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Sample pages

How to use this book

The *Pearson Chemistry 11 New South Wales Skills and Assessment* book provides 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. While offering opportunities for reinforcement of key concepts, knowledge and skills, these activities enable flexibility in the approach to teaching and learning.

Explicit scaffolding makes learning objectives clear, and there are regular opportunities for student reflection and self-evaluation at the end of individual activities throughout the book. Students are also guided in self-reflection at the end of each module. In addition, there are rich opportunities to take the content further with the explicit coverage of Working scientifically skills and key knowledge in the depth studies.

This resource has been written to the new New South Wales Chemistry Stage 6 Syllabus and addresses the first four modules of the syllabus. Each module consists of five main sections:
- key knowledge
- worksheets
- practical activities
- depth study/ies
- module review questions.

Explore how to use this book below.

Chemistry toolkit

The Chemistry toolkit supports development of the skills and techniques needed to undertake practical investigations, secondary-sourced investigations and depth studies, and covers examination techniques and study skills. It also includes checklists, models, exemplars and scaffolded steps. The toolkit can serve as a reference tool to be consulted as needed.

Module opener

Each book is split into the four modules of the syllabus, with the module opener linking the module content to the syllabus.

Key knowledge

Each module begins with a key knowledge section. This consists of a set of succinct summary notes that cover the key knowledge set out in each module of the syllabus. This section is highly illustrative and written in a straightforward style to assist students of all reading abilities. Key terms are bolded for ease of navigation. It also provides a ready reference for completing the worksheets and practical activities.

Worksheets

A diverse offering of instructive and self-contained worksheets is included in each module. Common to all modules is the initial 'Knowledge review' worksheet to activate prior knowledge, a 'Literacy review' worksheet to explicitly build understanding and application of scientific terminology, and finally a 'Thinking about my learning' worksheet, which provides a reflection and self-assessment opportunity for students. Each additional worksheet provides opportunities to revise, consolidate and further student understanding.

These worksheets function as formative assessment and are clearly aligned to the syllabus. A range of questions building from foundation to challenging are included within worksheets.

Practical activities

Practical activities provide the opportunity to complete practical work related to the various themes covered in the syllabus. All practical activities referenced in outcomes within the syllabus have been covered. Across the suite of practical activities provided, students are exposed to opportunities where they design, conduct, evaluate, gather and analyse data, appropriately record results and prepare evidence-based conclusions directly into the scaffolded practical activities. Students also have opportunities to evaluate safety and any potential hazards.

Each practical activity includes a suggested duration. Along with the depth studies, the practical activities meet the 35 hours of practical work mandated at Year 11 in the syllabus. Where there is key knowledge that will support the completion of a practical activity, students are referred back to it.

Like the worksheets, the practical activities include a range of questions building from foundation to challenging.

Depth studies

Each module contains at least one suggested depth study. The depth studies allow further development of one or more concepts found within or inspired by the syllabus. They allow students to acquire a depth of understanding and take responsibility for their own learning. They also promote differentiation and engagement.

Each depth study allows for the demonstration of a range of Working scientifically skills, with all depth studies assessing the Working scientifically outcomes of Questioning and predicting and Communicating. A minimum of two additional Working scientifically skills and at least one Knowledge and understanding outcome are also assessed.

Module review questions

Each module finishes with a comprehensive set of questions, consisting of multiple choice, short answer and extended response, that helps students to draw together their knowledge and understanding and apply it to these styles of questions.

Icons and features

The New South Wales Stage 6 Syllabus Learning across the curriculum content is addressed and identified using the following icons:

AHC A CC CCT DD EU ICT
IU L N PSC S WE

GO TO ➤ **GoTo icons** are used to make important links to relevant content within the book.

⚠ 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.

A **pre-lab safety box** is included. Students are to sign agreeing that they have understood the hazards associated with the material(s) in use and the control measures to be taken.

PRE-LAB SAFETY INFORMATION

Material used	Hazard	Control
Conductivity kit	Electricity	Construct the circuit with the power off. Do not touch the circuit while the power is on. Do not allow electrical equipment to come into contact with liquids.
Polluted water	harmful substances in the water	

Do not taste your polluted or 'purified water' sample. Wash hands after handling polluted water.

Please indicate that you have understood the information in the safety table.

Name (print): _____

I understand the safety information (signature): _____

Rating my learning

Rating my learning is an innovative tool that appears at the bottom of the final page of most worksheets and all practical activities. It provides students with the opportunity for self-reflection and self-assessment. It encourages students to look ahead to how they can continue to improve, and assists in highlighting focus areas for further skill and knowledge development.

The teacher may choose to use student responses to the 'Rating my learning' feature as a formative assessment tool. At a glance, teachers can assess which topics and which students need intervention for improvement.

RATING MY LEARNING	My understanding improved	Not confident ◄——► Very confident ○ ○ ○ ○ ○	I answered questions without help	Not confident ◄——► Very confident ○ ○ ○ ○ ○	I corrected my errors without help	Not confident ◄——► Very confident ○ ○ ○ ○ ○

Teacher support

Comprehensive answers and fully worked solutions for all worksheets, practical activities, depth studies and module review questions are provided in the *Pearson Chemistry 11 New South Wales* Teacher Support. An editable suggested assessment rubric for depth studies is also provided.

Pearson Chemistry 11
New South Wales
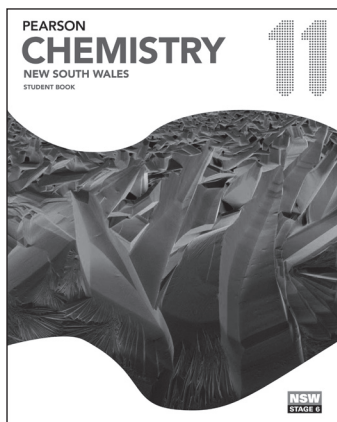
Student Book

Pearson Chemistry 11 New South Wales has been written to fully align with the 2018 New South Wales Chemistry Stage 6 Syllabus. The Student Book includes the very latest developments and applications of chemistry and incorporates best practice literacy and instructional design to ensure the content and concepts are fully accessible to all students.

Skills and Assessment Book

Pearson Chemistry 11 New South Wales Skills and Assessment gives students the edge in preparing for all forms of assessment. Key features include a toolkit, key knowledge summaries, worksheets, practical activities, suggested depth studies and module review questions. It provides guidance, assessment practice and opportunities to develop key skills.
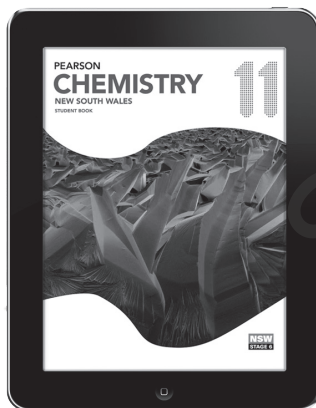
Pearson Reader+. Any device, every school.

