

2019 VCE Chemistry examination report

General comments

Areas of strength in student responses included:

- application of Le Chatelier's principle in equilibrium reactions
- role of coenzymes during catalysis
- calculations of energy content of different foods
- comparison of the sustainability of the use of different energy sources
- electroplating.

Key areas requiring attention include:

- consideration of measurement error – the definitions and use of accuracy, precision, validity, reliability, and uncertainty in VCE Chemistry
- the relationship between chiral centres and stereoisomers, and the difference between stereoisomers and structural isomers
- naming and representation of organic structures
- use of oxidation numbers
- interpretation of Maxwell-Boltzmann distribution curves
- drawing conclusions from experiments.

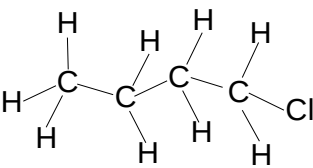
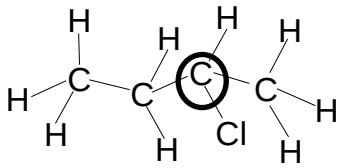
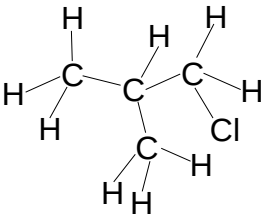
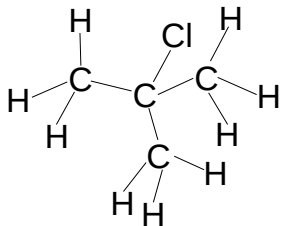
Students are advised to take care when calculating quantities, dealing with dilution factors, applying formulas, using correct units, and determining the number of significant figures in numerical questions.

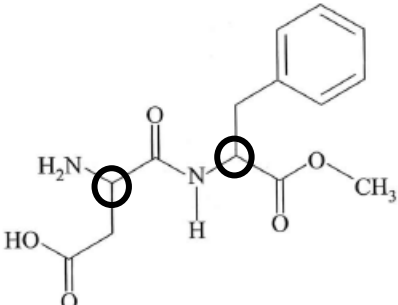
Section A – Multiple-choice questions

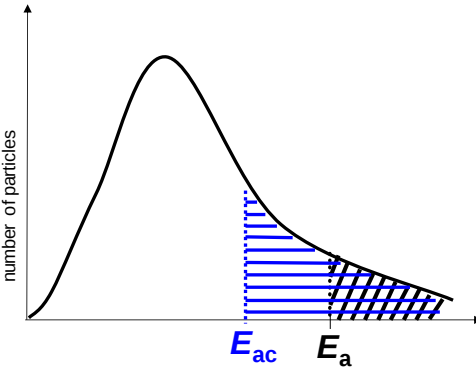
The table below indicates the percentage of students who chose each option. The correct answer is indicated by shading.

Qu.	%A	%B	%C	%D	% N/A	
1	5	6	10	78	0	
2	91	6	2	1	0	
3	2	8	8	83	0	$\text{CH}_3\text{COCH}(\text{CH}_3)_2 \rightarrow \text{C}_5\text{H}_{10}\text{O} \rightarrow \text{M} = 86.0 \text{ g mol}^{-1}$
4	2	8	26	63	0	The selection of sodium ions by some students may reflect confusion between the roles of antioxidants and preservatives in food.
5	26	62	5	7	0	The solution in the LHS half-cell will become darker green by the oxidation of Ni(s) (i.e. $\text{Ni(s)} \rightarrow \text{Ni}^{2+}(\text{aq}) + 2\text{e}^-$).

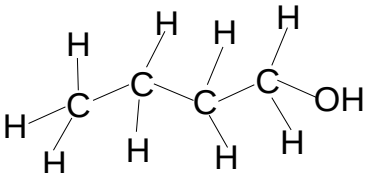
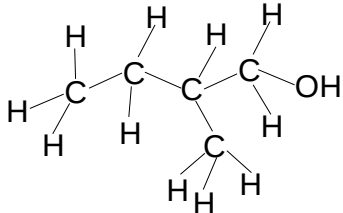
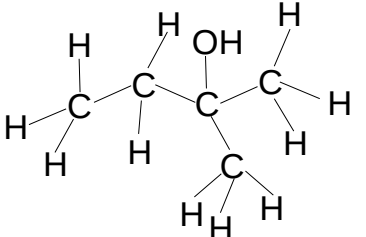
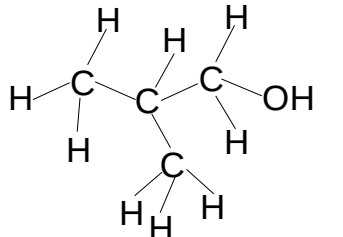
						Ni will be oxidised by oxidising agents that are higher on the electrochemical series (Table 2 Data Book) than the reducing agent Ni(s) (i.e. $\text{Cu}^{2+}(\text{aq})$ and $\text{Pb}^{2+}(\text{aq})$). Metal X could be Cu or Pb. With respect to option B, zinc and cadmium are both stronger reductants than nickel, therefore, solutions of their conjugate oxidising agents will not convert Ni(s) to $\text{Ni}^{2+}(\text{aq})$. The oxidising agents $\text{Cd}^{2+}(\text{aq})$ and $\text{Zn}^{2+}(\text{aq})$ are lower on the electrochemical series than the reducing agent Ni(s).
6	18	59	14	10	0	In the induced fit model, the shape of the active site adjusts to accommodate the shape of the substrate. This will require some adjustment in the tertiary structure of the enzyme. Enzymes catalyse reaction over a narrow temperature range. Options A and C reflect a lack of appreciation of the fundamentals of enzyme properties.
7	20	10	61	9	0	Predictions based on the electrochemical series are most accurate at 25 °C, 1 M solutions and 100 kPa, but the principle of 'strongest oxidising agent reacts with strongest reducing agent' may be utilised to determine the most likely electrode reactions for the molten mixture containing the reducing agents $\text{F}^{-}(\text{l})$ and $\text{Cl}^{-}(\text{l})$, and the oxidising agents $\text{Al}^{3+}(\text{l})$ and $\text{Na}^{+}(\text{l})$. Possible half-reactions at the two electrodes are: Anode (+): $2\text{Cl}^{-}(\text{l}) \rightarrow \text{Cl}_2(\text{g}) + 2\text{e}^{-}$; $2\text{F}^{-}(\text{l}) \rightarrow \text{F}_2(\text{g}) + 2\text{e}^{-}$ Cathode (-): $\text{Na}^{+}(\text{l}) + \text{e}^{-} \rightarrow \text{Na}(\text{l})$; $\text{Al}^{3+}(\text{l}) + 3\text{e}^{-} \rightarrow \text{Al}(\text{l})$ Al^{3+} is a stronger oxidising agent than Na^{+}, so aluminium will be produced at the cathode. Cl^{-} is a stronger reducing agent than F^{-}, so chlorine will be produced at the anode. This is also consistent with the relative positions of the elements on the periodic table. Option A may have been chosen based on the 3:1 ratio of $\text{F}^{-}:\text{Cl}^{-}$ in the mixture undergoing electrolysis.
8	14	51	14	21	0	Reaction is exothermic. Electrons are consumed (during reduction) at the positive electrode; they are released during oxidation at the negative electrode. In fuel cells, the oxidant and reductant are stored outside the cell. The electrodes are in contact with reactants and the electrolyte. Reactive electrodes will need to be replaced in a galvanic cell but fuel cell electrodes are not reactive and do not need regular replacement. Comparing the similarities and differences of different types of electrochemical cells is a common examination question. Thirty-five per cent of students selected an alternative, which suggests that they understood reactants to be stored in a fuel rather than externally and supplied during the production of electrical energy.
9	7	77	9	8	0	Reverse reaction is endothermic. $\Delta H = E(\text{products}) - E(\text{reactants})$ $= 50 \text{ kJ mol}^{-1} - 40 \text{ kJ mol}^{-1}$ $= +10 \text{ kJ mol}^{-1}$
10	7	4	85	4	0	

