VCE Chemistry Units 3&4 Complete Study Guide

Complete study guide · Units 3&4 · AceGuides

This guide follows the VCAA VCE Chemistry Study Design (accredited from 2023 for Units 1 and 2 and from 2024 for Units 3 and 4). It covers every key knowledge dot point in Unit 3 (How can design and innovation help to optimise chemical processes?) and Unit 4 (How are carbon-based compounds designed for purpose?), plus the student-designed investigation and scientific poster. This study design is in force for 2026. Check the VCAA website each year for any reaccreditation or replacement; if a new study design is released, most of the chemistry here (stoichiometry, redox, equilibrium, organic reactions and spectroscopy) is core content that carries over.

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About this guide

This guide is built to be worked through, not just read. Each section matches a part of the study design, explains every key knowledge point in plain English, shows fully worked examples, and finishes with original exam-style questions. Every answer is in the Worked solutions section near the end, so you can mark your own work.

How to use it

1. Read a section once quickly to see the big picture, then a second time with a pen, rewriting the bold definitions in your own words.
2. Cover the worked examples and try them yourself before reading the solution.
3. Do the "Check your understanding" questions under timed conditions, then mark them strictly against the worked solutions.
4. Keep a "mistakes log": every time you lose a mark, write down why. Re-read it before every SAC and before the exam.
5. In the final three weeks, sit the practice exam in 2 hours 30 minutes (plus 15 minutes reading time) and use the One-page summary for last-minute revision.

How VCE Chemistry Units 3&4 is assessed

Component	What it involves	Contribution to study score
Unit 3 School-assessed Coursework	Two tasks: one for Outcome 1 (fuels, galvanic and fuel cells) and one for Outcome 2 (rates, equilibrium, electrolysis); 40 marks each	20%
Unit 4 School-assessed Coursework	One task each for Outcome 1 (organic structures and reactions) and Outcome 2 (analysis and medicinal chemistry), plus the scientific poster for Outcome 3	30%
End-of-year examination	Written exam covering all of Units 3 and 4, including key science skills	50%

The SAC task types for Outcomes 1 and 2 are chosen by your school from: a comparison and evaluation of practical activities; analysis and evaluation of primary or secondary data; problem-solving with calculations in a real-world context; or analysis of a chemical innovation, case study, socio-scientific issue or media item. Each task type can be used only once across Units 3 and 4, and at least one task must involve sustainability.

The end-of-year exam is 2 hours 30 minutes of writing time plus 15 minutes of reading time. Section A is multiple choice; Section B is short-answer and extended-response questions. You are given the VCE Chemistry Data Book. Always check the current VCAA examination specifications for the exact format.

Suggested 10-week revision plan

Week	Focus	Tasks
1	Fuels, thermochemistry, calorimetry	Section 2 questions; make a formula card
2	Galvanic cells and fuel cells, Faraday's laws	Section 3 questions; practise half-equations daily
3	Rates and equilibrium	Section 4 questions; draw

		five concentration–time graphs
4	Electrolysis, secondary cells, green hydrogen	Section 5 questions; one Unit 3 past-style paper
5	Organic structure and naming	Section 6 questions; naming drills (20 a day)
6	Organic reactions, pathways, food molecules	Section 7 questions; draw a reaction pathway map from memory
7	Laboratory and volumetric analysis	Section 8 questions; titration calculations
8	Instrumental analysis and medicinal chemistry	Sections 9 and 10 questions; spectra drills
9	Mixed revision and investigation skills	Section 11; redo every question in your mistakes log
10	Exam practice	Sit the practice exam under exam conditions; mark it; revise weak areas

Contents

1. Key science skills and the data book
2. Fuels, energy and thermochemistry
3. Galvanic cells and fuel cells
4. Rates and equilibrium
5. Electrolysis and rechargeable cells
6. Organic structure, nomenclature and properties
7. Organic reactions, pathways and food molecules
8. Laboratory and volumetric analysis
9. Instrumental analysis: MS, IR, NMR and HPLC
10. Medicinal chemistry and enzymes
11. The student-designed investigation and scientific poster
12. Exam technique
13. Practice exam
14. Worked solutions
15. Glossary
16. One-page summary

1. Key science skills and the data book

The exam and every SAC test key science skills as well as content. Expect at least one question on experimental design, data analysis or evaluation in every paper.