Pearson Reader+ lets you use your Student Book online or offline on any device. Pearson Reader+ retains the look and integrity of the printed book. Practical activities, interactives and videos are available on Pearson Reader+ along with the fully worked solutions to the Student Book questions.
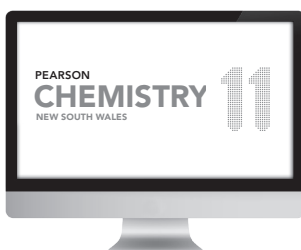
Teacher Support

The Teacher Support includes syllabus grids and a scope and sequence plan to support teachers with programming. It also provides the fully worked solutions and answers to all Student Book and Skills and Assessment Book questions, including all worksheets, practical activities, depth studies and module review questions. Teacher notes, safety notes, risk assessments and a laboratory technician's checklist and recipes are available for all practical activities. Depth studies are supported with suggested assessment rubrics and exemplar answers.

- examining spectral evidence for the Bohr model and introducing the Schrödinger model
- investigate the properties of unstable isotopes using natural and human-made radioisotopes as examples, including but not limited to:
  - types of radiation
  - types of balanced nuclear reactions

PERIODICITY

| INQUIRY QUESTION | **Are there patterns in the properties of elements?**

By the end of this module you will be able to:

- demonstrate, explain and predict the relationships in the observable trends in the physical and chemical properties of elements in periods and groups in the periodic table, including but not limited to:
  - state of matter at room temperature
  - electronic configurations and atomic radii
  - first ionisation energy and electronegativity
  - reactivity with water

BONDING

| INQUIRY QUESTION | **What binds atoms together in elements and compounds?**

By the end of this module you will be able to:

- investigate the role of electronegativity in determining the ionic or covalent nature of bonds between atoms ICT N
- investigate the differences between ionic and covalent compounds through:
  - using nomenclature, valency and chemical formulae (including Lewis dot diagrams) (ACSCH029)
  - examining the spectrum of bonds between atoms with varying degrees of polarity with respect to their constituent elements' positions on the periodic table
  - modelling the shapes of molecular substances (ACSCH056, ACSCH057)
- investigate elements that possess the physical property of allotropy ICT
- investigate the different chemical structures of atoms and elements, including but not limited to:
  - ionic networks
  - covalent networks (including diamond and silicon dioxide)
  - covalent molecular structures
  - metallic structure
- explore the similarities and differences between the nature of intermolecular and intramolecular bonds and the strength of the forces associated with each, in order to explain the:
  - physical properties of elements
  - physical properties of compounds (ACSCH020, ACSCH055, ACSCH058) ICT

Key knowledge

Properties of matter

TYPES OF MATTER

Chemistry is the study of the composition, properties and reactions of matter.

All matter is composed of **atoms**. A substance composed of only one type of atom is called an **element** and a substance composed of two or more different types of atom is called a **compound**.

Elements can be **monatomic** (existing as single atoms), be composed of clusters of atoms called **molecules** or form into large networks or **giant molecules**. Compounds can be molecules or networks. These molecules and networks are the basis of all of the materials that exist in the universe and are used in everyday life.

Matter can be classified as a pure substance or a mixture. A mixture can be further classified as **homogeneous** or **heterogeneous** (Figure 1.1).

An example of a homogeneous mixture is a **solution**. The **solute** and **solvent** particles in a solution are indistinguishable from each other and the solute is distributed evenly throughout the solution. An **aqueous** solution is formed when water is the solvent or main component in a solution.

PHYSICAL PROPERTIES AND CHANGES OF STATE

The components of matter are elements, compounds and mixtures. They may be in any of three most common states of matter: solid, liquid and gas (Figure 1.2). Liquids and gases can be referred to as **fluids** because they can be poured.

FIGURE 1.1 Matter is classified according to its components and how they are arranged.

All of the solids, liquids and gases that exist in the universe.

matter

Contains only one type of element or compound.

pure substance

A physical combination of two or more elements and/or compounds.

mixture

Contains only one type of atom. Cannot be broken down into simpler substances.

element

A chemical combination of two or more types of atom. Can be broken down into simpler substances by a process such as heating.

compound

Uniform in composition. All samples of the mixture are alike.

homogeneous mixture

Composition varies throughout the mixture. Samples taken from different places in the mixture will differ.

heterogeneous mixture

Solids are incompressible and hold their shape.

Liquids are incompressible and flow to adopt the shape of the container.
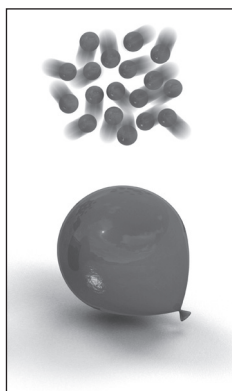
Gases are compressible and fill the shape of the container.

FIGURE 1.2 Solids, liquids and gases have different properties based on their different arrangements of particles.

Physical and chemical properties

A property is an observable characteristic of a substance. Properties can be physical or chemical:

- Physical properties can be observed or measured. Physical properties include appearance, colour, magnetism, density, brittleness or malleability, crystal shape, melting point and boiling point. Physical properties can be measured or observed without changing the substance.
- Chemical properties describe how readily a substance undergoes a chemical change. Chemical properties include the reactivity of a substance with water or acids. They also include how readily a substance will burn in oxygen and whether it is acidic or basic.

PHYSICAL AND CHEMICAL CHANGE

A **physical change** has the following characteristics:

- The physical properties of the substance are changed.
- The chemical composition of the substance is not changed.
- The change can be reversed.

The formation of a mixture from different components is a physical change because the chemical properties of each component stay the same. A physical change can also occur when a substance is heated. If it is heated enough, a change of state can occur, such as a solid melting to a liquid or a liquid evaporating to a gas. Removing the heat will reverse these physical changes.

When a **chemical change** occurs, a new substance is formed. The types of atom do not change but the atoms themselves rearrange and combine to form new substances.

SEPARATING MIXTURES

Components of a mixture can be separated by methods that use knowledge of physical properties such as magnetism, boiling point, particle size and density. The techniques most commonly used to separate mixtures in a laboratory are filtration and evaporation.

Filtration

Filtration is used to separate solids from fluids in a mixture. It uses knowledge of the physical states and the size of components in a mixture. A mixture is passed through a physical barrier called a filter. Solids are trapped by the filter while the fluid component passes through. The fluid component is called the **filtrate**. The size of the holes in the filter determines how much solid is trapped. Filtration does not completely separate the solid from the mixture. The filter can be paper or a membrane and it may have a charge. In some techniques, pressure is used to force the fluids through the filter.

Evaporation

Evaporation in the laboratory uses knowledge of the physical property of boiling point and the fact that different fluids have different boiling points. Evaporation can separate a liquid from a solid in a homogeneous solution. Boiling a solution will cause the water to evaporate, leaving behind the solute. As the solute becomes more concentrated it eventually **crystallises** out of solution. The crystals are collected by filtration

or **decanting**. During decanting, a liquid is carefully poured out of a container in which solids have settled to the bottom.

Evaporation can be used to separate a liquid from another liquid using a technique called **distillation**. When the mixture is warmed, the components with the lowest boiling point will evaporate first. The vapour can be collected and separated further by more distillation.