11	43	35	10	12	0	The combustion of ethanol from a test tube requires that the test tube be gently heated to vaporise the ethanol, which then burns as the open end of the test tube is held to a flame. Adding 2 mL of dilute NaOH will slow down release of ethanol vapour for combustion because ethanol molecules form hydrogen bonds with water molecules. Option B overlooks the fact that a larger exposed surface of ethanol provided by doubling the diameter of the test tube will increase the rate of evaporation of ethanol at the surface and thus increase the rate of the combustion reaction.
12	20	14	12	53	0	A stereoisomer of a compound with molecular formula C_4H_9Cl would arise from the presence of a chiral carbon (i.e. would have a C atom bonded to 4 different atoms or groups of atoms). There are four isomers of C_4H_9Cl:     Only 2-chlorobutane has a chiral carbon. On its NMR spectra it would have 4 C environments and 4 H environments, the same as 1-chloropropane but the peak area ratios on the 1H NMR spectra are different: 3:2:1:3 for 2-chloropropane but 3:2:2:2 for 1-chloropropane. Mass spectrometry would depend on the 2-chlorobutane producing a fragment not evident for any of the other isomers. Infra-red (IR) spectroscopy identifies bond type. All four isomers have the same bonds, although some differentiation might be possible via the fingerprint regions. High-performance liquid chromatography (HPLC) would depend on the presence of a column to which 2-chlorobutane had a significantly different level of attraction compared to the other isomers.
13	20	28	33	19	1	Option A is correct. Since butane is a gas at 25 °C (Table 11 Data Book), its flashpoint must be less than 25 °C. In Option B, a higher flashpoint reflects stronger intermolecular attraction, hence higher viscosity. Option C is incorrect. Since flashpoint relates to the liquid fuels it must be lower than the boiling temperature. Butan-1-ol has stronger intermolecular attraction than butane and will have a higher flashpoint than butane, so Option D is incorrect. Performance on this question suggests that most students were not clear about the relationship between flashpoint and structure and bonding, although the need for an understanding of this is specified in

						the study design. Students should be able to recognise that the intermolecular attraction between butane molecules is significantly weaker than the intermolecular attraction between butan-1-ol molecules.
14	60	16	17	8	0	Fat-soluble due to the long hydrocarbon chain – $[\text{CH}_2\text{CH}=\text{CH}(\text{CH}_3)\text{CH}]_{10}\text{H}$ Non-essential vitamins can be manufactured in the body.
15	15	32	35	18	0	Aspartame has two chiral centres:  Associated with each chiral centre are two optical isomers. Hence, aspartame has four optical isomers. Optical isomers are stereoisomers and a molecule with two chiral centres can have four stereoisomers. The maximum number of stereoisomers of a molecule is 2^n where n is the number of chiral centres. The selection of Option B suggested many students were not aware of the relationship between chiral centres and stereoisomers. The selection of Option D suggests that some students were not aware that there is a significant difference between structural isomers and stereoisomers.
16	17	24	18	39	2	$n(\text{H}_2) = 0.263 / 2.0 = 0.13 \text{ mol}$ $n(\text{C}=\text{C}) = 0.13 \text{ mol}$ $n(\text{fatty acid}) = 0.13 / X$ (where X is the number of $\text{C}=\text{C}$ in each molecule) $M(\text{fatty acid}) = m / n = 10 / (0.13 / X) = 10X / 0.13$ $M(\text{fatty acid}) = 76 X$ $X = M(\text{fatty acid}) / 76$ (X is a whole number) $282 / 76 = 3.7$ $278 / 76 = 3.7$ $312 / 76 = 4.1$ $304 / 76 = 4$ Alternatively, calculate n of each fatty acid and check $n(\text{H}_2) / n(\text{acid})$ is a whole number. $n(\text{arachidonic acid}) = 10.0 / 304 = 0.0329$ $n(\text{H}_2) / n(\text{arachidonic}) = 0.1315 / 0.0329 = 4$ Most students either did not settle on an effective method of identifying the fatty acid or did not persist to find a whole number ratio for $n(\text{H}_2) / n(\text{acid})$.
17	3	78	14	5	0	Oxidation at the anode, the Cu electrode: $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$ Reduction at the cathode, the location of shoe: $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$ Hence, the shoe is coated with copper metal at the cathode.

18	24	38	16	21	0	$E_{\text{cell}} = E^{\circ}(\text{oxidising agent half-cell}) - E^{\circ}(\text{reducing agent half-cell})$ A. $E[\text{Ni}^{2+}(\text{aq})/\text{Ni}(\text{s})//\text{Zn}^{2+}(\text{aq})/\text{Zn}(\text{s})] = -0.25 \text{ V} - (-0.76 \text{ V}) = 0.51 \text{ V}$ B. $E[(\text{H}^{+}(\text{aq})/\text{H}_2(\text{g}))/\text{Fe}^{2+}(\text{aq})/\text{Fe}(\text{s})] = 0.0 \text{ V} - (-0.44 \text{ V}) = 0.44 \text{ V}$ C. $E[\text{Ag}^{+}(\text{aq})/\text{Ag}(\text{s})//\text{Cu}^{2+}(\text{aq})/\text{Cu}(\text{s})] = -0.80 \text{ V} - (-0.34 \text{ V}) = 0.46 \text{ V}$ D. Since one half-cell is just an inert electrode in water, this cell would not be expected to generate a voltage. While there are half-cells on the electrochemical series in which water acts as an oxidising agent or reducing agent, these half-cells contain acidic or alkaline solutions (e.g. $\text{O}_2(\text{g}), \text{H}^{+}(\text{aq}) / \text{H}_2\text{O}(\text{l})$ and $\text{H}_2\text{O}(\text{l}) / \text{H}_2(\text{g}), \text{OH}^{-}(\text{aq})$). The popularity of Option B suggests that many students may have considered the relative half-cell potentials of $\text{Cl}_2(\text{g})/\text{Cl}^{-}(\text{aq})$ or $\text{O}_2(\text{g}), \text{H}^{+}(\text{aq})/\text{H}_2\text{O}(\text{l})$ as pertinent to the half-cell containing 1.0 M $\text{HCl}(\text{aq})$.
19	2	5	73	20	0	Statement 1 is incorrect; lactose intolerant people do not produce enough lactase. Statements 2 and 3 are correct. Statement 4 is incorrect; lactose hydrolyses into glucose and galactose. Students who selected Option D may have based their answer on the structure of lactose given in the Data Book. However, lactose hydrolyses into glucose and galactose molecules.
20	7	24	12	56	1	$K = [\text{SO}_2]^3 / [\text{SO}_3]^2[\text{O}_2]$ $[\text{SO}_3]^2 = K \times [\text{SO}_2]^3 / [\text{O}_2]$ $= 1.75 \times (0.12^2 \times 0.16)$ $= 4.03 \times 10^{-3}$ $[\text{SO}_3] = \sqrt{4.03 \times 10^{-3}}$ $= 6.3 \times 10^{-2} \text{ M}$ Option B was consistent with not following through to the last step of finding the square root.
21	15	13	14	58	0	The shape or position of the original distribution curve is not affected by the presence of a catalyst. However, the activation energy is lowered. The diagram represents the impact of a catalyst on activation energy and the proportion of collisions that are successful. The activation energy is decreased from E_a to E_{ac}.  The shaded areas under the graph represent the proportion of collisions that are successful. In the presence of a catalyst the

