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Unit 1: How can the diversity of materials be explained?

AREA OF STUDY 1

How can knowledge of elements explain the properties of matter?

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How to use this book

Heinemann Chemistry 1 5th edition

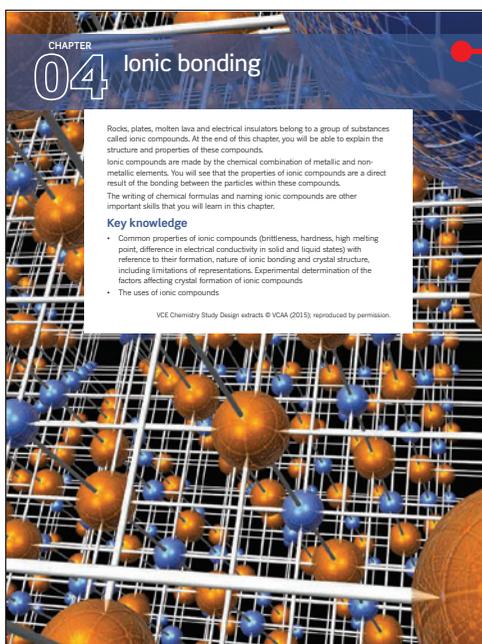
Heinemann Chemistry 1 5th Edition has been written to the new VCE Chemistry Study Design 2016–2021. The book covers Units 1 and 2 in an easy-to-use resource. Explore how to use this book below.

Extension

Extension material goes beyond the core content of the Study Design. It is intended for students who wish to expand their depth of understanding.

Highlight

Focus on important information such as key definitions, formulas and summary points.



Chapter opener

Chapter opening pages link the Study Design to the chapter content. Key knowledge addressed in the chapter is clearly listed.

Chemistry in Action

Chemistry in Action place chemistry in an applied situation or relevant context. These refer to the nature and practice of chemistry, applications of chemistry and the associated issues and the historical development of concepts and ideas.

ATOMIC RADIUS
Atomic radius is a measurement used for the size of atoms. It is the distance from the nucleus to the valence shell electrons. It is usually measured by halving the distance between the nuclei of two atoms of the same element that are bonded together.

2.2.6 depicts the atomic radii of many of the main group elements.

1 **Measure** sharply defined boundaries and so it is not possible to measure their radii directly. One method of obtaining atomic radii, and therefore an indication of atomic size, is to measure the distance between nuclei of atoms in molecules. For example, in a hydrogen molecule (H₂) the two nuclei are 74 picometres (pm) apart. The radius of each hydrogen atom is assumed to be half of that distance, i.e. 37 pm.

EXTENSION

Triads and octaves

In 1829, German chemist Johann Wolfgang Döbereiner noticed that many of the known elements could be arranged in groups of three on the basis of their chemical properties. He called these groups 'triads'. Within each of these triads, the properties of one element was intermediate between the other two. The intermediate's relative atomic weight was almost exactly the average of the others.

One of Döbereiner's triads was lithium, sodium and potassium. Sodium is more reactive than lithium, but less reactive than potassium. Sodium's atomic mass is 23, which is the average of lithium's (atomic mass 7) and potassium's (atomic mass 39) atomic masses.

However, Döbereiner's theory was limited. Not all elements could be included in triads. But his work was quite remarkable given he had fewer than 50 elements to work with at this time.

Decades later, English chemist John Alexander Newlands noticed a pattern in the atomic weight of elements. Newlands' law of octaves was published in 1865, and identified properties of new elements such as germanium. His patterns worked well for the lighter elements but did not fit for the heavier elements or allow movement for the discovery of new elements.

Four years later in 1869, Mendeleev, working independently, published his periodic law, which, with a few modifications, was similar to that of Newlands.

Worked example 2.2.1

CORE CHARGE

Determine the core charge of an atom of aluminium.	
Thinking	Working
Determine the number of electrons in an atom of the element, using the periodic table as a reference.	The atomic number of aluminium is 13. Therefore, an atom of aluminium has 13 protons and 13 electrons.
Use the number of electrons to determine the electronic configuration.	With 13 electrons the electronic configuration is 1s ² 2s ² 2p ⁶ 3s ² 3p ¹ .
Determine the core charge.	The third shell is the valence shell in this atom. There are 10 inner shell electrons, which in this atom is electrons in the first and second shell.

CHAPTER 2 | ELECTRON ARRANGEMENTS AND THE PERIODIC TABLE

CHEMISTRY IN ACTION

The sting of a bee

The formula for pentyl ethanoate, C₇H₁₄O₂, is represented by the structure shown in Figure 5.3.4.

