VCE Chemistry Units 1&2 Complete Study Guide

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This guide follows the VCAA **VCE Chemistry Study Design** accredited from 1 January 2023 (Units 1 and 2: 2023–2027; Units 3 and 4: 2024–2027). It covers every key knowledge dot point in Unit 1 (How can the diversity of materials be explained?) and Unit 2 (How do chemical reactions shape the natural world?), plus the key science skills that run through all four units.

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About this guide

How to use it

Each topic section matches one block of key knowledge in the study design. Read the explanation, cover the worked examples and try them yourself, then do the "Check your understanding" questions without looking at the answers. Full worked solutions for every question are in the Worked solutions section near the end. The Practice exam is designed to be sat under timed conditions once you have finished both units.

- **Bold** words are definitions you should be able to write from memory.
- Blue boxes are exam tips. Amber boxes are common mistakes that cost students marks every year.
- All numerical answers in this guide have been checked by computer. Molar masses use the one-decimal values in the VCAA data book style (for example C = 12.0, O = 16.0, Cl = 35.5).
- Constants used: Avogadro's constant $N_A = 6.02 \times 10^{23}$ mol^{-1}; gas constant R = 8.31 J mol^{-1} K^{-1}; molar volume of a gas at SLC (25 °C, 100 kPa) V_m = 24.8 L mol^{-1}; $K_w = 1.00 \times 10^{-14}$ at 25 °C; specific heat capacity of water c = 4.18 J g^{-1} K^{-1}; T(K) = θ(°C) + 273.

How Units 1&2 are assessed

All assessment in Units 1 and 2 is school-based. Your school decides the tasks and how they

are weighted, but every school must assess the three outcomes in each unit.

Unit	Area of Study	Outcome (what you must show)	Typical tasks
Unit 1	AoS 1: How do the chemical structures of materials explain their properties and reactions?	Explain how elements form carbon compounds, metallic lattices and ionic compounds; investigate properties; use chromatography	Practical reports, tests, data analysis
Unit 1	AoS 2: How are materials quantified and classified?	Mole calculations, organic naming, polymer design and its consequences	Tests, problem sets, media analysis
Unit 1	AoS 3: How can chemical principles be applied to create a more sustainable future?	Research investigation on a material, communicated in a chosen format	Research report, poster, presentation
Unit 2	AoS 1: How do chemicals interact with water?	Properties of water; acid–base and redox reactions and their uses	Practical reports, tests
Unit 2	AoS 2: How are chemicals measured and analysed?	Concentration, solubility, volumetric analysis, gases, analysis of salts	Titration reports, tests, data analysis
Unit 2	AoS 3: How do quantitative scientific investigations develop our understanding of chemical reactions?	Design or adapt an investigation, generate primary data and draw conclusions	Practical investigation with a scientific report or poster

Most schools also run an end-of-semester or end-of-year exam. These usually copy the Units 3&4 VCAA exam style: Section A multiple choice, Section B short-answer and extended-response questions, with a data book supplied. You must keep a **logbook** of all practical work in each unit, dated and kept up to date, because it is used to authenticate your

work.

> **Exam tip:** Units 1&2 do not count directly towards your study score, but almost every skill here (moles, stoichiometry, titrations, gas calculations, redox half-equations) is assumed knowledge in Units 3&4. Master them now.

At the time of writing, VCAA had not published a replacement study design. If a new or revised design appears on the VCAA website for 2028 or later, the core chemistry here (atomic structure, bonding, moles, stoichiometry, acids and bases, redox) is the foundation of every VCE Chemistry design and will carry over.

Suggested revision plan

Use this ten-week plan before your exams, or work through one topic per week alongside class.

Week	Topics	Tasks
1	Sections 1–2: periodic table, metals	Read, learn trends table, Check your understanding
2	Sections 3–5: ionic, covalent, separation	Learn solubility table and VSEPR shapes; Lewis structure practice
3	Section 6: quantifying atoms and compounds	Ten mole calculations a day; empirical formula practice
4	Sections 7–9: organic compounds, polymers, sustainability	Naming drills; compare plastics; green chemistry principles
5	Sections 10–11: water, acids and bases	pH calculations; write neutralisation equations with states
6	Section 12: redox	Balance ten half-equations in acidic conditions
7	Sections 13–14: concentration, volumetric analysis	Unit conversions; titration calculations
8	Sections 15–16: gases, analysis of salts	pV = nRT practice; hydrate and gravimetric problems

9	Section 17 and Exam technique	Key science skills definitions; redo weakest questions
10	Practice exam	Sit under timed conditions, mark with Worked solutions, fix gaps

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1. Elements and the periodic table

Elements, isotopes and ions

An **element** is a substance made of atoms that all have the same number of protons. That number is the **atomic number** (Z). The **mass number** (A) is the number of protons plus neutrons in the nucleus. We write an atom as $^{A}_{Z}X$, for example $^{35}_{17}Cl$ has 17 protons, 35 − 17 = 18 neutrons and, as a neutral atom, 17 electrons.