						activation energy, E_{ac}, is lower and the rate of reaction increases due to a larger proportion of collisions that are successful. The popularity of the incorrect alternatives suggests scope for improvement in understanding the information conveyed in Maxwell-Boltzmann distribution curves.
22	30	12	18	40	0	Precise results may be biased because even though they are close together they may have been obtained from a preferred sample and not reflect the true characteristics of the substance under analysis. Sensitive instruments should give more accurate measurements, but may be subject to random error associated with environmental fluctuations. The method must be appropriate for the analysis to be valid. Repeating a procedure using the same equipment will not remove the uncertainty associated with systematic errors. Systematic errors are consistent repeatable errors associated with faulty equipment or flaws in experimental method or design. As well as significant issues with understanding of systematic errors, performance on this question suggests a lack of a common understanding of the best descriptions of precision, accuracy, uncertainty, validity, etc. as they apply to VCE Chemistry.
23	4	47	15	34	0	A. ΔH for an endothermic reaction is > 0 (i.e. positive) B. Correct, energy is released as a gas condenses; this process is exothermic. C., D. $\Delta H = E(\text{products}) - E(\text{reactants})$ The decision by 47 per cent of the students that activation energy is directly involved in the determination of the enthalpy change, ΔH, for a reaction suggests a need for better understanding of energy profiles. It appears that some students were not aware that condensation is an energy-releasing process.
24	57	7	18	17	1	Metal ions present in the solutions are Ag^+, Cd^{2+}, Pb^{2+}, Al^{3+}. $n(\text{metal produced}) = n(e^-) / \text{charge on ion}$ $n(e^-) = Q/F = It / F = 3 \times 60 \times 60 / 96500$ $= 0.12 \text{ mol}$ $n(\text{Ag}) = 0.12 \text{ mol}$, $m(\text{Ag}) = 0.12 \times 107.9 = 13 \text{ g}$ $n(\text{Cd}) = 0.06 \text{ mol}$, $m(\text{Cd}) = 0.06 \times 112.4 = 6.8 \text{ g}$ $n(\text{Pb}) = 0.06 \text{ mol}$, $m(\text{Pb}) = 0.06 \times 207.2 = 12.4 \text{ g}$ $n(\text{Al}) = 0.04 \text{ mol}$, $m(\text{Al}) = 0.04 \times 27.0 = 1.1 \text{ g}$ but for 1 M solutions at 25°C, Al(s) will not be produced because $\text{H}_2\text{O(l)}$ is a stronger oxidant than $\text{Al}^{3+}(\text{aq})$. Selecting Option C was consistent with not taking into account the charge on the ions. Students who chose Option D may have simply defaulted to the highest ion charge as the basis of their selection.
25	59	6	29	5	0	Since the concentration of P increases as a result of the temperature increase, it must be produced when the equilibrium mixture is heated, while Q and R, which both decrease in concentration, must be consumed. The change in concentration of Q is twice the changes in concentration of P and R, hence the favoured reaction is $2\text{Q(g)} + \text{R(g)} \rightarrow \text{P(g)}$, which is endothermic. This is consistent with the equilibrium

						$P(g) \rightleftharpoons 2Q(g) + R(g)$, $\Delta H < 0$ (i.e. forward reaction is exothermic) Students who selected Option C identified the correct reaction but did not correctly identify that the formation of P was an endothermic process.
26	14	22	51	12	2	Calorimeter constant = $E / \Delta T$ $= VIt / \Delta T$ $= 6.5 \times 3.6 \times 4.0 \times 60 / 0.48$ $= 1.17 \times 10^4 \text{ J } ^\circ\text{C}^{-1}$ Energy released by 4.20 g sucrose = $1.17 \times 10^4 \text{ J } ^\circ\text{C}^{-1} \times 6.2 ^\circ\text{C}$ $= 7.25 \times 10^4 \text{ J}$ Energy per gram of sucrose = $7.25 \times 10^4 / 4.20$ $= 1.7 \times 10^4 \text{ J g}^{-1}$ Students who selected C had completed the first two steps accurately but did not proceed to divide by the mass of sucrose even though the unit 'joules per gram' was stated in the question.
27	9	34	35	22	1	A. 4 carbon environments  B. 5 carbon environments  C. 4 carbon environments  D. 3 carbon environments  Both butan-1-ol ($\text{C}_4\text{H}_{10}\text{O}$) and 2-methylbutan-2-ol ($\text{C}_5\text{H}_{12}\text{O}$) will show four distinct peaks on their ^{13}C NMR spectra. $M(\text{C}_4\text{H}_{10}\text{O}) = 74.0 \text{ g mol}^{-1}$ $M(\text{C}_5\text{H}_{12}\text{O}) = 88.0 \text{ g mol}^{-1}$ Students who selected Options B or D did not accurately identify the number of carbon environments in the associated molecules. This may have been due to not referring to, or inaccurate, structural formulae.
28	15	58	14	13	1	$K_c = 1.0 \times 1.0^4 / (1.0 \times 1.0^2) = 1.0 \text{ M}^2$ $K_c = [\text{NH}_3]^2 / ([\text{N}_2][\text{H}_2]^3) = 1.0^2 / (1.0 \times 1.0^3) = 1.0 \text{ M}^{-2}$ $K_c = 1.0^2 / (1.0 \times 1.0) = 1.0$ $K_c = 1.0 / 1.0^2 = 1.0 \text{ M}^{-1}$ Many students were unable to determine the correct unit for K.
29	15	23	37	25	1	A. Adding less water to the conical flask has no effect on $V(\text{titre})$, since $n(\text{I}_2)$ required to react with vitamin C is not affected.

						B. If the $c(I_2)$ was recorded as higher than the true value, the calculated $n(I_2)$ in the titre, the calculated $n(\text{vitamin C})$ in 5.0 mL grapefruit juice, and consequently calculated $c(\text{vitamin C})$ will be overestimated. C. If the initial volume in the burette is read as higher than true the calculated $V(\text{titre})$ (i.e. final volume), initial volume will be lower than the true value so the calculated $n(I_2)$ in the titre, the calculated $n(\text{vitamin C})$ in 5.0 mL grapefruit juice and consequently the calculated $c(\text{vitamin C})$ will be underestimated. D. If the recorded $m(\text{grapefruit juice})$ was lower than the true value, this would have no effect on the titration data, but since the determination of % m/m requires division by a lower than true number, the calculated $c(\text{vitamin C})$ will be overestimated. This question required the ability to see through the steps in the calculation of concentration and decide where and how the errors would have impacted on the final answer. This can be a time consuming exercise, which may have affected performance.
30	11	39	38	11	1	$n(I_2) = c(I_2) \times V(\text{titre}) = 9.367 \times 10^{-4} \times 21.50 \times 10^{-3}$ $= 2.01 \times 10^{-5} \text{ mol}$ $n(C_6H_6O_6) = n(I_2) = 2.01 \times 10^{-5} \text{ mol}$ $m(C_6H_6O_6) = 2.01 \times 10^{-5} \text{ mol} \times 176.0 \text{ g mol}^{-1}$ $= 0.00354 \text{ g}$ $c(C_6H_6O_6) - \% \text{ m/m} = [m(C_6H_6O_6) / m(\text{grapefruit juice})] \times 100$ $= (0.00354 / 4.90) \times 100$ $= 0.0723 \%$ Option C was consistent with adjusting the accurately calculated mass of vitamin C to the mass in 100 grams of grapefruit juice without considering the actual mass of the sample analysed.

Section B

Asterisks (*) are used for some questions to show where marks were awarded

Question 1a.