Key science skills you must be able to do

- Develop a **research question**, state an **aim** and write a testable **hypothesis** ("If… then… because…").
- Identify the **independent variable** (what you change), **dependent variable** (what you measure) and **controlled variables** (what you keep the same).
- Choose suitable equipment and explain why (for example, a volumetric pipette rather than a measuring cylinder for an aliquot).
- Process data: tables, graphs with lines of best fit, gradients, means, and **significant figures**.
- Evaluate data and methods: accuracy, precision, repeatability, reproducibility, validity, errors and uncertainty.
- Use chemical conventions: states in equations, SI units, correct symbols.
- Discuss safety and ethics, including risk assessments and safety data sheets.

Measurement terms (very commonly examined)

Term	Meaning	Example
Accuracy	How close a measurement is to the true value	Experimental ΔH of −1215 kJ mol^{-1} vs data book −1364 kJ mol^{-1} is not very accurate
Precision	How close repeated measurements are to each other	Titres of 16.80, 16.85, 16.75 mL are precise
Repeatability	Same result when the same person repeats with the same method and equipment	Concordant titres in one lab session
Reproducibility	Same result when a different person, method or equipment is used	Another class gets the same K value
Validity	The experiment measures what it claims to measure	Only one variable changed

	(fair test)	
Systematic error	Error that shifts all results the same way; not reduced by repeating	Heat loss in calorimetry always gives a low ΔH
Random error	Unpredictable variation; reduced by repeating and averaging	Reading a meniscus slightly differently
Personal error	A mistake by the experimenter	Spilling some of an aliquot; not included in error analysis, the trial is repeated
Outlier	A result that does not fit the pattern	A rough titre; exclude it with a stated reason

Exam tip: "Repeat the experiment" only improves precision and reduces random error. It never fixes a systematic error. If the question is about accuracy, suggest a change to the method (e.g. insulate the calorimeter, use a lid, calibrate the instrument).

Common mistake: Saying "human error" in an evaluation. VCAA wants the specific error and its effect: "heat lost to the surroundings means less heat is absorbed by the water, so the calculated ΔH is smaller in magnitude than the true value."

Significant figures

Give your final answer to the same number of significant figures as the least precise data given. Keep full values in your calculator during the working and round only at the end. Volumes of burettes and pipettes are read to two decimal places (e.g. 16.80 mL).

Using the data book

The VCE Chemistry Data Book is provided in the exam. Know where to find:

- **Periodic table** with relative atomic masses (H 1.0, C 12.0, O 16.0 and so on).
- **Electrochemical series** (standard reduction potentials, E°, at 25 °C, 100 kPa and 1.0 mol L^{-1}).
- **Physical constants**: Avogadro constant 6.02 × 10^{23} mol^{-1}, Faraday constant F = 96 500 C mol^{-1}, molar volume of an ideal gas at SLC (25 °C, 100 kPa) = 24.8 L mol^{-1}, specific heat capacity of water 4.18 J g^{-1} $°C^{-1}$, density of water about 1.00 g mL^{-1} at 25 °C.
- **Formulas**: n = m/M, n = cV, n = V/V_m, Q = It, n(e^-) = Q/F, q = mcΔT, percentage yield,

atom economy, calibration factor.

- **Heats of combustion** of common fuels and **energy content of food** (carbohydrate, protein, fat).
- **Spectroscopy data**: IR absorption bands, ^{13}C and ^{1}H NMR chemical shifts.
- **Structures of selected organic molecules**: amino acids, fatty acids, vitamins, medicines and biomolecules.
- **Acid–base indicators** with pH ranges and colours.