CALCULATING PERCENTAGE COMPOSITION

Remember that compounds and mixtures are made up of more than one component:

- Compounds contain more than one element.
- Mixtures contain more than one element and/or compound.

The amount of each element in a compound or each component in a mixture can be expressed as a percentage composition by mass. It is determined using the mass of the component in a particular mass of the substance.

$$\% \text{ mass} = \frac{\text{mass of component in sample (g)}}{\text{total mass of sample (g)}} \times 100\%$$

Worked example 1.1: Find the percentage composition of copper in the copper-containing ore chalcocite. A 650 g rock of chalcocite contains 519 g of copper.

Thinking	Working
Calculate %Cu.	$\%\text{Cu} = \frac{519}{650} \times 100$ $= 79.8\%$

Worked example 1.2: Find the percentage composition of each element in the compound copper(II) carbonate. 45.0 g of copper(II) carbonate was determined to contain 23.1 g of copper, 4.37 g of carbon and 17.5 g of oxygen.

Thinking	Working
Calculate %Cu.	$\%\text{Cu} = \frac{23.1}{45.0} \times 100$ $= 51.3\%$
Calculate %C.	$\%\text{C} = \frac{4.37}{45.0} \times 100$ $= 9.71\%$
Calculate %O.	$\%\text{O} = \frac{17.5}{45.0} \times 100$ $= 38.9\%$

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 in order of increasing atomic number, and elements that share chemical properties are grouped together. A full version of the periodic table appears later in the book.

The modern periodic table has the following features:

- Each box of the periodic table contains one element and information about it (Figure 1.3).
- 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.

FIGURE 1.3 Periodic table information for lithium. Different periodic tables may contain different information.

The elements in the periodic table can be described as metals, non-metals or metalloids (Figure 1.4). Metallic elements and non-metallic elements are grouped because they share properties (Table 1.1). Knowing the location of an element on the periodic table can allow the prediction of some of its physical properties.

FIGURE 1.4 Elements are classified as metals, non-metals or metalloids in the periodic table.

TABLE 1.1 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

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 chemical and chemical properties (Table 1.2).

TABLE 1.2 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	lithium (Li), sodium (Na), potassium (K), rubidium (Rb), caesium (Cs), francium (Fr)	low melting and boiling point, soft, low density, highly reactive
2	beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), radium (Ra)	shiny, silvery-white, somewhat reactive, low density
18	helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), radon (Rn)	colourless, odourless gas at room temperature, unreactive or inert, exist as single atoms

Atomic structure and atomic mass

INSIDE ATOMS

Atoms are composed of smaller subatomic particles called **protons**, **neutrons** and **electrons**. Protons and neutrons are located in the very dense nucleus of an atom and are referred to collectively as **nucleons**. Protons, neutrons and electrons have different masses and charges (Table 1.3).

TABLE 1.3 Mass, charge and location of subatomic particles

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

Atoms are electrically neutral because they contain an equal number of negative electrons and positive protons.

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. The **atomic number** (Z) of an element indicates the number of protons in the nucleus. The **mass number** (A) indicates the total number of nucleons (protons plus neutrons) (Figure 1.5).

mass number
$^{11}_{5}\text{B}$ — element symbol
atomic number
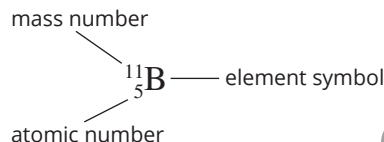
FIGURE 1.5 Representation of a boron atom

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 masses are called **isotopes** (Figure 1.6).

$^{20}_{10}\text{Ne}$ 10 protons
10 neutrons
10 electrons

$^{22}_{10}\text{Ne}$ 10 protons
12 neutrons
10 electrons
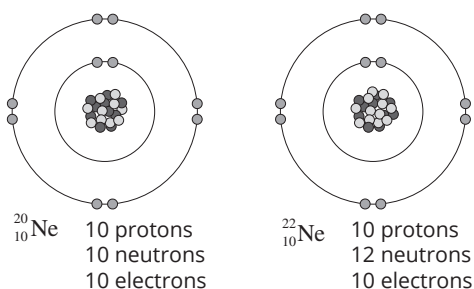
FIGURE 1.6 Isotopes of neon

Radioisotopes

Radioisotopes are isotopes that are radioactive. The nuclei of radioisotopes are unstable and will decay to form more stable nuclei. Different types of radiation can be emitted (Table 1.4).

TABLE 1.4 Types of radiation emitted during the decay of radioisotopes

Type of radiation and symbol	Energy of radiation	Description	Reason for decay
alpha (α) particle, $^{4}_{2}\text{He}$	relatively low	two protons and two neutrons; a helium nucleus	nuclei have too few neutrons to be stable
beta (β) particle, $^{0}_{-1}\text{e}$	higher than alpha particle	usually an electron, emitted from nucleus	nuclei have too many neutrons to be stable
gamma (γ) radiation	relatively high	electromagnetic radiation	unstable atom releasing energy

Balanced equations of nuclear reactions can be used to show decay of radioisotopes. **Balanced nuclear reactions** have the following features:

- The different types of radiation are represented by their symbols.
- The atomic numbers add up to the same value on both sides of the equation.
- The mass numbers add up to the same value on both sides of the equation.

For example, polonium-208 decays to produce lead-204, an alpha particle and gamma radiation. The equation is:

$$^{208}_{84}\text{Po} \rightarrow {}^{204}_{82}\text{Pb} + {}^{4}_{2}\text{He} + \gamma$$
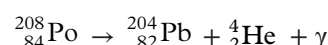
Iodine-131 decays to produce xenon-131 and a beta particle:

$$^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe} + {}^{0}_{-1}\text{e}$$
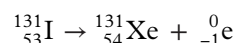
MASSES OF PARTICLES

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. Carbon-12 was selected as the standard in 1961 as a compromise between the preferences of physicists and chemists at the time. Two of the masses scientists use for different elements are:

- **relative isotopic mass** (I_r), which is the relative mass of each individual isotope of an element. Isotopes have different masses because of their different numbers of neutrons.
- **relative atomic mass** (A_r), which is the weighted average of the relative masses of the naturally occurring isotopes of a particular element. The relative atomic mass of each element is included in the periodic table.

Determination of the relative atomic mass of an element

A **mass spectrometer** is used to identify the existence of isotopes of an element and their **relative isotopic abundances**.

The data from a mass spectrometer is displayed as a **mass spectrum** (Figure 1.7). Each peak represents one isotope. The position of each peak indicates the relative isotopic mass, and the height of the peak indicates relative isotopic abundance. The masses and relative isotopic abundances of isotopes of a particular element allow the calculation of relative atomic mass.