Marks	0	1	Average
%	38	62	0.6

One of:

- carboxyl and amino functional groups attached to the same C atom
- $-\text{COOH}$ and $-\text{NH}_2$ / $-\text{NH}$ attached to the same C atom
- $\text{H}_2\text{NCHXCOOH}$ or diagram of same
- amino ($-\text{NH}_2$) functional group attached to second C atom (C-2)

Considering that the wording of the question asked for one structural feature, the presence of $-\text{NH}_2$ or $-\text{COOH}$ or similar was also accepted. A few responses suggested the presence of a chiral carbon, which, while true for most alpha amino acids, is not the case for glycine.

Question 1bi.

Marks	0	1	Average
%	33	67	0.7

Hydrolysis reaction.*

Question 1bii.

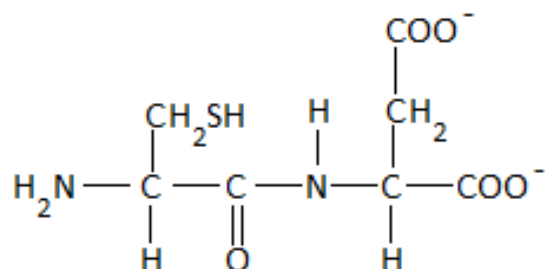
Marks	0	1	Average
%	62	38	0.4

Condensation reaction.*

Most responses overlooked what might have been expected to be the obvious chemical process of protein production via condensation reaction between amino and carboxyl groups.

Question 1biii.

Marks	0	1	2	Average
%	39	40	21	0.8



One mark was awarded for correctly drawn out peptide (amide) group.

One mark was awarded for the rest of the structure being correct, including both carboxyl groups deprotonated.

Most errors on this question related to inaccurate representation of either the deprotonated carboxyl groups or the peptide link.

Question 1c.

Marks	0	1	2	Average
%	29	22	50	1.2

Palmitic acid.

In palmitic acid, a saturated fatty acid, molecules have increased/stronger intermolecular forces, have more dispersion forces between molecules, and are more closely packed than in palmitoleic acid, so more energy is required to separate the molecules.

In palmitoleic acid, a mono-unsaturated fatty acid, a kink is present within the structure of molecules due to the C=C double bonds, so the molecules do not pack together as closely as palmitic acid molecules. Intermolecular and dispersion forces are weaker, so less energy is required to separate molecules.

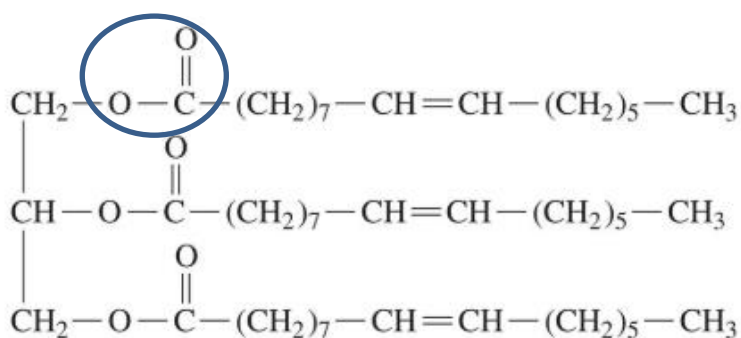
One mark was awarded for identifying the correct fatty acid. One mark was awarded for relating relative melting temperatures to the intermolecular attraction/packing.

This question was relatively well handled, although there were responses that apparently incorrectly considered the relative ease of breaking C=C double bonds and C-C single bonds to be a factor in intermolecular attraction.

Question 1d.

Marks	0	1	2	Average
%	48	28	24	0.8

Ester group

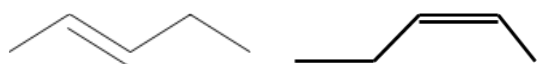


One mark was awarded for the correct semi-structural formula. One mark was awarded for correctly circling and labelling the functional group.

The main errors in the responses to this question were to do with connectivity in the structure. Incorrect representations of the ester group bonding in a triglyceride and/or the hydrocarbon chain were common. The structure of glycerol and semi-structural formula of palmitoleic acid were given in the Data Book and students should be aware of the outcome of reaction between an -OH group on glycerol and the -COOH group on the fatty acid. In some responses the correct structure was shown but the functional group was not labelled.

Question 2ai.

Marks	0	1	Average
%	26	74	0.8



Strong performance on this question indicated skeletal structures are well appreciated.

Question 2aii.

Marks	0	1	Average
%	43	57	0.6

Pentan-2-ol/2-pentanol

Chemical names must be spelt and represented accurately.

Question 2aiii.

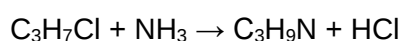
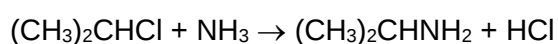
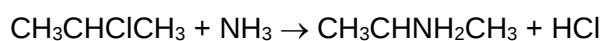
Marks	0	1	Average
%	63	37	0.4

 $\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}_3$

Students should know the outcome of oxidation of alcohols and that secondary alcohols are oxidised to ketones. Answers that showed an aldehyde or carboxylic acid suggested this is an area with significant room for improvement, along with writing the semi-structural formula of a ketone.

Question 2bi.

Marks	0	1	Average
%	56	44	0.5



This question was based on the expected knowledge associated with organic reaction pathways, with many responses impacted by incorrect formulae, lack of HCl or atom imbalance.

Question 2bii.

Marks	0	1	Average
%	58	42	0.4

Propan-2-amine/2-propanamine

The production of amines from chloroalkanes should be known by most students.

Question 2biii.

Marks	0	1	Average
%	29	71	0.7

Substitution reaction.

Question 2biv.

Marks	0	1	2	Average
%	34	13	54	1.2

$$\begin{aligned}
 \% \text{ atom economy} &= (\text{mass of product} / \text{total mass of reactants}) \times 100 \\
 &= [M(\text{C}_3\text{H}_7\text{NH}_2) / M(\text{C}_3\text{H}_7\text{Cl} + \text{NH}_3)] \times 100\% * \\
 &= [59.0 / (78.5 + 17.0)] \times 100\% \\
 &= 61.8\% (62\%) *
 \end{aligned}$$

One mark was awarded for accurately using the correct relationship.

One mark was awarded for the correct answer.

The relationship for determining atom economy was in the Data Book.

Question 3a.

Marks	0	1	2	Average
%	24	23	53	1.3

Exothermic *

- Lower absorbance at 80 °C indicates there is a smaller amount of $\text{Co}^{2+}(\text{aq})$, a product, at the higher temperature, and a larger amount of $\text{Co}^{2+}(\text{aq})$, a product, at the lower temperature, so the forward reaction is exothermic.
- Higher absorbance at 30 °C indicates there is more $\text{Co}^{2+}(\text{aq})$ at the lower temperature, so forward reaction is favoured at the lower temperature and is exothermic.
- Absorbance is proportional to the concentration of Co^{2+} and the graph indicates that a smaller amount of products are formed at high temperatures, and a larger amount of products at lower temperatures, hence forward reaction is exothermic.

One mark was awarded for 'exothermic'.

One mark was awarded for a suitable reason with reference to the absorbance graph.

This question was generally well handled, although some responses were affected by lack of even indirect reference to the graph provided.

Question 3b.

Marks	0	1	2	Average
%	54	34	12	0.6

The final colour is darker than just after the water was added but lighter than the colour at the initial equilibrium, and not quite as pink as before the change (between the diluted colour and original colour). Adding water decreases the concentration of all species. The system partially opposes this change, favouring the reaction producing more particles in aqueous solution, the forward reaction ($1 \text{ mol} \rightarrow 5 \text{ mol}$).