Pentyl ethanoate, C₇H₁₄O₂, is the compound that gives bananas their characteristic odour. It is also a pheromone released by bees when they sting. A pheromone is a chemical produced by an animal or insect that changes the behaviour of another animal or insect of the same species. Bees release pentyl ethanoate as an alarm pheromone to alert other bees to danger. The compound is released near the sting shaft and attracts other bees to the area, where the group behaves defensively, charging and stinging. Smoke masks the alarm pheromone, interrupting the defensive response and calming the bees, allowing beekeepers an opportunity to work with the beehive.

Each time a bee stings, one-thousandth of a milligram (1.0 × 10⁻⁶ g) of pentyl ethanoate is released. Knowing the mass of pentyl ethanoate released in a bee sting enables chemists to calculate the number of pentyl ethanoate molecules in each sting using the relationship between mass and mole.

As the molar mass of pentyl ethanoate (C₇H₁₄O₂) is equal to 130.0 g mol⁻¹, using the formula $n = \frac{m}{M}$, 1.0 × 10⁻⁶ g of pentyl ethanoate is equal to 7.7 × 10⁻⁹ mol.

From section 5.2, you know that the number of particles can be calculated using the formula $N = n \times N_A$. The number of pentyl ethanoate molecules in each bee sting is therefore equal to 4.6 × 10¹⁵.

You are now in a position to count atoms by weighing. When you use the mole, you are effectively counting the number of particles in a substance. The number of particles present in a substance is equal to the number of moles of the substance multiplied by 6.02 × 10²³.

Some calculations require you to use both of the formulas $n = \frac{m}{M}$ and $n = \frac{N}{N_A}$. Worked Example 3.3.2 is such a calculation.

CHEMFILE

Avogadro's number

It is very difficult to imagine just how big Avogadro's number really is, especially when atoms, ions and molecules are so small. Here are some examples to help:

- 6.02 × 10²³ grams of sand, placed side by side, would stretch from the Earth to the Sun and back about 7 million times.
- A computer counting 10 billion times every second would take 2 million years to reach 6.02 × 10²³.
- 6.02 × 10²³ of the marshmallows shown in Figure 5.2.6 would cover Australia to a depth of 900 km!

FIGURE 5.2.6 One mole of 6.02 × 10²³ marshmallows would cover Australia to a depth of 900 km!

AREA OF STUDY 1 | HOW CAN KNOWLEDGE OF ELEMENTS EXPLAIN THE PROPERTIES OF MATTER?

ChemFile

ChemFiles include a range of interesting information and real-world examples.

Worked examples

Worked examples are set out in steps that show thinking and working. This enhances student understanding by linking underlying logic to the relevant calculations.

Each Worked example is followed by a Try Yourself: Worked example. This mirror problem allows students to immediately test their understanding.

Fully worked solutions to all Try Yourself: Worked examples are available on *Heinemann Chemistry 5th Edition ProductLink*.

Chapter review

Each chapter finishes with a set of higher order questions to test students' ability to apply the knowledge gained from the chapter.

Section summary

Each section includes a summary to assist students consolidate key points and concepts.

1.7 Review

SUMMARY

- The shell model of the atom was unable to fully explain the properties of atoms and a new model was needed to describe the electron behaviour in atoms.
- The Schrödinger model proposed that electrons behave as waves and occupy a three-dimensional space around the nucleus.
- The Schrödinger model predicted that subshells are energy levels within the major shells. The subshells consist of orbitals.
- An orbital can be regarded as a region of space surrounding the nucleus in which an electron may be found.
- Orbitals of similar energy are grouped in subshells that are labelled s, p, d and f.
- Each orbital can hold a maximum of two electrons (Table 1.7.3).
- Each subshell has a different energy in an atom.
- Electrons fill the subshells from the lowest energy subshell to the highest energy subshell.
- The 4s-subshell is lower in energy than the 3d-subshell, so the fourth shell accepts two electrons before the third shell is completely filled.
- Electronic configurations of atoms in the Schrödinger model specify the number of electrons in each subshell.

TABLE 1.7.3

Shell	Subshells	Orbitals in subshell
1	1s	1
2	2s 2p	1 3
3	3s 3p 3d	1 3 5
4	4s 4p 4d 4f	1 3 5 7

KEY QUESTIONS

- Copy and complete the following table to write the electronic configuration of each of the atoms listed.