From the mass spectrum data in Figure 1.7:
- one isotope has a relative mass of 62.9 and relative abundance of 69.1%
- one isotope has a relative mass of 64.9 and relative abundance of 30.9%.
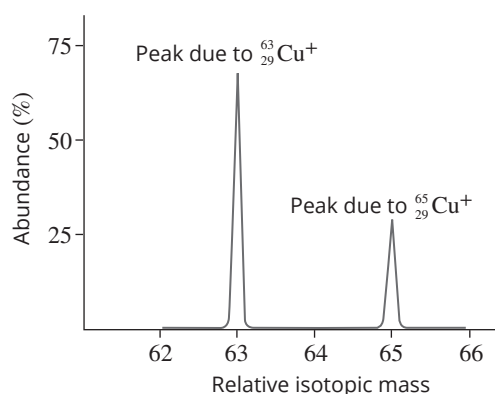
FIGURE 1.7 Mass spectrum of copper

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

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

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

$$= 63.5$$

ELECTRONIC STRUCTURE OF ATOMS

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

Neils Bohr's model of the atom explains the emission spectra of hydrogen very well. The model of the atom that existed prior to Bohr could not explain the coloured lines. In the **Bohr model**, electrons are placed into fixed orbits of specific energy (Figure 1.8):
- 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 fixed-energy 'jumps' appear in emission spectra and are unique to each element.
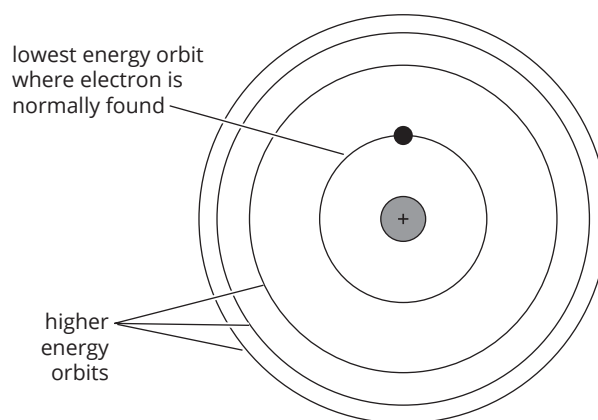
FIGURE 1.8 Bohr's model of the atom

ELECTRONIC CONFIGURATION AND THE SHELL MODEL

The energy levels of atoms are called shells. Electrons in the same shell are a similar distance from the nucleus and have similar energy. Ionisation energies were used by scientists to determine the number of electrons that can occupy each shell. Ionisation energy is the energy needed to remove an electron from an atom.

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 1.5).

TABLE 1.5 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 **electronic configuration** for an element lists the number of electrons in 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 electronic configuration of sodium is 2,8,1.

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

SCHRÖDINGER MODEL OF THE ATOM

Bohr's model could not explain the emission spectra of elements with more than one electron.

Erwin Schrödinger refined Bohr's model by proposing a 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 given orbit but behave as negative clouds of charge found in regions of space called **orbitals** (Figure 1.9).
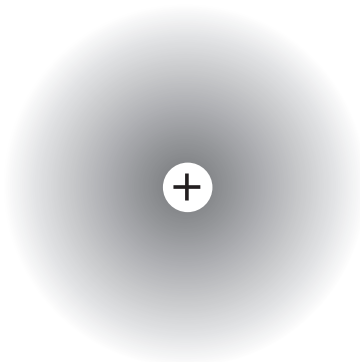
FIGURE 1.9 Electron cloud around a nucleus

The orbitals are located in subshells within shells (Table 1.6).

TABLE 1.6 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**.
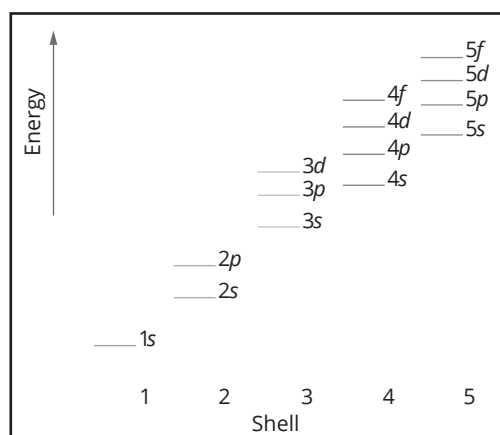
FIGURE 1.10 Energy levels in an atom

Note that some subshells are higher in energy than subshells of the next shell (Figure 1.10). For instance, the unfilled 3d subshell is higher in energy than the

unfilled 4s-subshell. Therefore the 4s subshell is filled before the 3d. The electronic configurations of lithium, nitrogen, potassium and nickel are shown in Table 1.7.

TABLE 1.7 Electronic configurations of some elements

Element	Atomic number	Electronic 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. Their electronic configurations are:

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

Cu: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$
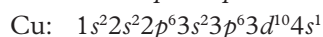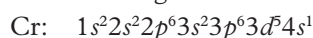
Valence electrons occupy the shell furthest from the nucleus. The valence electrons determine an element's chemical properties. Atoms can lose or gain valence electrons to form charged particles called **ions**.

Periodicity

THE PERIODIC TABLE

In terms of electronic 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 electronic configuration.
- Four large blocks of the periodic table can be identified (Table 1.8).

TABLE 1.8 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 1.9) 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 radii** are increasing and valence electrons are becoming further from the nucleus. This makes the valence electrons less tightly held so they can be more easily removed.
- Going across a period, the **core charge** of successive elements increases by one for each element (core charge = number of protons – number of inner shell electrons). As the core charge increases, the valence electrons experience a greater attraction to the nucleus and are held more tightly. They become more difficult to remove.

TABLE 1.9 Trends in the periodic table

Property	What it indicates	Trend going down a group	Trend going from left to right across a period
state of matter at room temperature	whether an element is a solid, liquid or gas at 25°C	There is no distinguishable trend.	Melting points increase across periods 1–3 from groups 1–14 then drastically drop for groups 15–18.
electronic configuration	number of electrons in each shell (Bohr) or subshell (Schrödinger) written in order of increasing energy	Number of occupied shells increases.	Number of valence electrons increases.
atomic radius	size of the atom	Atomic radius increases.	Atomic radius decreases.
electronegativity	ability of an atom to attract shared electrons in a molecule and how strongly the valence electrons are attracted to the nucleus	Electronegativity decreases.	Electronegativity increases.
first ionisation energy	minimum amount of energy required to remove the highest energy electron from an atom or ion and how tightly the highest energy electron is held to the nucleus	First ionisation energy decreases.	First ionisation energy increases.
reactivity with water	how readily an element will react with water, how readily a metal atom will release its outer shell electrons and how readily a non-metal atom will accept an electron	Reactivity of metals increases. Reactivity of non-metals decreases.	Reactivity of metals decreases. Reactivity of non-metals increases. However, last element in each period is an unreactive noble gas.

Bonding

Metallic elements exist as structures that contain large numbers of metal atoms bonded together. Apart from the noble gases, non-metallic elements exist as molecules in which two or more atoms are bonded together. In compounds, two or more different types of atom are bonded together. The nature of the 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.

METALLIC BONDING

Remember from Table 1.1 that metals are usually:
- **lustrous** (reflective) when freshly cut or polished
- good **conductors** of heat
- good conductors of electricity

- **malleable**, which means they can be shaped by beating or rolling
- **ductile**, which means they can be drawn into a wire.

Not all metals have all of these properties. A limitation of the metallic bonding model is that it cannot explain these exceptions.