Concentration of $\text{Co}^{2+}(\text{aq})$ at the new equilibrium is less than prior to the addition of water but greater than after dilution. *

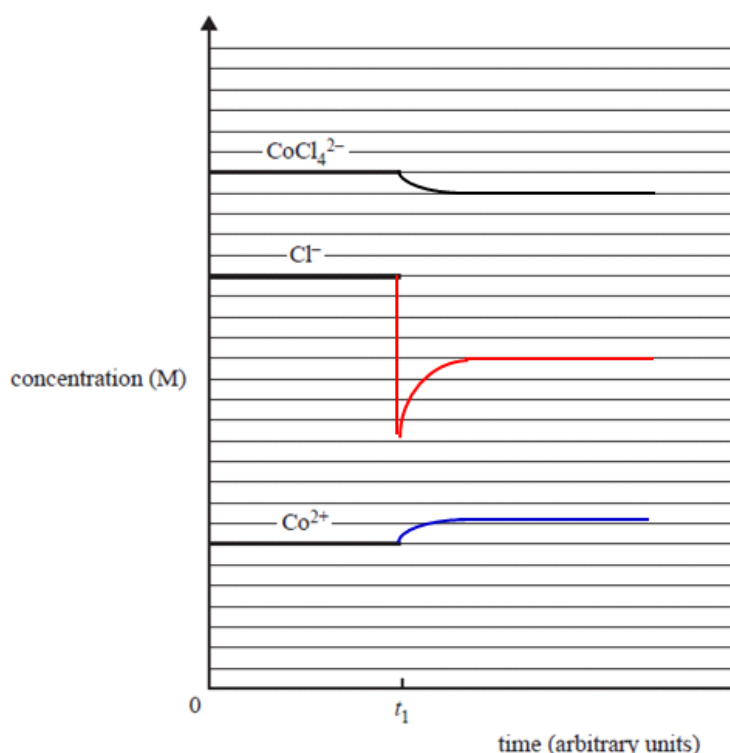
One mark was awarded for recognition that the final colour is **between** the colours of the initial and diluted solutions. One mark was awarded for explaining the colour change in terms of Le Chatelier's principle.

Most responses to this question did not adequately describe the outcome of the change based on the system 'partially' compensating as it returns to equilibrium so that, as a result of dilution, the colour becomes lighter, then darker, but not as dark as it was prior to dilution.

Dilution decreases the concentration of all species in the reaction, so the system responds, favouring the reaction that produces more particles in order to increase overall concentration.

Question 3c.

Marks	0	1	2	3	Average
%	38	37	18	7	1



One mark was awarded for initial change at t_1 – decrease in concentration of chloride ions **only** (no change to concentrations of Co^{2+} and CoCl_4^{2-}).

One mark was awarded for the correct shape for increasing concentrations of Cl^- and Co^{2+} and decreasing concentration of CoCl_4^{2-} as the system compensates for the sudden decrease in $[\text{Cl}^-]$. One mark was awarded for correct changes in concentrations for all reactants and products that a system returns to and reaches equilibrium again at the same point of time. The curve of chloride and cobalt ions should increase by $4x$ and x respectively and the curve of CoCl_4^{2-} decreases by x .

Practical experience with concentration-time graphs is important. It may be that some students were not aware that adding $\text{Ag}^+(\text{aq})$ would precipitate AgCl out of the solution.

Question 4a.

Marks	0	1	2	3	Average
%	33	11	23	33	1.6

$$M(\text{C}_8\text{H}_{18}) = 114.0 \text{ g mol}^{-1}; M(\text{C}_2\text{H}_5\text{OH}) = 46.0 \text{ g mol}^{-1}$$

$$1 \text{ mol C}_8\text{H}_{18} + 1 \text{ mol C}_2\text{H}_5\text{OH} = 114.0 + 46.0 = 160.0 \text{ g fuel}$$

80 g of fuel mix contains 0.50 mol C_8H_{18} and 0.50 mol $\text{C}_2\text{H}_5\text{OH}$ *

$$\begin{aligned} \text{Energy released} &= 0.50 \text{ mol} \times 5460 \text{ kJ mol}^{-1} + 0.50 \text{ mol} \times 1360 \text{ kJ mol}^{-1} * \\ &= 2730 + 680 \text{ kJ} \\ &= 3.4 \times 10^3 \text{ kJ} * (3410 \text{ kJ}) (3411 \text{ kJ}) \end{aligned}$$

Alternatively:

$$m(\text{C}_8\text{H}_{18}) = (114/160) \times 80 = 57 \text{ g}$$

$$m(\text{C}_2\text{H}_5\text{OH}) = (46/160) \times 80 = 23 \text{ g}$$

$$\begin{aligned} \text{Energy released} &= 57 \text{ g} \times 47.9 \text{ kJ g}^{-1} + 23 \text{ g} \times 29.6 \text{ kJ g}^{-1} \\ &= 3.4 \times 10^3 \text{ kJ} \end{aligned}$$

Intuitive:

$$\text{Energy from 160 g fuel (1 mol C}_8\text{H}_{18} + 1 \text{ mol C}_2\text{H}_5\text{OH}) = 5460 + 1360 = 6820 \text{ kJ}$$

$$\text{Energy from 80 g fuel} = 6820 / 2 = 3.4 \times 10^3 \text{ kJ}$$

One mark was awarded for calculating moles or mass of each compound in 80 g of the fuel blend. One mark was awarded for the correct use of heats of combustion of both compounds. One mark was awarded for the correct answer.

The most common approach was to try to determine the mass of each fuel in 80 g of the mixture and using the heats of combustion in kJ g^{-1} . However, there were some relatively common errors, such as incorrectly calculating the mass of each fuel in the mixture, adding the heats of combustion (kJ g^{-1}) and multiplying by the mass of the mixture, and inaccurate use or application of units.

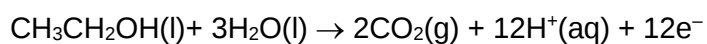
Question 4bi.

Marks	0	1	Average
%	30	70	0.7

Anode

Question 4bii.

Marks	0	1	Average
%	79	21	0.2

**Question 4biii.**

Marks	0	1	2	Average
%	26	41	33	1.1

Acceptable advantages included:

- Fuel cells are inherently more efficient than internal combustion engines and so produce less CO_2 .
- Ethanol can be produced renewably.
- Bioethanol is closer to carbon neutral than fossil fuels.
- Ethanol reacts more cleanly than fossil fuels (less carbon monoxide, other gases and particulates).
- Fuel cells produce less total greenhouse gases/pollutants.
- Fuel cells are quieter.

One mark was awarded for each of two advantages.

This question was generally well handled.

Question 5ai.

Marks	0	1	Average
%	30	70	0.7

 0.30 g L^{-1}

Question 5aii.

Marks	0	1	2	Average
%	71	19	11	0.4

Diluted soft drink solution (100 mL containing 5.0 mL of soft drink) is diluted by a factor of 25 (10 mL into 250 mL) for testing in HPLC.

$$c(\text{sucrose}) \text{ in tested sample} = 0.30 \text{ g L}^{-1}$$

$$\begin{aligned} c(\text{sucrose}) \text{ in 100 mL solution made from soft drink} &= 25 \times 0.30 \\ &= 7.5 \text{ g L}^{-1} * \end{aligned}$$

$$\begin{aligned} m(\text{sucrose}) \text{ in 5.0 mL soft drink} &= m(\text{sucrose}) \text{ in 100 mL solution} \\ &= (7.5 / 1000 \times 100) \\ &= 0.75 \text{ g} \end{aligned}$$

$$\begin{aligned} \% \text{ (m/V) sucrose in origin} &= (0.75 \text{ g} / 5.0 \text{ mL}) \times 100 \\ &= 15\% * \end{aligned}$$

Alternatively:

Original soft drink had been diluted by 20 (5 mL → 100 mL) then 25 (10 mL → 250 mL)

$$\begin{aligned} c(\text{sucrose}) \text{ in original soft drink} &= 0.30 \text{ g L}^{-1} \times 20 \times 25 \\ &= 150 \text{ g L}^{-1} \end{aligned}$$

$$m(\text{sucrose}) \text{ in 100 mL of soft drink} = 15 \text{ g} \rightarrow 15\% \text{ (m/V)}$$

One mark was awarded for the correct sucrose concentration.