Element (atomic number)	Electronic configuration using the shell model	Electronic configuration using the subshell model
Boron (5)	2, 3	1s ² 2s ² 2p ¹
Lithium (3)		
Chlorine (17)		
Sodium (11)		
Neon (10)		
Potassium (19)		
Scandium (21)		
Iron (26)		
Bismuth (83)		
- In terms of energy levels, what is the essential difference between the shell model and the subshell model of the atom?

AREA OF STUDY 1 | HOW CAN KNOWLEDGE OF ELEMENTS EXPLAIN THE PROPERTIES OF MATTER?

Chapter review

KEY TERMS

adsorption
alpha particle
atom
atomic number
atomic theory of matter
Bohr model
chemical symbol
compound
covalent network lattice
electron
electron shell
electronic configuration
electrostatic attraction

element
emission spectrum
energy level
excited state
giant molecule
ground state
ionisation energy
isotope
mass number
matter
model
molecule
monatomic

nanomaterial
nanoscale
nanotechnology
neutron
noble gas
nucleon
nucleus
orbital
periodic table
periodic table
proton
quantum
quantum mechanics
radioactive
scanning tunnelling
microscope (STM)
Schrödinger model
subatomic particle
subshell
valence electrons
valence shell

Nanomaterials and nanoparticles

- Nanotechnology is often represented by two fundamentally different approaches: 'top-down' and 'bottom up'. Research the differences between these two approaches.
- Convert the following lengths into nanometres (express your solutions in scientific notation).
 - 5 cm
 - 12 mm
 - 2 km
- Zinc oxide powder and zinc oxide nanoparticles both absorb UV light. What property of zinc oxide nanoparticles makes them more suitable than zinc oxide powder for use in sunscreen.

The atomic world

- Which of Dalton's predictions about the nature of atoms was later proven to be incorrect?
- Classify the following elements according to whether they are monatomic, made up of molecules or form a large network of atoms bonded together: sulfur, copper, carbon, tin, helium, neon, gold, oxygen, krypton, nitrogen.

Inside atoms

- Where would you find 99.97% of the mass of an atom?
- How are protons, neutrons and electrons arranged in an atom?
- Compare the mass and charge of protons, neutrons and electrons.

Classifying atoms

- An atom of chromium can be represented by the symbol $^{52}_{24}\text{Cr}$.
 - Determine its atomic number and mass number.
 - Determine the number of electrons, protons and neutrons in the chromium atom.

- Two atoms both have 20 neutrons in their nucleus. The first has 19 protons and the other has 20 protons. Are they isotopes? Why or why not?

- Explain why the number of electrons in an atom equals the number of protons.

- Using the element bromine as an example, explain why elements are best identified by their atomic number and not their mass number.

- In a hydrogen atom, which electron shell will the electron be in if the atom is in the ground state?

- Determine which shell the 30th electron of an atom would go into according to the rules for determining the electronic configuration of an atom.

- What is the name of the element that has an electronic configuration of 2,8,2?

- The Schrödinger model of the atom

- Write electronic configurations, using subshell notation, for the following elements. The atomic number of each element is shown in brackets.
 - Helium (2)
 - Carbon (6)
 - Fluorine (9)
 - Aluminium (13)
 - Argon (18)
 - Nickel (28)
 - Bromine (35)

- Use a fluorine atom as an example, explain the difference between the terms 'shell', 'subshell' and 'orbital'.

- Determine the Schrödinger model of electronic configuration that corresponds to the shell model electronic configuration 2,8,6.

CHAPTER 1 | THE ATOMIC NATURE OF MATTER

Section review

Each section finishes with questions to test students' understanding and ability to recall the key concepts of the section.

Area of Study review

Each Area of Study finishes with a comprehensive set of exam-style questions, including multiple choice and extended response, that assist students to draw together their knowledge and understanding and apply it to this style of questions.

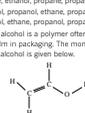
UNIT 1 • Area of Study 2

- Which one of the following alternatives correctly describes the intermolecular forces in pure samples of F_2 , HF and CH_2F_2 ?

F_2	HF	CH_2F_2
A Dispersion forces only	Dispersion forces and hydrogen bonds	Dispersion forces and dipole-dipole attraction
B Dispersion forces and hydrogen bonds	Dispersion forces and hydrogen bonds	Dispersion forces and hydrogen bonds
C Dispersion forces only	Dispersion forces and hydrogen bonds	Dispersion forces and hydrogen bonds
D Dispersion forces	Dispersion forces and dipole-dipole attraction	Dispersion forces and dipole-dipole attraction

- Which one of the following alternatives lists the compounds in order of increasing boiling points?
 - Ethane, propanone, ethanol, propanol
 - Ethane, ethanol, propanone, propanol
 - Ethanol, propanone, ethane, propanone
 - Ethanol, ethane, propanol, propanone

- Polyvinyl alcohol is a polymer often used as a water soluble film in packaging. The monomer used to form polyvinyl alcohol is given below.