Metallic bonding model

Metal atoms generally have one, two or three electrons in their outer shell and tend to have electrons removed in their interactions with other atoms.

The **metallic bonding model** (Table 1.10) describes metals as a metallic structure which consists of a regular arrangement of stable, positively charged metal ions, called **cations**, surrounded by a 'sea' of freely moving **delocalised** valence electrons. The metal atoms achieve stability by releasing their valence electrons to become the surrounding 'sea'. **Metallic bonds** are an electrostatic attraction between the cations and the freely moving electrons.

TABLE 1.10 Summary of the metallic bonding model

Type of material	Constituent particles	Bonding model	Properties
metals (e.g. iron)	• metal cations formed when metal atoms lose their valence electrons • delocalised valence electrons	 positive ions 'sea' of delocalised electrons	• generally high melting temperature • good conductor of electricity • malleable • ductile • lustrous

Structure of metallic crystals

When a metal is cooled from its liquid form, or when a metal is produced from a solution by a chemical reaction, the structure starts to form into **crystals** at many different places at once. Generally, the smaller the crystals, the less free movement of layers of ions over each other, hence the metal becomes harder and less malleable. Smaller crystals indicate more disruptions to the structure overall so the metal becomes more brittle.

IONIC BONDING

Most ionic compounds:

- are **brittle**, which means they shatter when hit with a hammer
- are **hard**, which means they are resistant to scratching
- have high melting points
- are unable to conduct electricity in solid state
- are good electrical conductors in liquid or aqueous states.

Ionic bonding model

Ionic compounds usually contain metal and non-metal atoms. The bonding model (Table 1.11) describes an ionic network that consists of a regular arrangement of metal cations and negatively charged non-metal ions called **anions**. The electronegativity difference between metal and non-metal atoms is generally high. The metal atoms fully transfer their electrons to the more electronegative non-metal atoms. **Ionic bonds** are the electrostatic attractions between the oppositely charged ions.

All models of bonding are only a representation of what is occurring at the atomic scale and so they have limitations. For example, the diagram in Table 1.11 shows the space occupied by the anions and cations but does not show the actual ionic bonds.

Ionic crystals

The arrangement of ions in a regular geometric structure is called a crystal. The exact arrangement of ions in a crystal varies according to the size and ratio of the ions.

Charges on ions

The positive or negative charge on an ion indicates whether the atom has lost or gained electrons (Table 1.12). The size of the positive or negative charge indicates the number of electrons removed or gained. The charge on an ion is called its **electrovalency**.

Ionic formulae

Anions and cations are formed when electrons are transferred from metal atoms to non-metal atoms during the formation of ionic compounds (Fig. 1.11).

TABLE 1.11 Summary of the ionic bonding model
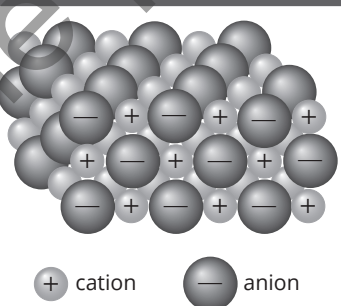
Type of material	Constituent particles	Bonding model	Properties
ionic compounds (e.g. sodium chloride)	• cations, such as those formed when metal atoms transfer their outer shell electrons to non-metal atoms • anions, such as those formed when non-metal atoms gain electrons from metal atoms	+ cation − anion	• very high melting temperature • cannot conduct electricity when solid • can conduct electricity when molten or dissolved • brittle

TABLE 1.12 Charges on some common ions

Element	Electrons in outer shell	Tendency	Electrovalency	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^-

Mg (2,8,2) — donates two electrons to — O (2,6) — to form — Mg^{2+} (2,8) — and — O^{2-} (2,8)
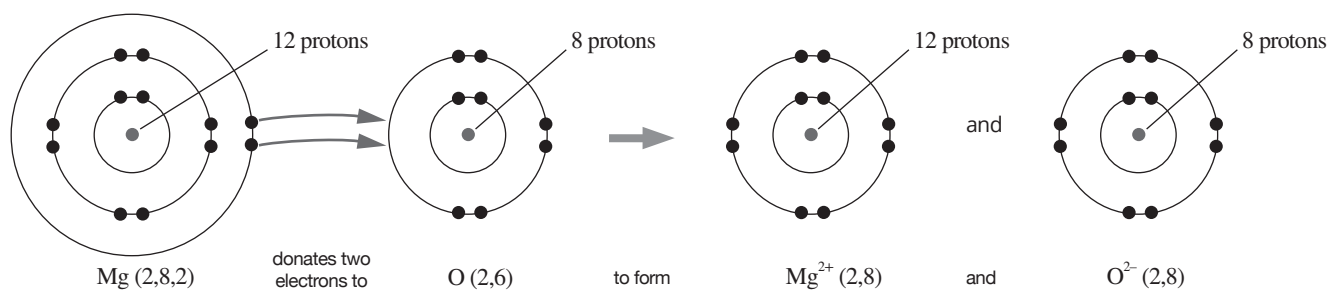
FIGURE 1.11 Transfer of electrons when magnesium reacts with oxygen

The ratio of metal to non-metal atoms in the compound is written in the ionic formula and depends on the electrovalencies of the ions involved (Table 1.13). The overall charge must be balanced.

TABLE 1.13 Formation of ionic compounds from ions of different electrovalencies

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

COVALENT BONDING

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** (individual) **molecules** are formed containing fixed numbers of atoms. Molecules then interact with other molecules to give the material its observable properties.

Intramolecular forces

In general, electrons are shared between non-metal atoms so that each atom has 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 and hard to break:

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

The structures of molecules are most often represented by:

- **Lewis dot diagrams**, in which dots represent each valence electron (Figure 1.12a)
- structural formulae, in which a single line represents each covalent bond. Non-bonding electron pairs are not shown (Figure 1.12b).
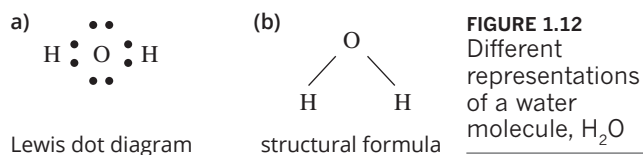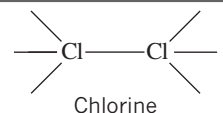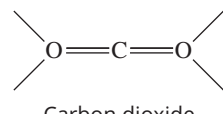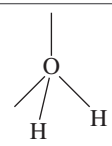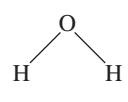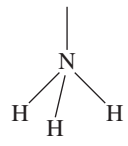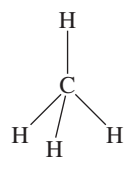
FIGURE 1.12 Different representations of a water molecule, H_2O

Lewis dot diagram   structural formula

The four electron pairs of a stable outer shell form themselves into a **tetrahedral** shape. In this shape the pairs of negatively charged electrons have achieved maximal separation from each other within the atom according to the **valence shell electron-pair repulsion theory**. The shape of the molecule is determined by the positions of atoms. Molecules can be linear, V-shaped, pyramidal or tetrahedral (Table 1.14).

