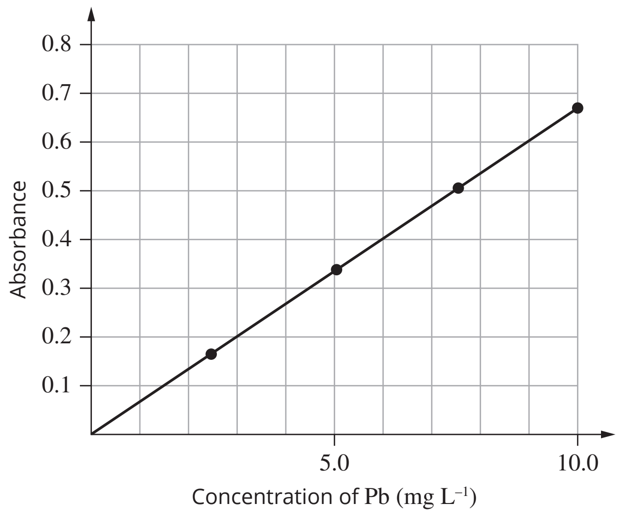


a What is the definition of an isotope?

b How many isotopes are evident in the sample?

c Use the information in the spectrum to calculate the relative atomic mass of rubidium.

2 Atomic absorption spectroscopy was used to determine the lead concentration in a sample of contaminated soil. A calibration curve obtained by analysis of standard solutions is shown below.



A 1.0 g sample of soil was dissolved in acid and diluted to a total volume of 50.0 mL. The absorbance of the solution was measured as 0.25.

a Determine the concentration, in $mg\,L^{-1}$, of lead in the diluted solution.

b Calculate the mass, in mg, of lead present in the soil sample.

3 Explain the reasons for the following observations.

a Fluorine has an atomic radius of 0.147 nm, which is smaller than lithium's atomic radius of 0.152 nm.

b Rubidium has a first ionisation energy of 403 $kJ\,mol^{-1}$, which is lower than lithium's first ionisation energy of 520 $kJ\,mol^{-1}$.

c Different metal ions produce different colours in flame tests. Draw a labelled diagram as part of your answer.

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d All bonding in covalent molecules and ionic compounds is due to electrostatic attraction.

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SAMPLE ASSESSMENT TASK IA1

Data test

Duration: 5 minutes reading time and 60 minutes working time

Task

The data test requires you to apply a range of cognitions to respond to scientific data. The test will be held in a set time frame under test conditions.

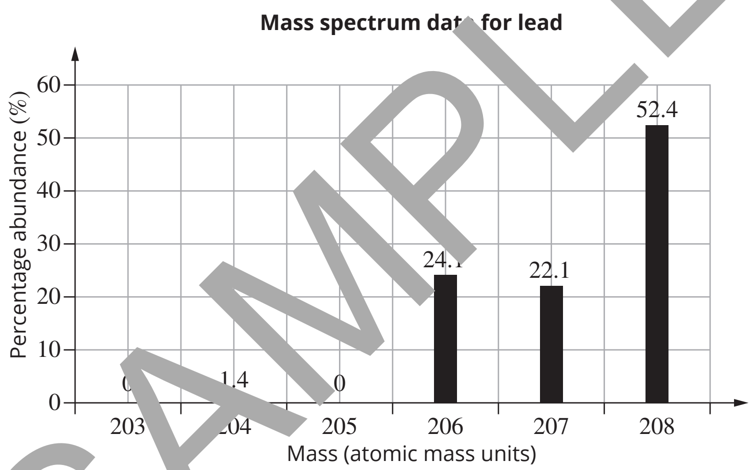
Each dataset will enable you to analyse and interpret data in order to apply your understandings of the properties and structure of atoms and materials, and chemical reactions.

You will be asked to respond using single words, sentences (up to 150 words per question) and calculations.

Dataset 1: Analysing lead with mass spectrometry (MS) (11 marks)

Lead is a bluish-white lustrous metallic element. It has an atomic number of 82. It is widely used in car batteries, organ pipes, the glass of computer and television screens, glassware and ammunitions.

A student investigating lead isotopes used mass spectrometry (MS) to obtain the spectrum shown below.



Item 1: Identify the number of isotopes of lead that are evident in this data. ______________ (1 mark)

Item 2: Identify the mass of the second most abundant isotope. ______________ (1 mark)

Item 3: Identify the percentage abundance of the lightest isotope. ______________ (1 mark)

Item 4: Determine whether there are any patterns or trends evident in this data between the mass of the isotope and percentage abundance. Justify your answer. (2 marks)

Item 5: **a** Determine the abundance of the heaviest isotope. (1 mark)

b Determine the mass of the least abundant isotope. (1 mark)

Research investigation

Introduction

The research investigation requires you to gather evidence related to a research question to evaluate a claim relevant to Unit 1 or 2 subject matter. Your teacher will provide a list of claims for you to select from.

You will plan your investigation, collect information, analyse the information, then communicate your response in one of the following ways:

Multimodal (at least two modes delivered at the same time): up to 11 minutes

Written: up to 2000 words

Evidence must be obtained from scientifically credible sources, such as:

- books and podcasts by well-credentialled scientists
- 'popular' science websites or magazines
- websites of governments, universities, independent research bodies or science and technology manufacturers
- scientific journals.

Parts of the investigation

Criteria	Inclusions
Forming and Finding	• a research question • rationale that identifies clear development of the research question from the claim • selection of sources • use of genre conventions • acknowledgement of sources through referencing
Analysing	• identification of evidence • identification of trends/patterns/relationships in evidence • identification of limitations in evidence
Interpreting	• scientific arguments • conclusion • use of scientific language/representations
Evaluating	• discussion of quality of the evidence • application of findings of the research to the claim • suggested improvements and extensions to the investigation

The following sections provide a more detailed guide to the steps you might take to work through this investigation. An example is provided. A final written report based on the example can be found in the *Skills and Assessment Book* online resources.

Forming and finding

A student selects a claim from a list provided by their teacher.

Claim: Biofuels are a sustainable alternative to fossil fuels

To develop a research question, the student uses a range of sources to first conduct research into relevant scientific concepts identified from the claim. This includes researching answers to questions such as:

- What is the definition of a fossil fuel?
- What are some examples of fossil fuels?
- How are fossil fuels obtained?
- What is the definition of a biofuel?
- What are some examples of biofuels?

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