One mark was awarded for the correct % (m/V), consistent with answer to Question 5ai.

Question 5aiii.

Marks	0	1	Average
%	70	30	0.3

$$\begin{aligned} m(\text{sucrose}) &= [\%(\text{m/V})/100] \times V(\text{drink}) \\ &= [15 / 100] \times 330 \\ &= 50 \text{ g (49.5 g)} \end{aligned}$$

While answered better than Question 5aii., many responses incorrectly converted 330 mL to 0.330 L and multiplied that by the answer to Question 5aii.

Question 5b.

Marks	0	1	Average
%	90	10	0.1

Acceptable responses included:

- The method is valid as data is consistent for standard solutions of different concentrations made up from pure sucrose.
- The conditions used in the HPLC were consistent across all the standards and the soft drink solution.
- Peak areas for the standard solutions and the diluted soft drink sample were recorded at the same retention time (of sucrose).
- The method is **invalid** because not enough points were established from zero glucose through to 0.80 g L⁻¹ glucose.

This question was not well handled. Many responses did not refer in any way to the validity of the method used. Each part of the experiment should have produced reliable results because the same conditions were applied for each standard solution and for the diluted soft drink sample.

Superficial responses along the lines of 'it is valid because a result was obtained' were common.

Question 5c.

Marks	0	1	2	3	Average
%	42	37	15	6	0.9

Metabolic reactions:

- Sucrose hydrolyses to glucose and fructose / $C_{12}H_{22}O_{11} \rightarrow 2 C_6H_{12}O_6$
- Aspartame hydrolyses to Phenylalanine, Aspartic acid and methanol
- Glucose oxidises in respiration / $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$
- Glucose undergoes condensation polymerisation to form glycogen
- Excess glucose from sucrose can be converted to fat causing weight gain. This is not an issue with Aspartame.

Glycaemic indices:

- Rapid increase in blood sugar levels from sucrose due to high GI. Can make it hard to control diabetes due to insulin variations.
- Aspartame does not raise blood sugar levels since it does not produce glucose.
- Sucrose is useful where a quick energy burst is required. Aspartame releases energy more slowly via different pathways.

Energy content:

- Aspartame has the same energy content per gram as sucrose but is 180 times as sweet; therefore, significantly less aspartame is required for the same effect. This reduces overall energy intake.

Full marks were awarded for a correct point in each category.

The differences in metabolic reactions were addressed infrequently, and when they were, misconceptions such as 'aspartame hydrolysis is faster hence has a high GI' were common. Confusion between energy content and relative sweetness was evident in responses that suggested that 'because aspartame is sweeter than sucrose and less is used in food it has a higher energy content'. Higher-scoring responses identified relative digestion products and linked the lower GI of aspartame with it not releasing glucose as a digestion product.

Question 6a.

Marks	0	1	Average
%	38	62	0.6

Energy = protein + fats/oils
 $= 9.1 \text{ g} \times 17 \text{ kJ g}^{-1} + 2.5 \text{ g} \times 37 \text{ kJ g}^{-1}$
 $= 154.7 + 92.5$
 $= 2.5 \times 10^2 \text{ kJ (247 kJ)}$

Question 6b.

Marks	0	1	Average
%	16	84	0.9

Lock and key/induced fit

Question 6c.

Marks	0	1	Average
%	68	32	0.3

Secondary and tertiary (and quaternary) structures break down as bonds are weakened by increasing temperature.

Many responses demonstrated a strong understanding of disruption of the tertiary structure but did not refer to the secondary (or quaternary) structures. Denaturation does not impact on the primary structure.

Question 6di.

Marks	0	1	Average
%	44	56	0.6

Glycogen

Question 6dii.

Marks	0	1	2	Average
%	40	28	33	1

Amylose has a more linear (unbranched) structure, whereas amylopectin has a more branched structure.

Amylopectin branching provides a greater surface area for enzyme access and action leading to faster hydrolysis (breakdown) into glucose (blood sugar) and a higher GI.

One mark was awarded for describing the difference in structure (amylopectin branched structure).

One mark was awarded for linking amylopectin structure to hydrolysis/enzyme activity and higher GI.

The key structural difference between amylose and amylopectin was accurately identified in most cases, but explaining how that difference leads to different GI values proved more challenging.

Question 6e.

Marks	0	1	Average
%	63	37	0.4

In omega-3 fatty acids a C=C double bond starts at the third C atom from the omega carbon/end of the hydrocarbon chain/terminal methyl group/end away from the carboxyl group.

Responses referring simply to the 'third carbon from the end' were not accepted. Clear indication that it was from the omega end of the molecule was required.

Question 6fi.

Marks	0	1	2	Average
%	35	44	22	0.9

$$\begin{aligned}
 \text{Energy transferred to water} &= SHC \times m(\text{H}_2\text{O}) \times \Delta T \\
 &= 4.18 \times 200 \times 6 \\
 &= 5.02 \times 10^3 \text{ J (5.02 kJ) *}
 \end{aligned}$$

$$\begin{aligned}
 \text{Mass of bread} &= \text{energy} / \text{energy per gram of bread} \\
 &= 5.02 \text{ kJ} / (1000/100) \text{ kJ g}^{-1} \\
 &= 0.5 \text{ g} * (1 \text{ sig fig})
 \end{aligned}$$

One mark was awarded for accurate energy calculation.

One mark was awarded for accurate m(bread).

Question 6fii.

Marks	0	1	Average
%	63	37	

$$\begin{aligned}
 \% \text{ Efficiency} &= (\text{energy absorbed by water} / \text{energy released by bread sample}) \times 100 \\
 &= (\text{energy released by 0.5 g bread} / \text{energy released by 1.2 g bread}) \times 100 \\
 &= [(0.5 \text{ g} \times 10 \text{ kJ g}^{-1}) / (1.2 \text{ g} \times 10 \text{ kJ g}^{-1})] \times 100 \\
 &= (0.5 / 1.2) \times 100 \\
 &= 4 \times 10^1 \% * (1 \text{ sig fig})
 \end{aligned}$$

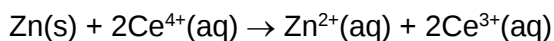
Alternatively:

$$\% \text{ efficiency} = [m(\text{bread}) \text{ used in calorimeter} / m(\text{bread}) \text{ used in different method}] \times 100$$

The efficiency was determined from the ratio of the m(bread) used in the calorimeter / m(bread) used in the 'different' method.

Question 7a.

Marks	0	1	Average
%	57	43	



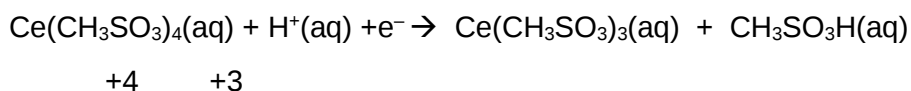
In responding to this question, it was important to recognise that the half-equations provided were in the opposite order to what they would be on the electrochemical series. Ineffective simplification of the overall equation, for example not cancelling common species such as $\text{CH}_3\text{SO}_3\text{H}$, often led to atom imbalance.

Question 7b.

Marks	0	1	2	Average
%	49	27	23	

Oxidising agent is $\text{Ce}(\text{CH}_3\text{SO}_3)_4 / \text{Ce}^{4+}$

Oxidation number of Ce decreases from +4 [in $\text{Ce}(\text{CH}_3\text{SO}_3)_4$] to +3 [in $\text{Ce}(\text{CH}_3\text{SO}_3)_3$] or $\text{Ce}(\text{CH}_3\text{SO}_3)_4$ is reduced according to



One mark was awarded for the correct oxidising agent.