TABLE 1.14 Molecular shapes

Shape	Description	Example
linear	The two atoms of a diatomic molecule must be in a straight line.	 Chlorine
	The double bonds of triatomic molecules such as carbon dioxide repel each other. A straight line is as far apart as the electrons can get.	 Carbon dioxide
V-shaped (also known as angular or bent)	In a triatomic molecule, non-bonding pairs repel the bonding pairs of electrons. The bonding pairs also repel each other and try to achieve a linear shape, so a V-shape results.	 Water (showing bonding and non-bonding electron pairs) Water (drawn without the non-bonding electron pairs, the V-shape of a water molecule is more obvious)
pyramidal	A molecule consisting of a central atom and three bonded atoms might be expected to form a flat triangular shape. These central atoms will usually have a non-bonded pair that repels the three bonded pairs, so the triangular shape becomes a pyramid.	 Ammonia
tetrahedral	A molecule consisting of a central atom and four bonded atoms has four sets of bonding pairs trying to get as far apart as possible. The resulting shape is tetrahedral.	 Methane

Polarity of molecules

Whether a molecule is polar or non-polar depends on the distribution of charge across the molecule. When two atoms bond that have different electronegativities, the atom with the higher electronegativity gains a greater share of the shared electron pair and thus carries a partial negative charge. The other atom will carry a partial positive charge. The molecule is called a dipole and the bond is said to be a **polar** bond (Figure 1.13).

$$\overset{\delta+}{H}\!\!-\!\!\overset{\delta-}{Cl}$$
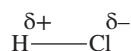
δ+ represents a small amount of positive charge.
δ− represents a small amount of negative charge.

FIGURE 1.13 Representation of a polar bond

A polar molecule:
- contains polar bonds
- has partial charges, distributed asymmetrically across the molecule (Figure 1.14).
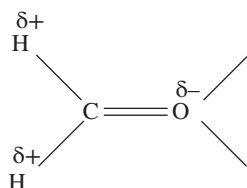
FIGURE 1.14 Structure of formaldehyde (methanal), a polar molecule

A **non-polar** molecule may (Figure 1.15) or may not (Figure 1.16) contain polar bonds. If it contains polar bonds, the partial charges are distributed symmetrically across the molecule.
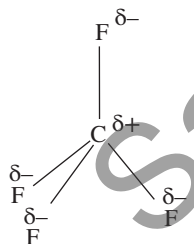
FIGURE 1.15 The C–F bond in tetrafluoromethane is polar, but the molecule is non-polar.
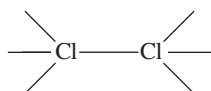
FIGURE 1.16 Chlorine is a non-polar molecule without polar bonds.

Intermolecular forces

The common properties of covalent molecular substances include:
- low melting and boiling points due to relatively weak intermolecular forces (A covalent molecular structure can form if a covalent molecular substance is cooled enough for the molecules to form into a fixed lattice arrangement.)
- non-conduction of electricity in solid or molten states because no free-moving particles are present
- softness.

These properties can be explained by the intermolecular forces, that is, the forces between different molecules. The most significant type of intermolecular force present depends on the polarity and structure of the molecule (Table 1.15).

In contrast to the metallic or ionic bonding models, the covalent bonding model describes a number of different types of bond, each with a different strength (Figure 1.17).

TABLE 1.15 Types of intermolecular force

Force	When it is present	Bond occurs between	Relative strength
dispersion force	between all atoms/molecules, but only relevant in non-polar molecules when no other forces are present	two different atoms or molecules	weak, but increases as the size of the atom or molecule increases
dipole–dipole bond	when molecules are polar	partially positive charge on one polar molecule and partially negative charge on another	generally stronger than dispersion forces but weaker than hydrogen bonds
hydrogen bond	when molecules are polar and have a H bonded to an N, O or F	partially positive H atom on one molecule and lone pair of electrons on N, O or F atom on another molecule	strongest intermolecular force but a lot weaker than a covalent bond

dispersion forces   dipole–dipole attractions   hydrogen bonds   covalent bonds

Increasing strength of bonds

FIGURE 1.17 Increasing strengths of different types of bonds involved in covalent bonding models

Covalent networks
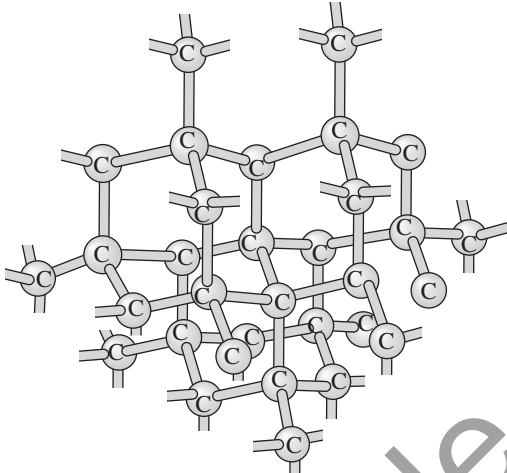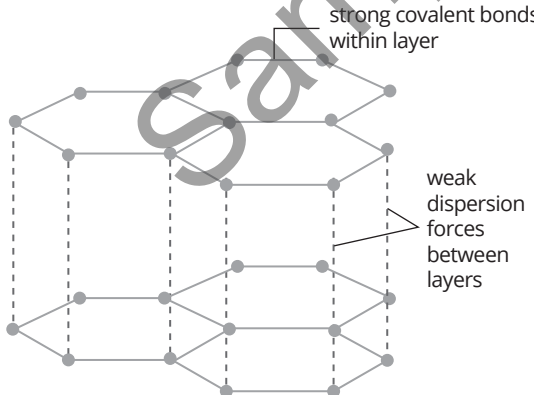
Carbon can form networks and a range of large molecules by bonding carbon atoms in different ways. These structures are called **allotropes**. The allotropes of carbon have significantly different structures and properties.

Carbon networks

There are different types of covalent networks (Table 1.16):

- A **covalent network structure** forms when covalent bonds extend throughout an entire substance. Diamond is a carbon covalent network.
- A **covalent layer network** forms when covalent bonds extend throughout layers in a substance, and there are only weak dispersion forces between layers. Graphite is a carbon covalent layer network.
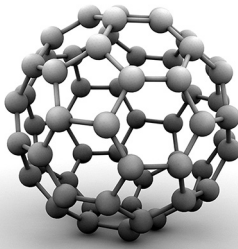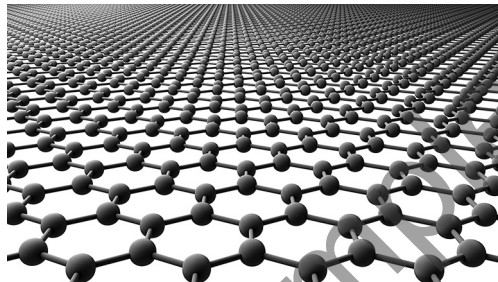
TABLE 1.16 Types of carbon network

Allotrope	Structure	Properties	Uses
diamond	covalent network structure; each carbon atom is covalently bonded to four other carbon atoms in a tetrahedral arrangement	• very hard • very high melting point • non-conductor of electricity	jewellery, cutting tools, drills
graphite	covalent layer network; each carbon atom is covalently bonded to three other carbon atoms in a layer. There is one delocalised electron per atom	• good conductor of electricity • high melting point • soft, greasy	electrodes, lubricant, pencils

Carbon nanomaterials

Carbon nanomaterials are molecules made only of carbon atoms. These materials can be measured at the nanoscale. There are different types of carbon nanomaterials (Table 1.17).