Exam tip: Values in the data book beat values you remember. If a question says "use the data book", look the value up even if you think you know it.

Common mistake: Using 22.4 L mol^{-1} (the old STP value). In this study design all gas calculations are at SLC: 24.8 L mol^{-1}.

Check your understanding: Section 1

1. A student measures the enthalpy of combustion of propan-1-ol three times and gets −1650, −1660 and −1655 kJ mol^{-1}. The accepted value is −2021 kJ mol^{-1}. Comment on the accuracy and precision of the results. (2 marks)
2. Explain why repeating the experiment in Question 1 would not bring the mean closer to the accepted value. (2 marks)
3. Identify the independent, dependent and one controlled variable in an investigation of how temperature affects the rate of reaction between magnesium ribbon and hydrochloric acid. (3 marks)

2. Fuels, energy and thermochemistry

This section covers Unit 3 Area of Study 1 key knowledge on carbon-based fuels and measuring energy changes.

What is a fuel?

A **fuel** is a substance that releases useful energy when it undergoes a chemical reaction (usually combustion) or a nuclear change. In this study design you focus on chemical fuels.

- **Fossil fuels** (coal, natural gas, petrol) formed from the remains of organisms over millions of years. They are **non-renewable**: they cannot be replaced within a relatively short time.
- **Biofuels** (biogas, bioethanol, biodiesel) are made from recently living biomass. They are **renewable**: the resource can be replaced by natural processes within a relatively short period of time.
- **Renewability** is about whether the resource is replaced quickly. **Sustainability** is broader: whether using it meets present needs without compromising future generations (it includes land use, water, emissions and economics).

Fuel	Source	Main component	Renewable?	Notes
Coal	Fossilised plant matter	Mostly carbon	No	High CO_2 per unit energy; particulates, SO_2
Natural gas	Underground deposits	Methane, CH_4	No	Cleanest-burning fossil fuel; CH_4 leaks are a potent greenhouse gas
Petrol	Fractional distillation of crude oil	C_5–C_{12} alkanes, e.g. octane	No	Liquid, high energy density; easy to transport
Biogas	Anaerobic digestion of waste	CH_4 and CO_2	Yes	Uses waste; lower energy content per litre because CO_2 is present
Bioethanol	Fermentation of	C_2H_5OH	Yes	Blended with

	glucose then distillation			petrol (e.g. E10); uses crops, so competes with food
Biodiesel	Transesterification of plant oils or animal fats	Fatty acid methyl esters	Yes	Biodegradable; more viscous in cold weather

Biofuels are often described as **carbon neutral** because the CO_2 released when they burn was recently absorbed by plants in photosynthesis. In practice they are not fully carbon neutral, because fossil fuels are used for farming, fertiliser, transport and distillation.

Exam tip: When comparing fuels, use specific criteria: energy content (kJ g^{-1} or kJ mol^{-1}), renewability, greenhouse gas emissions, state and ease of transport, cost, land and water use. One clear point per criterion scores better than a vague paragraph.

Photosynthesis, respiration and fermentation

Three equations appear in the study design. Learn them with states.

- **Photosynthesis** converts light energy into chemical energy: $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$. It is endothermic.
- **Cellular respiration** oxidises glucose, the body's main carbohydrate energy source: $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$. It is exothermic and releases about the same energy that photosynthesis stored.
- **Fermentation** by yeast (anaerobic, about 35 °C) produces bioethanol: $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$. The mixture is then **distilled** (fractional distillation) to concentrate the ethanol, because ethanol has a lower boiling point (78 °C) than water.

Fuel sources for the body

The body uses three nutrient classes as fuels, compared in kJ g^{-1}:

Nutrient	Approximate energy content	Role as a fuel
Carbohydrates	16 kJ g^{-1}	Main, fast energy source; glucose oxidised in respiration; stored as glycogen
Proteins	17 kJ g^{-1}	Mainly for growth and repair;

		used for energy only when other sources are low
Fats and oils (lipids)	37 kJ g^{-1}	Most energy-dense; long-term energy store

Fats store more energy per gram because their molecules contain a larger proportion of C–H bonds and fewer oxygen atoms; they are less oxidised to begin with. Use the data book values in the exam.