One mark was awarded for accurate justification using oxidation numbers.

Performance on this question was impacted by errors in part a. and lack of, or superficial, reference to the role of oxidation numbers.

Question 7c.

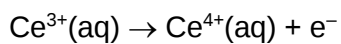
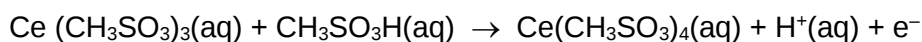
Marks	0	1	Average
%	34	66	0.7

$$\begin{aligned}
 E_{\text{cell}} &= E^{\circ}(\text{oxidant}) - E^{\circ}(\text{reductant}) \\
 &= 1.64 - (-0.76) \\
 &= 2.40 \text{ V}
 \end{aligned}$$

Cell voltages are not negative.

Question 7d.

Marks	0	1	Average
%	74	26	0.3



Errors in previous parts of Question 7 clearly influenced responses to this part. During recharging the positive electrode is the anode, hence the site of oxidation.

Question 7e.

Marks	0	1	Average
%	61	39	0.4

Acceptable responses included:

- to prevent the oxidant and reductant from coming into direct contact
- to prevent a spontaneous redox reaction occurring when the reductant and oxidant come into contact with each other
- to separate the two half-cells
- to prevent the excessive release of thermal energy in the cell.

One mark was awarded for a valid description of the function of the membrane.

There was a wide variety of responses. Repeating statements made in the question introduction (e.g. 'the membrane separates the electrodes') is not a valid response.

Question 7f.

Marks	0	1	Average
%	71	29	0.3

One of:

- loss/breakdown/oxidation/corrosion of the Zn electrode
- side reactions at the electrodes
- electrolysis of water during recharging
- $(-) 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$; $(+) 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^-$
- significant temperature change
- build-up of gases around electrode.

Many responses to this question were not pertinent. Several simply stated 'temperature', but such a cell is designed to operate at a relatively low temperature (aqueous solutions are used) although it may be affected by a major change in temperature (e.g. electrolyte evaporation at high temperatures).

Question 7g.

Marks	0	1	Average
%	66	34	0.4

Fuel cell: supply of reactants ($\text{Zn}^{2+}/\text{Ce}^{4+}/\text{Ce}^{3+}$) from outside the cell.

Secondary cell: rechargeable/discharge reaction can be reversed.

One mark was awarded for appropriate reference to both fuel cell property **and** secondary cell property.

The secondary cell property was much more evident than the fuel cell property.

Question 8a.

Marks	0	1	Average
%	73	27	0.3

Peak at $m/z = 75$ could be due to the presence of a one-unit heavier isotope such as ^{13}C , ^2H or ^{17}O .

Many responses identified an isotope as being associated with the designated peak but did not give a relevant example or indicate it must have an extra neutron.

Question 8bi.

Marks	0	1	2	Average
%	32	27	42	1.1

$\text{C}_3\text{H}_6\text{O}_2$ *

$\text{C}_4\text{H}_{10}\text{O}$ *

There are only two possible formulae based on the parent ion peak at $m/z = 74$ and the presence of only C, H and O in the compound. C_2H_5COOH and C_4H_9OH are not molecular formulae. (Three carbon esters and carboxylic acids ($C_3H_6O_2$) will have three carbon environments, as will the four-carbon alcohol, 2-methylpropan-1-ol ($C_4H_{10}O$), all with molar masses of 74 g mol^{-1}).

Question 8bii.

Marks	0	1	2	Average
%	30	57	13	0.9

There are three hydrogen environments (from three sets of peaks).

There are six hydrogen atoms (or a multiple of six H atoms) from peak area ratio 3:2:1. Three environments contain 3, 2 and 1 H atoms respectively.

Molecular formula is $C_3H_6O_2$

One mark was awarded for recognition of three hydrogen environments or six hydrogen atoms.

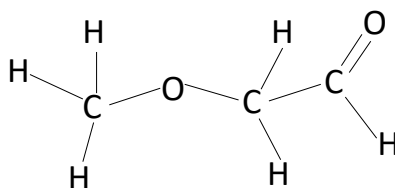
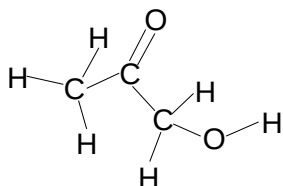
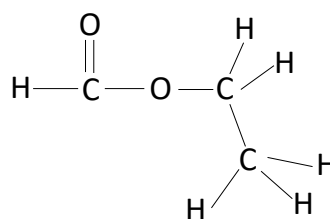
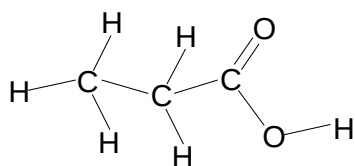
One mark was awarded for identifying $C_3H_6O_2$ as the molecular formula.

Most responses gained the first mark, but few gave the correct molecular formula.

Question 8c.

Marks	0	1	2	Average
%	42	22	36	1

Possible structural isomers included:



One mark was awarded for one $C_3H_6O_2$ isomer showing all bonds.

One mark was awarded for a second isomer $C_3H_6O_2$ isomer showing all bonds.

Performance on this question was significantly influenced by issues associated with responses to parts bi. and bii.

Question 8di.

Marks	0	1	Average
%	17	83	0.9

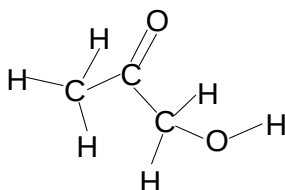
A: -OH (hydroxyl)

B: C=O (carbonyl/ketone)

One mark was awarded for achieving both correct answers.

Question 8dii.

Marks	0	1	Average
%	94	6	0.1



The most common response to this question was the structure of propanoic acid. This is perhaps the automatic response to the presence of O-H and C=O absorptions on the IR spectrum. However, the O-H stretch shown is clearly in the O-H (alcohol) range of 3200-3600 cm⁻¹, rather than the O-H(acid) range of 2500-3600 cm⁻¹. Also, the peak between 2900 and 3100 cm⁻¹ is consistent with the C-H stretch (2850-3090 cm⁻¹), which is distinct from O-H in an alcohol but overlapped by O-H in a carboxylic acid.

Question 9a.

Marks	0	1	Average
%	35	65	0.7

Current efficiency/Volume of gas collected *

The definition of dependent variable refers to 'the variable being tested' and/or 'the variable being measured' in the investigation, with this variable dependent on the independent variable.

It was appropriate to accept 'current efficiency' in the context of 'being tested' and 'volume of gas collected' in the context of 'being measured'. It is not so simple when we consider 'tested' and 'measured' as implying the same thing, in which case 'volume of gas collected' might be considered the better option.

Question 9bi.

Marks	0	1	Average
%	63	37	0.4

H₂(g) is flammable/explosive.

Cl₂(g) is toxic.

NaOH is corrosive.

One mark was awarded for a specific chemical and associated risk.

Despite the question clearly referring to a 'product' of the electrolysis, there was a suggestion in many responses that a solution of NaCl is hazardous.

Question 9bii.

Marks	0	1	Average
%	26	74	0.8

Ensure no ignition sources are present.

Limit exposure to chlorine by using a chemical (fume) hood/respirator (gas mask).

One mark was awarded for a safety measure consistent with the answer provided in part bi.

Question 9c.

Marks	0	1	Average
%	37	63	0.7

Results are precise/have a high level of precision.

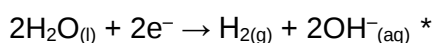
They are all in within a range of 0.5 mL/all within 0.3 mL of the mean values/within 0.3% of the mean values.

