

2023 VCE Chemistry external assessment report

General comments

A number of the multiple-choice questions in Section A of the examination, specifically Questions 4, 7, 12 and 23, were handled well by students. These questions relied on a basic understanding of concepts that have clearly been well learned by the students, and therefore simple recall skills were sufficient to perform well. The questions where students were most challenged were the application-type questions, where data had to be analysed and interpreted. When approaching these more complex questions, it is very important that students take time to annotate the question, write out chemical reactions, or draw structures/diagrams to assist their processing skills.

In Section B of the examination, students were able to provide responses to most questions. Clear strengths can be seen in all the mathematics-based questions. This was enhanced by an encouraging trend where most students showed their working out. This enabled easy access to consequential marks.

Students have continued the trend of the past few years, once more finding it difficult to successfully respond to redox-based questions. This was most clearly shown in responses to Question 9a. The dot points in the stem of the question appeared to assist some students, where there were frequent attempts at defining electrolysis; however, from this point on very few students provided reference or justification for their statements based on the electrochemical series as requested in the stem of the question. Likewise, the overall response for how the electrolytic cell can purify copper was rarely given. Question 9b. was much better handled. However, a significant number of responses were mathematical in their approach, rather than explaining what these mathematical relationships show.

Another observed trend relates to the written communication skills of students. Frequently, the 'explain' questions were not fully supported in responses. A typical example can be seen from the data shown by Question 2b.i., where the students were asked to explain what the GI of a food indicates. Good responses started with a clear definition of what GI means and then explained how this definition applies to the way food affects glucose levels. A significant number of responses were too general and only referred to blood sugar levels, not blood glucose levels, and then also failed to discuss how the food needs to be broken down into these glucose molecules which are then transferred into the bloodstream. This trend continued in Questions 2c.iv. and 2c.v. In all these questions students scored less than 50%, on average.

There is evidence to show that students are relying heavily on factual recall, as scoring on questions such as 2c.i., 5a. and 6a. were all around 80-90%. This also caused issues for students in relation to answers where they automatically applied pre-learned material to concepts without demonstrating understanding. A typical example of this was found with Question 6c., where students were asked to identify how the polarity of the electrodes can be established. A significant number of students wrote that the 'polarity of the electrodes change' without understanding that this is not correct because it is the 'process' occurring at these electrodes that changes.

Application questions are showing a distinct trend where students are not easily able to problem-solve their way through to a correct response. This was clearly shown in Question 1d., where only 23% of students were able to determine how the three fatty acids effectively undergo condensation reactions to form the triglyceride. Question 9a. also followed this pattern, and the careful use of logical, step-by-step processes was not evident.

Two questions, Question 20 of the multiple-choice section and Question 1a. of the short-answer section, were identified as having issues in terms of clarity and/or confusing content, and so both of these questions were automatically awarded one mark.

Specific information

Note: Student responses reproduced in this report have not been corrected for grammar, spelling or factual information.

This report provides sample answers, or an indication of what answers may have included. Unless otherwise stated, these are not intended to be exemplary or complete responses.

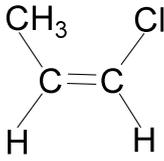
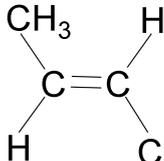
The statistics in this report may be subject to rounding, resulting in a total of more or less than 100 per cent.

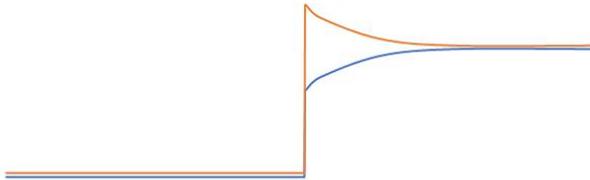
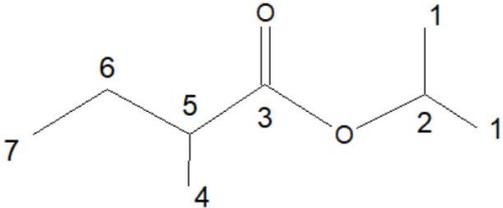
Section A