Isotopes are atoms of the same element with different numbers of neutrons, so they have the same atomic number but different mass numbers. ^{35}Cl and ^{37}Cl are isotopes. Isotopes of an element have the same chemical properties because chemistry depends on electrons, not neutrons.

An **ion** is a charged particle formed when an atom (or group of atoms) gains or loses electrons. A **cation** is positive (lost electrons, for example Na^{+}); an **anion** is negative (gained electrons, for example O^{2-}).

Particle	Protons	Neutrons	Electrons
^{24}Mg	12	12	12
$^{24}Mg^{2+}$	12	12	10
$^{37}Cl^{-}$	17	20	18
$^{56}Fe^{3+}$	26	30	23

Common mistake: Changing the number of protons when an ion forms. Only electrons change. A 2+ ion has two fewer electrons than protons.

Electronic configuration: shells and subshells

Electrons occupy **shells** (n = 1, 2, 3, 4…) at increasing distances from the nucleus. Each shell is divided into **subshells** labelled s, p, d and f, which hold a maximum of 2, 6, 10 and 14 electrons. Shell n holds at most $2n^2$ electrons.

Subshells fill in order of increasing energy: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p. Note that 4s fills before 3d.

Element	Shell configuration	Subshell configuration

Na (Z = 11)	2, 8, 1	$1s^2\ 2s^2\ 2p^6\ 3s^1$
Cl (Z = 17)	2, 8, 7	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$
K (Z = 19)	2, 8, 8, 1	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$
Fe (Z = 26)	2, 8, 14, 2	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$
Br (Z = 35)	2, 8, 18, 7	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^5$

Two points that are regularly examined:

- **Chromium and copper exceptions.** Cr is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$ and Cu is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$. A half-filled or full 3d subshell is more stable.
- **Transition metal ions lose 4s electrons first.** Fe^{2+} is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$, not $3d^4\ 4s^2$.

Exam tip: VCAA generally writes 3d before 4s when listing a configuration (grouping by shell), but either order is normally accepted as long as the electron counts are right. Always check that the superscripts add up to the number of electrons.

The periodic table as an organisational tool

Elements are arranged in order of atomic number. **Groups** are vertical columns: elements in a group have the same number of outer-shell (valence) electrons and similar chemical properties. **Periods** are horizontal rows: the period number equals the number of occupied shells.

The table is divided into **blocks** according to the subshell being filled: the s-block (groups 1–2), the p-block (groups 13–18), the d-block (transition metals, groups 3–12) and the f-block (lanthanoids and actinoids).

Core charge is the attraction the valence electrons feel from the nucleus: core charge = number of protons − number of inner-shell electrons. For main-group elements it equals the number of valence electrons (for example Na: 11 − 10 = +1; Cl: 17 − 10 = +7).

Trends in the periodic table

Property	Across a period (left to right)	Down a group	Reason
Core charge	Increases	Stays the same	More protons, same inner shells

Atomic radius	Decreases	Increases	Across: higher core charge pulls shells in. Down: more shells
Electronegativity	Increases	Decreases	Stronger attraction of nucleus for bonding electrons when core charge is high and radius small
First ionisation energy	Generally increases	Decreases	Outer electron held more tightly across; further from nucleus and shielded down
Metallic character	Decreases	Increases	Metals lose electrons easily; this is easiest with low core charge and large radius
Reactivity	Metals: decreases; non-metals: increases	Metals: increases; non-metals (e.g. halogens): decreases	Metals react by losing electrons; non-metals by gaining them

Electronegativity is the ability of an atom to attract the electrons in a covalent bond towards itself. Fluorine is the most electronegative element. **First ionisation energy** is the energy needed to remove one electron from each atom in a mole of gaseous atoms.

Exam tip: Explaining a trend needs two links: (1) what changes in the atom (core charge or number of shells), and (2) how that changes the attraction between the nucleus and the outer electrons. "Because it is further down the group" earns nothing on its own.