One mark was awarded for indication of why the results are precise.

Generally, a good understanding of why the results are precise was demonstrated.

Question 9d.

Marks	0	1	Average
%	69	31	0.3



In electrolysis reduction occurs at the negative electrode.

In an aqueous solution of Na^+ ions H_2O is the stronger oxidising agent and is preferentially reduced.

Question 9ei.

Marks	0	1	2	3	Average
%	44	8	15	33	1.4

$$Q = It = 2.0 \times 5 \times 60 = 600 \text{ C}$$

$$n(\text{e}^-) = Q / F = 600 / 96500 \\ = 0.00622 *$$

$$n(\text{H}_2) = 0.00622 / 2 \\ = 0.00311 \text{ mol} *$$

$$V(\text{H}_2) = 0.00311 \times 24.8 \\ = 0.077 \text{ L} * \\ = 77 \text{ mL (2 sig figs)}$$

One mark was awarded for correct $n(\text{e}^-)$.

One mark was awarded for correct $n(\text{H}_2)$.

One mark was awarded for correct $V(\text{H}_2)$.

Question 9eii.

Marks	0	1	Average
%	77	23	0.3

$$\text{Current efficiency} = [V(\text{gas}) \text{ produced} / V(\text{gas}) \text{ predicted from Faraday's law}] \times 100$$

$$\text{Volume (H}_2\text{) produced} = 170.0 - 100.1 \\ = 69.9 \text{ mL}$$

$$\text{Current efficiency} = (69.9 / 77) \times 100 \\ = 91\% *$$

It was important, in this question, to identify the volume of gas collected as the 'change' in volume at the negative electrode.

Question 9f.

Marks	0	1	2	Average
%	58	25	17	0.6

Current efficiency increases with concentration.

The average volume of gas produced (H_2) at the negative electrode increases as the concentration of NaCl increases.

or

The impact of concentration on current efficiency is not clear at the positive electrode.

Judgment can only be made at the negative electrode because of increasing $\text{Cl}_2:\text{O}_2$ ratio at the positive electrode depending on $c(\text{Cl}^-)$.

One mark was awarded for an appropriate conclusion.

One mark was awarded for a correct corresponding reasoning.

Many responses did not include an appropriate conclusion or provide a valid reason as to why a conclusion could not be drawn. In this experiment, since the aim was to investigate the effect of concentration on current efficiency, the conclusion should reflect the outcome of that investigation.

Question 9g.

Marks	0	1	2	Average
%	67	16	17	0.5

Change:

Use higher, or a greater range of, concentrations of NaCl.

Justification:

The current experimental design has two different oxidation reactions occurring. Both $\text{O}_2(\text{g})$ and $\text{Cl}_2(\text{g})$ are produced at the anode (+ electrode).

Higher concentrations of NaCl more likely to produce Cl_2 .

A greater range produces a more viable trend line.

One mark was awarded for identifying a valid change.

One mark was awarded for a correct justification.

Question 9h.

Marks	0	1	2	Average
%	44	27	28	0.9

Acceptable responses included:

- whether the data supports or refutes the aim/hypothesis
- comparison of expected to actual results
- analysis experimental design and errors
- relating to earlier work/theory (e.g. electrochemical series and its use in predicting electrode half-equations).

Full marks were awarded for two valid points.

Most responses identified at least one aspect appropriate for inclusion in the discussion section.

Question 10a.

Marks	0	1	2	3	4	Average
%	20	15	28	26	12	2

Valid discussion points included:

Carbon

- For:
 - CO₂ is absorbed/used by the crops/plants (used to produce the biodiesel)
 - more carbon neutral as biodiesel produces less new CO₂ than other fuels
- Against:
 - use of petroleum diesel (or other fuels) to produce biodiesel – a large amount of energy is required to produce biodiesel fuel from soy crops, as energy is needed for sowing, fertilising, harvesting, transporting and processing crops
 - clearing land for crops by burning trees releases CO₂ and destroys habitats
 - there is less photosynthesis when land is cleared
 - burning biomass directly emits a bit more carbon dioxide than fossil fuels for the same amount of generated energy

Sustainability of using biodiesel as a fuel

- For:
 - plants can be produced/grown in a short period of time
 - can be made from waste vegetable oils, animal fats, or restaurant grease
 - releases fewer toxic chemicals if spilled or released to the environment/many by-products are biodegradable
 - biodiesel produces less soot (particulate matter)/carbon monoxide/unburned hydrocarbons/sulfur dioxide
 - crops (that produce oil) can be grown in many places
 - can use second-generation technologies to convert material such as crop residues into bioenergy and avoid competition for land
- Against:
 - some regions are not suitable for oil producing crops
 - uses crops/land that could be used for food/food production
 - the excess use of fertilisers can result in soil erosion and land pollution
 - nitrous oxide released from fertilisers could have a greater (300 times more) global warming effect than carbon dioxide
 - the use of water to produce more crops can put pressure on local water resources

Using biodiesel as a fuel for transport

- For:
 - produces less toxic pollutants and greenhouse gases than petroleum diesel
 - reduces dependence on foreign oil reserves as it is domestically produced

- can be used in any diesel engine with little or no modification to the engine or the fuel system
- higher flashpoint, which makes it less combustible and therefore safer to handle, store and transport
- the lubricating property of the biodiesel may lengthen the lifetime of engines
- Against:
 - higher viscosity/not suitable for use in low temperatures
 - biodiesel fuel is more expensive than petroleum diesel fuel.

Two marks were awarded for at least two valid points for, two valid points against, or one valid point for and one valid point against carbon neutrality related to biodiesel. The same was awarded for sustainability related to biodiesel.

OR

One mark for at least one valid point (for or against) regarding sustainability related to biodiesel.

One mark for at least one valid point (for or against) regarding carbon neutrality related to biodiesel.

One mark for at least one valid point (for or against) use of biodiesel as a fuel.

One mark for a second valid point (for or against) one of carbon neutrality, sustainability, use as a fuel.

Sixty-five per cent of students obtained two or more marks, although many did not fully explain why biofuels were carbon neutral or renewable. Some who tried to incorporate the media statements did so without really making headway in explanation. There was evidence that time pressure affected some students.

Question 10b.

Marks	0	1	2	3	4	5	Average
%	37	17	23	17	6	1	1.5

Acceptable points included:

- energy content of biodiesel slightly lower than petrodiesel
- biodiesel contains oxygen, therefore is already partially oxidised, whereas petrodiesel is mainly composed of hydrocarbons
- more biodiesel is required to produce the same amount of energy thus it is less efficient to use biodiesel/more biodiesel must be produced to replace less petrodiesel
- in situations where storage of the fuel is limited, either smaller distances can be travelled, or more frequent refuelling is required when using biodiesel
- cars require a larger fuel tank or closer refuelling stops
- petrodiesel molecules have mostly saturated hydrocarbon chains, whereas biodiesel molecules made from oleic acid have a longer monounsaturated hydrocarbon chain
- biodiesel molecules are alkyl esters, whereas petrodiesel molecules are hydrocarbons
- ester groups/bonds increase the viscosity of biodiesel due to the stronger polar interactions between the molecules
- higher viscosity of biodiesel limits its use at low temperatures/more energy is required to pump the fuel.

One mark was awarded for recognition that biodiesel has a lower energy content. One mark was awarded for explaining the difference in energy content. One mark was awarded for the impact of the lower energy content on the use of biodiesel as a fuel. One mark was awarded for the effect of the ester group on the interactions between the molecules. One mark was awarded for the effect of intermolecular forces on viscosity.

This question was handled significantly less well than part a. The main areas in which responses were less successful were explanation of the energy content difference and the relationship between intermolecular attraction and viscosity/flow.