TABLE 1.17 Types of carbon nanomaterials

Allotrope	Structure	Properties	Uses
fullerene	roughly spherical molecule in which each carbon atom is covalently bonded to three other carbon atoms. There is one delocalised electron per carbon atom	• possibility of electrical conductivity • strong • insoluble in water	• composite materials • photovoltaic cells
graphene	single layer of graphite	• good conductor of electricity • extremely strong and tough	• computer chips • circuits • electrodes • filtration of water • reinforcement

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, to indicate 1, 2, 3, 4, etc. to indicate the number 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 immediately after the metal in the compound.

WORKSHEET 1.1

Knowledge review—thinking about matter

Examine the three atoms represented by these shell models.

neutrons   electrons

protons
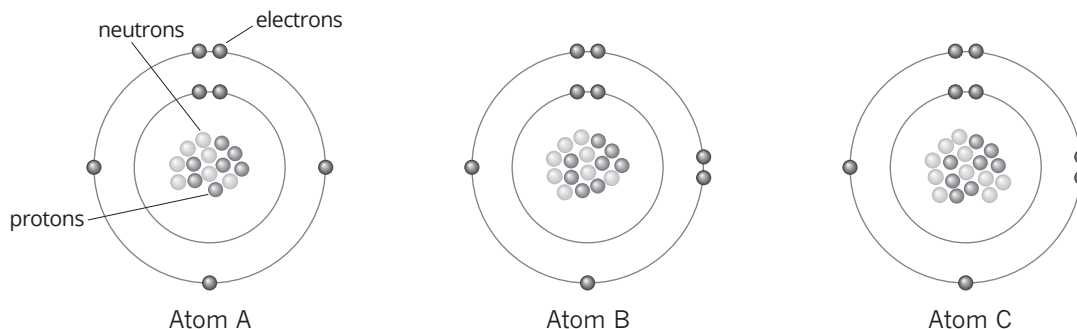
Atom A   Atom B   Atom C

1 Complete the information for each atom.

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

2 The three types of subatomic particle are labelled in atom A.

a Which subatomic particle has a negative charge? _____

b Which subatomic particle has a positive charge? _____

c Which two subatomic particles 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. Mark 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 1.2

Balancing protons and neutrons—radiation

1 Identify the type(s) of radiation being emitted in each of these reactions.

Nuclear reaction	Type(s) of radiation
$^{239}_{92}U \rightarrow ^{229}_{90}Th + ^{4}_{2}He$	
$^{99}_{43}Tc \rightarrow ^{99}_{43}Tc +$	
$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He +$	
$^{90}_{38}Sr \rightarrow ^{90}_{39}Y + ^{0}_{-1}e$	

2 a Balance these nuclear reactions.

   i $^{6}_{2}He \rightarrow$ _____ $+ ^{0}_{-1}e$

   ii $^{146}_{62}Sm \rightarrow ^{142}_{60}Nd +$ _____

   b Describe the knowledge and skills you used to balance the equation in part **a**.

   _____

   _____

   _____

   _____

   _____

3 Use the internet to find out about a human-made radioisotope that is produced for a specific purpose. Write the information you find, including a balanced nuclear reaction, in the space provided.

   _____

   _____

   _____

   _____

   _____

   _____

   _____

   _____

   _____

   _____

RATING MY LEARNING	My understanding improved	Not confident ← → Very confident ○ ○ ○ ○ ○	I answered questions without help	Not confident ← → Very confident ○ ○ ○ ○ ○	I corrected my errors without help	Not confident ← → Very confident ○ ○ ○ ○ ○

PRACTICAL ACTIVITY 1.1

Separation techniques—purification of polluted water

Suggested duration: 50 minutes

INTRODUCTION

Water is never found pure in nature. It dissolves many impurities, and insoluble substances may remain in suspension. Any purification process needs to take account of the different types of substances found in water. Common water purification methods include:

- filtration: Insoluble particles are separated from water. In the laboratory, filtration can be achieved using different grades of filter paper.

- charcoal adsorption: Charcoal has the ability to adsorb many substances, that is, to hold them to its surface. Charcoal can be used to adsorb the dyes that colour water, or to adsorb substances that give water a foul odour or taste.

- distillation: Water is separated from other liquids and solids dissolved in it.

- oil–water separation: When allowed to stand undisturbed, a mixture of oil and water forms two layers, with the oil on top. The water can then be drained using a separating funnel. This method is based on the principle that oil and water have different densities and polarities, and are essentially insoluble in one another.

MATERIALS

- 100 mL polluted water
- activated charcoal
- separating funnel
- filter papers
- distillation equipment
- conductivity kit
- safety glasses

PURPOSE

- To devise and carry out a method for purification of polluted water.

- To obtain as large a volume, and as pure a sample, of water as possible from a sample of polluted water.

PRE-LAB SAFETY INFORMATION		
Material used	**Hazard**	**Control**
conductivity kit	electricity	Construct the circuit with the power off. Do not touch the circuit while the power is on. Do not allow electrical equipment to come into contact with liquids.
polluted water	harmful substances in the water	Do not taste your polluted or 'purified water' sample. Wash your hands after handling polluted water.
Please indicate that you have understood the information in the safety table. Name (print): _____ I understand the safety information (signature): _____		

PROCEDURE

Record all of your procedure results in Table 1.

1   Record the volume, appearance and odour of your sample of water.

2   Using a voltage of 8 V, construct a simple circuit to test the electrical conductivity of the purified water. Be very careful not to let the electrodes touch each other.

3   Design a method of purifying your water sample. List the steps as a flow chart.

4   Identify the chemicals and equipment you will need. Show your proposed method and materials to your teacher for approval.

_____

_____

_____

_____

5   Carry out your approved procedure. Record the purpose of each step and carefully note the appearance, odour and volume of the water as you proceed.

6   When you have completed the procedure, record the appearance, odour and volume of purified water. Use the conductivity kit to determine the conductivity of the water.

7   Record the appearance, volume and conductivity of distilled water.

RESULTS

TABLE 1 Observations of water at each step of purification

Description of step	Purpose of step	Volume (mL)	Colour	Odour	Conductivity	Observations
untreated polluted water	not applicable				not applicable	
1					not applicable	
2					not applicable	
3					not applicable	
4						
distilled water						

PROCESSING DATA

Calculate the percentage yield of water at each step and record your results in Table 2.

$$\text{percentage yield} = \frac{\text{volume of water obtained (mL)}}{\text{initial volume of untreated water (mL)}} \times 100\%$$

TABLE 2 Percentage yield of water at each step

Step	Volume of water (mL)	Percentage yield
1		
2		
3		
4		

ANALYSIS OF RESULTS

1   Rate your ability to purify the water as 'very high', 'high', 'medium' or 'low'. Give a reason for your answer.

_____

_____

2   Which step was the most effective at purifying water? Give a reason for your answer.

_____

_____

3 What physical and/or chemical properties did you use to purify the water at each step?

_____

_____

_____

4 Compare your purified water sample with those of other students. How does your sample compare in terms of:

a percentage recovery?