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

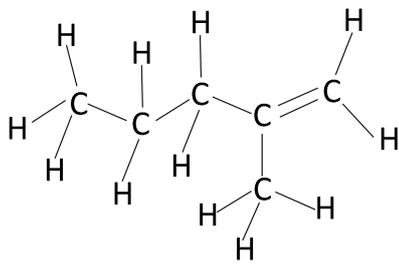
Question	Correct answer	% A	% B	% C	% D	Comments
1.	B	8	67	8	17	In human cells, glucose reacts with oxygen in respiration – an energy-releasing, i.e. exothermic, reaction. $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6\text{O}_2(\text{g}) \rightarrow 6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}), \Delta H = -2880 \text{ kJ}$
2.	A	40	5	42	13	Fuel cells and galvanic cells both produce heat energy as well as electrical energy. Galvanic cell electrodes may be active, as in the $\text{Zn}^{2+}(\text{aq})/\text{Zn}(\text{s})$ half-cell, or inert, as in the $\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})$ half-cell where a Pt or C(graphite) electrode could be used. Both fuel cells and galvanic cells can have porous electrodes because this increases the surface area for reaction. Electrons do not flow through the electrolyte in electrochemical cells; they travel through the external circuit between the anode and the cathode.
3.	A	70	2	26	1	The larger the number of C=C double bonds in the molecule the more loosely the chains pack together, the weaker the intermolecular attraction, and the lower the melting point. Therefore, Z has the lowest melting point and Y, with no C=C double bonds, and the strongest intermolecular attraction, has the highest melting point.
4.	D	14	2	5	79	The polarity of the physical electrodes does not change. The positive electrode remains positive in both galvanic and electrolytic cells. However, the process at that electrode changes – from reduction in a galvanic cell to oxidation in an electrolytic cell – due to the change in the direction of electron flow. A cell is classified as a secondary cell if it operates as both a galvanic and electrolytic cell. Secondary cells have all reactants contained within the cells.
5	D	16	38	3	42	All three statements are properties of coenzymes. Coenzymes assist enzymes to catalyse a reaction, by binding loosely to the active site of the enzymes and supporting the transfer of electrons and atoms during the reaction.
6	C	16	30	43	10	HPLC is qualitative in that comparing retention times with those of standard samples enables the possible identification of the components of a mixture. HPLC is quantitative in that relative areas under peaks are used to calculate the percentage of each component in the mixture.

Question	Correct answer	% A	% B	% C	% D	Comments
						Triplets are associated with ^1H NMR spectroscopy.
7.	B	6	73	21	1	<p>Biofuel production potentially does damage the environment by degrading land used to grow food and through emissions from fuels used in production and transport.</p> <p>Both biofuel and fossil fuels do generate greenhouse gases – $\text{CO}_2(\text{g})$ and/or $\text{H}_2\text{O}(\text{g})$.</p> <p>Biofuels are renewable but fossil fuels, while traceable back to plants, take millions of years to form and are not considered renewable.</p>
8.	D	15	15	18	52	<p>$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \quad K = 4.10 \text{ M}^{-2}$</p> <p>The original equation coefficients have been doubled, so the Kvalue is raised to the power of 2 (squared).</p> <p>$2\text{N}_2(\text{g}) + 6\text{H}_2(\text{g}) \rightleftharpoons 4\text{NH}_3(\text{g}) \quad K = (4.10 \text{ M}^{-2})^2 = 16.8 \text{ M}^{-4}$</p>
9.	D	5	3	38	54	<p>The main component of coal seam gas is a mixture of methane – 88 to 98% – with small amounts of other hydrocarbons.</p> <p>Petroleum gas, associated with crude oil, is also a mixture of lighter hydrocarbons.</p> <p>Both coal seam gas and petroleum gas are fossil fuels and produce CO_2 on combustion.</p>
10.	A	26	47	18	8	<p>A. A higher value for the equilibrium expression suggests a higher proportion of products / increased product concentration compared to reactants, and hence a higher yield.</p> <p>B. An increase in reactant concentration will increase the yield in any equilibrium where the concentration fraction (reaction quotient) increases, as a result of a change that favours the forward reaction. The system moves to compensate for the change by favouring the forward reaction.</p> <p>However, if the concentration increase occurs by decreasing the volume of an equilibrium mixture in which there are the same number of mol of particles on both sides, as in the equilibrium</p> $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{HCl}(\text{g}),$ <p>the value of the concentration fraction (reaction quotient) $\frac{[\text{HCl}]^2}{[\text{H}_2][\text{Cl}_2]}$ does not change and there is no change in the yield.</p> <p>C. A decrease in activation energy increases the reaction rate and allows the system to get to equilibrium faster but has no effect on the equilibrium yield.</p> <p>D. A pressure increase will cause the reaction to favour the</p>