Critical elements and recycling

A **critical element** is one that is essential to modern technology or the economy but whose supply is at risk, because reserves are limited, concentrated in a few countries, or hard to extract. The study design names these groups:

Critical element(s)	Main uses	Why supply is at risk
Helium	Cooling MRI magnets, welding, leak detection	Obtained from natural gas; escapes to space once released

Phosphorus	Fertilisers (phosphate) for food production	Mined from phosphate rock found in only a few countries
Rare-earth elements (e.g. neodymium)	Permanent magnets in wind turbines and electric motors, phone screens	Mining and refining concentrated in few countries; difficult separation
Post-transition metals (e.g. gallium, indium, tin)	Semiconductors, LEDs, touchscreen coatings, solder	Produced as by-products of other ores in small amounts
Metalloids (e.g. silicon, germanium, antimony)	Solar cells, computer chips, fibre optics, flame retardants	High demand; energy-intensive purification

Recycling recovers these elements from discarded products (e-waste) so that less new ore must be mined, reducing environmental damage and protecting future supply.

Check your understanding

Q1.1 (2 marks) State the number of protons, neutrons and electrons in $^{40}Ca^{2+}$.

Q1.2 (2 marks) Write the full subshell electronic configuration for (a) the sulfur atom and (b) the Cu^{2+} ion.

Q1.3 (3 marks) Explain why the atomic radius of chlorine is smaller than that of sodium, even though chlorine has more electrons.

Q1.4 (2 marks) Explain why potassium is more reactive than sodium.

Q1.5 (2 marks) Define the term critical element and explain why recycling indium from old touchscreens is important.

2. Metals and metallic bonding

Metallic bonding and properties of metals

In a metal, atoms release their valence electrons, forming a regular three-dimensional **lattice of cations** surrounded by a **"sea" of delocalised electrons**. **Metallic bonding** is the non-directional electrostatic attraction between the cations and the delocalised electrons.

Property	Explanation using the metallic bonding model
Electrical conductivity	Delocalised electrons are free to move through the lattice when a potential difference is applied
Thermal (heat) conductivity	Delocalised electrons and closely packed vibrating cations transfer kinetic energy quickly
Malleability and ductility	Bonding is non-directional, so layers of cations can slide past each other without the lattice breaking apart
Lustre	Delocalised electrons absorb and re-emit light at the surface
High melting point (most metals)	Strong electrostatic attraction throughout the whole lattice requires a lot of energy to overcome

> **Common mistake:** Saying metals conduct because "ions move". In a solid metal the cations are fixed in the lattice. It is the delocalised electrons that move.

Limitations of the model: it does not explain why melting points vary so widely (mercury is liquid at room temperature, tungsten melts above 3400 °C), why some metals are magnetic, or why conductivity differs between metals.

Determining a reactivity series experimentally

The **reactivity series** ranks metals by how readily they lose electrons. You can build it by reacting metals with water, dilute acid and oxygen, and observing how vigorous the reaction is.

Metal	Cold water	Dilute acid	Oxygen (heating in air)
Potassium, sodium	Vigorous; hydrogen gas and hydroxide form	Dangerously violent (not done)	Burn rapidly
Calcium	Steady bubbling	Vigorous	Burns
Magnesium	Very slow (reacts well with steam)	Rapid bubbling	Burns with bright white flame
Zinc, iron	No reaction (react with steam)	Moderate bubbling	Oxidise slowly when heated
Copper, silver, gold	No reaction	No reaction	Copper forms a black oxide when heated; silver and gold do not react

This gives the order: K > Na > Ca > Mg > Al > Zn > Fe > Sn > Pb > Cu > Ag > Au. Typical equations:

- $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
- $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$
- $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

Common mistake: Using aluminium to judge reactivity in a quick test. Aluminium is coated in a thin, unreactive oxide layer, so it often appears less reactive than it really is.

Metal recycling and the circular economy

In a **linear economy** resources are taken, made into products, used and thrown away. In a **circular economy** materials are kept in use for as long as possible and then recovered and remade, so waste and the need for new raw materials are minimised.

The life cycle of a metal: mining the ore → extraction and refining → manufacturing products → use → collection and recycling → reprocessing into the same or a repurposed product. Recycling metals saves energy (recycled aluminium needs only about 5% of the energy of producing it from bauxite), reduces mining waste and greenhouse gas emissions, and conserves finite ores.

Check your understanding

Q2.1 (2 marks) Use the metallic bonding model to explain why copper is used for electrical

End of free sample

This is 10 of 57 pages.

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