- Which one of the following structures shows a possible segment of the polymer?
 -
 -
 -
 -

- The polymer is stronger.
 - I only
 - II and III only
 - I, II and III
 - II and IV only

- Graphenes and fullerenes are classified as carbon nanomaterials. Which of the following is equivalent to one nanometre?
 - 10⁻⁴ mm
 - 10⁻⁶ mm
 - 10⁻⁹ mm
 - 10⁻¹² m

- I only

- II and IV only

- III and IV only

- II and III only

- It would be possible to test whether the particles in a compound were held together by ionic or covalent bonds by measuring the compound's:
 - melting temperature
 - hardness and brittleness
 - electrical conductivity in the solid state
 - electrical conductivity in the liquid (molten) state.

- Polyethylene is a polymer that has a wide range of uses. It can be produced as a high density product (HDPE) or a lower density form (LDPE) that is softer and more flexible.
 - Higher softening temperature due to a greater degree of branching of the polymer chain
 - Higher softening temperature due to a smaller degree of branching of the polymer chain
 - Lower softening temperature due to a greater degree of branching of the polymer chain
 - Lower softening temperature due to a smaller degree of branching of the polymer chain.

- The percentage of crystalline regions in a polymer can be increased during manufacture. Which of the following statements about a polymeric material with an increased percentage of crystalline regions is correct?
 - The polymer is stronger.
 - The polymer is more transparent.
 - The polymer has a higher softening temperature.
 - I only
 - II and III only
 - I, II and III
 - II and IV only
 - III and IV only

- Graphenes and fullerenes are classified as carbon nanomaterials. Which of the following is equivalent to one nanometre?
 - 10⁻⁴ mm
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 - 10⁻⁹ mm
 - 10⁻¹² m

- I only

- II and IV only

- III and IV only

- II and III only

Short-answer questions

- Draw the structure of each of the following compounds and include any non-bonding pairs of electrons. Give the name of the shape of the molecule and predict whether the molecule is polar or non-polar.
 - H_2S
 - PF_3
 - CO_2
 - CS_2
 - SH_2

- Crude oil (petroleum) is an important resource to our society.
 - What is the origin of crude oil?
 - Crude oil is not a pure substance but a mixture.
 - Briefly describe the composition of crude oil.
 - Give the molecular formula of two hydrocarbons present in crude oil.

- Give the name of each of the following compounds:
 - CH_3COCH_3
 - $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
 -

- Draw an electron dot formula of an ammonia molecule, including non-bonding electron pairs.
 - Draw a structural formula for 2-ammonia molecules. Clearly show, and give the name of, the shape of these molecules. On your diagram, label the type of bonds that exist:
 - between the atoms within each ammonia molecule
 - between the two ammonia molecules.
 - Draw a structural formula for a molecule of:
 - nitrogen gas.
 - carbon dioxide gas.
 - Explain why the bonds between nitrogen molecules and those between molecules of carbon dioxide are of the same type even though the bonds inside these molecules differ in strength and polarity.
 - Explain why the bonds between ammonia molecules are different from those between nitrogen molecules or carbon dioxide molecules.

- Give the structural formula of each of the following compounds:
 - Hex-1-ene
 - Propanoic acid
 - Ethylenediamine
 - 2-methylpropan-2-ol
 - Pent-2-yne

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 - Pent-2-yne

Answers

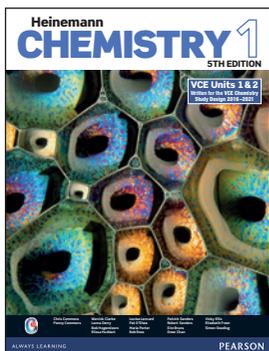
Numerical answers and key short response answers are included at the back of the book. Comprehensive answers and fully worked solutions for all section review questions, Try Yourself: Worked examples, chapter review questions and Area of Study review questions are provided via *Heinemann Chemistry 5th Edition ProductLink*.

Glossary

Key terms are shown in bold and listed at the end of each chapter. A comprehensive glossary at the end of the book includes and defines all key terms.

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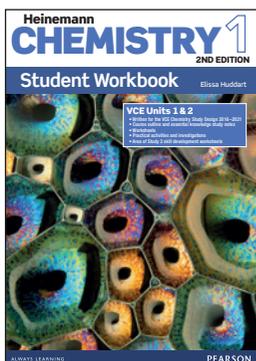
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