Exothermic and endothermic reactions

Enthalpy change (ΔH) is the heat energy exchanged with the surroundings at constant pressure.

- **Breaking bonds absorbs energy** (endothermic). **Making bonds releases energy** (exothermic).
- In an **exothermic** reaction more energy is released forming product bonds than is absorbed breaking reactant bonds. ΔH is negative. The surroundings get hotter. Example: all combustion.
- In an **endothermic** reaction more energy is absorbed than released. ΔH is positive. The surroundings get colder. Example: photosynthesis, thermal decomposition of $CaCO_3$.

Units of ΔH matter:

- **kJ**: the actual amount of energy for a stated quantity (e.g. "burning 2.00 g released 99.6 kJ").
- **kJ mol^{-1}**: the molar enthalpy change, matched to the equation as written.
- **kJ g^{-1}**: used for mixtures such as petrol, coal and foods, which have no single molar mass.

Energy profile diagrams plot enthalpy (vertical axis) against reaction progress. Show reactants and products as horizontal lines, the activation energy (E_a) as the rise from reactants to the peak, and ΔH as the difference between products and reactants. For an exothermic reaction the products are lower; for an endothermic reaction they are higher.

Common mistake: Labelling ΔH from the peak to the products. ΔH is always measured from reactants to products; E_a is measured from reactants to the peak.

Thermochemical equations and combustion

A **thermochemical equation** is a balanced equation with states and a ΔH value for the amounts shown.

- **Complete combustion** (excess oxygen): products are $CO_2(g)$ and H_2O. Example: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H = -890$ kJ mol^{-1}.

- **Incomplete combustion** (limited oxygen): products include carbon monoxide, CO(g), and/or soot, C(s), plus water. Example: $2CH_4(g) + 3O_2(g) \rightarrow 2CO(g) + 4H_2O(l)$. Less energy is released per mole of fuel because the carbon is not fully oxidised.

How ΔH scales:

- Double the coefficients, double ΔH. Example: $2CH_4(g) + 4O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$ $\Delta H = -1780$ kJ mol^{-1}.
- Reverse the equation, change the sign of ΔH.
- Water as a liquid gives a more negative ΔH than water as a gas, because condensing steam releases extra energy. Data book heats of combustion assume $H_2O(l)$.

Worked example 2.1: writing a thermochemical equation from data. The heat of combustion of octane is 5460 kJ mol^{-1}. Write the thermochemical equation for the complete combustion of octane.

Step 1: Balance. $C_8H_{18} + O_2 \rightarrow CO_2 + H_2O$. Carbon: $8CO_2$. Hydrogen: $9H_2O$. Oxygen needed: 16 + 9 = 25 atoms, which is 12½ O_2. Double everything to remove the half.

Step 2: $2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$.

Step 3: Two moles of octane react, so $\Delta H = 2 \times (-5460) = -10\,920$ kJ mol^{-1}.

Answer: $2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$ $\Delta H = -10\,920$ kJ mol^{-1}.

> **Exam tip:** The heat of combustion in the data book is a positive number (energy released). When you write ΔH in an equation for combustion it must be negative.

Stoichiometry for combustion: mass, volume and energy

The key relationships (all from the data book):

Quantity	Formula	Units
Amount from mass	$n = m \div M$	mol, g, g mol^{-1}
Amount of gas at SLC	$n = V \div 24.8$	mol, L
Amount in solution	$n = c \times V$	mol, mol L^{-1}, L
Energy released	$E = n \times \Delta H_c$ (or m × energy per gram)	kJ

Gas calculations in this study design are limited to SLC (25 °C and 100 kPa).

Worked example 2.2: mass–volume and energy. 100 g of octane (M = 114.0 g mol^{-1}, ΔH_c =

End of free sample

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