_____

b apparent purity?

_____

5 Suggest some possible reasons for the differences between your sample and those of others in your class.

_____

_____

_____

6 Suggest how the purity of your sample could be further increased.

_____

_____

_____

DISCUSSION

7 Find out what chemicals are added to a community's water supply in order to make it fit for drinking. How do those chemicals increase the purity of the water?

_____

_____

_____

CONCLUSION

_____

_____

_____

_____

_____

_____

_____

RATING MY LEARNING	My understanding improved	Not confident ← → Very confident ○ ○ ○ ○ ○	I answered questions without help	Not confident ← → Very confident ○ ○ ○ ○ ○	I corrected my errors without help	Not confident ← → Very confident ○ ○ ○ ○ ○

DEPTH STUDY 1.1

Properties of substances—practical investigation

Suggested duration: 1 hour 45 minutes (including writing time)

INTRODUCTION

The properties of substances can indicate the nature of the particles from which the substances are made and the forces between the particles. If a substance conducts electricity, it must contain charged particles that are free to move. If a substance has a high melting temperature, there must be strong forces of attraction between the particles that make up the substance.

This depth study requires you to develop a hypothesis for a scientific investigation into the properties of different substances. You will then design and conduct an investigation, and analyse the data and information you have collected. You will communicate your ideas in a written practical report.

The questions and analysis provided here are a guide to what should be included in your report. The toolkit provides a guide to the sections and subheadings that must be included in your submitted report. **GO TO ➤** page ix

PURPOSE

To determine whether the properties of a substance can be related to the elements from which it is made.

QUESTIONING AND PREDICTING

In this investigation you will use three groups of substances: those that are made only of metal elements, those that are made only of non-metal elements and those that contain both metal and non-metal elements. Use your background knowledge and the information in the introduction to develop a hypothesis for this practical investigation.

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MATERIALS
• 5 cm strips of aluminium, tin and zinc
• iron nail
• approx. 8 mL of 0.1 mol L⁻¹
– copper(II) sulfate
– potassium iodide
– sodium chloride
– sucrose
• solid samples of candle wax, copper(II) sulfate, potassium iodide, sodium chloride and sucrose (approx. 5 g)
• quartz crystal
• approx. 8 mL ethanol or methylated spirits
• test-tubes and rack
• spatula
• conductivity apparatus
• 50 mL beakers
• crucibles
• gauze mat or pipeclay triangles
• Bunsen burner
• matches

PRE-LAB SAFETY INFORMATION		
Material used	**Hazard**	**Control**
candle wax	flammable	Heat gently and stop heating once wax has melted. If it ignites, remove the Bunsen burner and put a lid on the crucible to extinguish the flame.
0.1 mol L⁻¹ copper(II) sulfate	harmful if ingested; irritating to skin and eyes	Avoid contact. Wash hands well after use.
ethanol	flammable	Do not use near open flame.
methylated spirits	flammable; irritating to eyes, respiratory system and skin	Do not use near open flame. Avoid contact. Wash hands well after use.
potassium iodide (solid)	toxic; irritating to eyes and skin	Avoid contact. Wash hands well after use.

Please indicate that you have understood the information in the safety table.

Name (print): _____

I understand the safety information (signature): _____

CONDUCTING YOUR INVESTIGATION

Part A—Solubility in water

1   Design an investigation that will allow you to determine the solubility of each substance in water. Write your method in the space provided.

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2   Record the materials you will require for your investigation.

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3   Check your method and materials with your teacher, then carry out your investigation. Record your results in a suitable table. This will be Table 1.

Part B—Electrical conductivity

1 Place, in turn, samples of each of the substances in a 50 mL beaker. (Use a washed, dried beaker for each new sample.) Use enough of each substance to cover the bottom of the beaker to a depth of about 0.5 cm.

2 Test electrical conductivity of each substance for the states specified in Table 2. Substances should only be tested in the states indicated by unshaded cells in the table. Note that teacher demonstrations will be carried out for the testing of substances that have to be melted (other than candle wax). Electrical conductivity can be tested by placing the probes of a conductivity kit into the beaker or crucible containing the sample.

3 To test the conductivity of molten candle wax, place candle wax in the crucible to a depth of about 0.5 cm and heat gently over a Bunsen burner flame until the wax has melted.

4 In Table 2, record whether or not each sample tested conducts electricity.

TABLE 2 Electrical conductivity of the samples in different states

Substance	Electrical conductivity		
	In solid state	**In molten (or liquid) state**	**Dissolved in water**
aluminium			
candle wax			
copper(II) sulfate			
ethanol			
iron			
potassium iodide		teacher demonstration	
quartz crystal			
sodium chloride			
sucrose		teacher demonstration	
tin		teacher demonstration	
water			
zinc			

Part C—Melting temperature

1 Use secondary sources to find out the melting temperature of each of the substances. Enter the data into an appropriate table. Make sure you acknowledge the references you used, and use an appropriate referencing style as directed by your teacher.

PROCESSING DATA

Devise an appropriate table for inclusion in your final report that records all of the raw data you collected in parts A–C of the investigation, as well as the type(s) of element found in each substance.

ANALYSING DATA AND INFORMATION

1   Devise a table in which you can make generalisations about the solubility, electrical conductivity and melting temperature of the types of substance you tested, i.e. substances that contain only metals, substances that contain only non-metals and substances that contain both metals and non-metals. Substances with melting temperatures less than 250°C are 'low'. Substances with melting temperatures greater than 600°C are 'high'. Melting temperatures between 250°C and 600°C are 'medium'.

These questions have been designed to guide your discussion in your practical report. You should add additional analyses of your results and/or the investigation as you see fit.

2   Identify any substances that do not seem to fit with the generalisations you made in the analysis of data.

DISCUSSION

3   For a substance to conduct electricity, it must contain free-moving charged particles. Which types of substance contain free-moving charged particles?

4   Identify a type of substance that contains charged particles that are not free-moving.

5   The melting temperature of a substance depends on the strength of the forces of attraction between particles in the substance. Make generalisations about the forces of attraction between the particles in each of the three types of substance.

6   Discuss any errors or limitations in the data you have collected in this investigation.

7 What modifications, if any, can you make to your hypothesis based on the new evidence collected in this investigation?

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8 What improvements could be made to this investigation?

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COMMUNICATING

Write a practical report for this investigation in a Word document or similar. The questions you have answered will guide your report but you can also add more to your discussion. Refer to the toolkit to see what should be included in each section of a practical report. Don't forget to include a conclusion and references, especially for the secondary sources you used to research melting temperatures. GO TO ➤ pages ix–xvii