Question	Correct answer	% A	% B	% C	% D	Comments
						side of the equilibrium with the lower number of mol of particles. However, it has no impact on the yield of an equilibrium system with the same number of particles on both sides, as in $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{HCl}(\text{g})$
11.	A	63	15	19	3	Reaction rate is the change in the quantity of a reactant or product per unit time, i.e. $\text{M} / \text{s} = \text{mol L}^{-1} / \text{s} = \text{mol L}^{-1} \text{s}^{-1}$
12.	A	88	2	2	8	The presence of a catalyst <ul style="list-style-type: none"> lowers the activation energy has no effect on the enthalpy change, ΔH has no effect on the enthalpy of reactants or products.
13.	C	12	9	59	20	The terms ' <i>cis</i> ' and ' <i>trans</i> ' are commonly associated with unsaturated compounds with a C=C double bond. These two forms must show the two carbons on either end of the double bond attached to two different atoms or groups of atoms. One of the atoms attached to each C in the C=C double bond must be the same, and these two atoms may be on the same side (<i>cis</i>) of the C=C double bond, or on diagonally opposite sides of the C=C double bond (<i>trans</i>). CH_2CBrCl does not have <i>cis</i> and <i>trans</i> isomers because the two H atoms are attached to the same C atom. CH_3CHBrCl does not have <i>cis</i> and <i>trans</i> isomers because there is no C=C double bond in the molecule. CH_3CHCHCl does have <i>cis</i> and <i>trans</i> isomers. <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p><i>cis</i>-1-chloropropene</p> </div> <div style="text-align: center;">  <p><i>trans</i>-1-chloropropene</p> </div> </div> $(\text{CH}_3)_2\text{CCCl}_2$ does not have <i>cis</i> and <i>trans</i> isomers because there is only one type of atom or group attached to each C.
14.	C	43	1	44	12	Initially, when the temperature is increased, the rates of both the forward and backward (reverse) reactions immediately increase. Since the forward reaction is endothermic, the forward reaction is favoured as the system returns to equilibrium. So, the rate of the forward reaction will decrease as reactant concentrations decrease BUT at the new equilibrium the rate

Question	Correct answer	% A	% B	% C	% D	Comments
						<p>of the forward reaction will still be higher than prior to the temperature increase.</p> <p>The rate of the reverse reaction will further increase as the product concentrations increase.</p> <p>When equilibrium is established at 80 °C, the rates of both the</p>  <p>forward and reverse have increased compared to the equilibrium at 35 °C.</p> <p>Alternatively, the rate of any reaction at 80 °C, exothermic or endothermic, would be expected to be higher than at 35 °C.</p>
15	A	41	12	35	12	<p>Petrol-powered drones convert chemical energy into thermal energy and mechanical energy. The reaction products are CO₂(g) and H₂O(g).</p> <p>Hydrogen-powered drones convert chemical energy into electrical energy and thermal energy. The reaction product is H₂O (g).</p> <p>Since energy is released during the reaction in both types of drones, both reactions are exothermic.</p> <p>Both CO₂(g) and H₂O(g) are greenhouse gases.</p>
16.	C	21	23	43	12	<p>CH₃CH₂CH(CH₃)COOCH(CH₃)₂</p> <p>There are seven different carbon environments.</p> 
17.	D	9	10	24	57	<p>Since the power station is only 39% efficient, 42 MJ usable energy is only 39% of the total energy released by the lignite undergoing combustion.</p> <p>42 MJ = 0.39 x total energy released from lignite.</p> <p>Total energy = 42 / 0.39 = 107.7 MJ</p> <p>$m(\text{lignite required}) = 107.7 \text{ MJ} / 19.0 \text{ MJ tonne}^{-1}$</p> <p>= 5.67 tonne</p>
18	C	8	45	37	9	According to the calibration curve for diluted folic acid solution:

Question	Correct answer	% A	% B	% C	% D	Comments
						<p>peak at peak area 0.35 → 18 ng mL⁻¹ concentration.</p> <p>The sample had been diluted by a factor of 1000 (1 mL to 1 L).</p> <p>So, the concentration of the original undiluted sample was:</p> $1000 \times 18 \text{ ng mL}^{-1} = 18 \times 10^3 \text{ ng mL}^{-1}$ <p>According to Table 6 of the Data Book:</p> $1 \text{ ng} = 10^{-3} \mu\text{g} \text{ so } 1 \mu\text{g} = 10^3 \text{ ng}$ <p>Concentration of original sample = 18 μg L⁻¹</p> <p>The large number of responses for 'B' is indicative of the failure to allow for the dilution that occurred.</p>
19.	A	59	15	4	22	<p>Omega-6 fatty acids contain a C=C double bond between the 6th and 7th carbons in the hydrocarbon chain.</p> <p>This creates a kink in the chains that prevents them from packing as close together as the chains in saturated fatty acids.</p> <p>Consequently omega-6 fatty acids have</p> <ul style="list-style-type: none"> • lower densities • lower melting points <p>than saturated fatty acids.</p> <p>Because omega-6 fatty acids have C=C double bonds they undergo addition reactions, and having <u>fewer</u> hydrogen atoms in each molecule they undergo substitution reactions <u>less</u> readily than saturated fatty acids.</p>
20.	All	28	2	49	20	<p>There was no correct or best answer to this question and all students were awarded the mark.</p> <p>Water in the burette will dilute the liquid being added from the burette and cause a larger titre for a particular indicator.</p> <p>For a specific titration, different indicators will show different endpoints and result in different titre volumes.</p> <p>Using methyl red (pH 4.4–6.2) rather phenolphthalein (pH 8.3–10) for the titration of CH₃COOH(aq) by NaOH(aq) will require a smaller titre volume and lead to a less accurate result. Both indicators may lead to precise results but only the use of the correct indicator will produce an accurate result.</p> <p>Water in the pipette reduces the concentration of the aliquot in the titration flask, causing a smaller titre to be used. So, in the titration of a base – in the aliquot – by an acid, the smaller titre volume will lead to an overestimation of the acid concentration.</p> <p>According to the Royal Australian Chemical Institute (RACI; www.raci.org.au) – 'A Guide to Titration':</p> <p>'Insert the tip of the pipette well inside the titration flask, remove the filler, and allow the solution to drain with the pipette held vertically. Then touch the tip of the pipette against</p>

Question	Correct answer	% A	% B	% C	% D	Comments
						<p>the side of the flask at the liquid/air interface for 10 seconds to complete the draining.'</p> <p>The distinction between touch and tap was considered too fine a distinction for students to make, and since there should be some contact between the tip of the burette and the inside of the conical flask, alternative D was also considered incorrect.</p>
21	D	23	7	5	65	<p>Denaturation can also be caused by certain chemicals as well as changes in pH or temperature.</p> <p>Denaturation changes are generally considered as being irreversible in the environment in which they occur.</p> <p>Denaturation does not affect the primary structure.</p> <p>Denaturation alters the secondary (and tertiary and quaternary) structures.</p>
22.	B	5	41	17	37	<p>The relevant equations and half equations are:</p> $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ $\text{CH}_4 + 2\text{H}_2\text{O} \rightarrow \text{CO}_2 + 8\text{H}^+ + 8\text{e}^-$ $\text{CH}_3\text{OH} + 1\frac{1}{2}\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ $\text{CH}_3\text{OH} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 6\text{H}^+ + 6\text{e}^-$ <p>The amounts of greenhouse gas per mol of fuel are the same – 1 mol CO₂ and 2 mol H₂O – for both CH₄ and CH₃OH.</p> <p>The numbers of electrons per mol of fuel are different for the two fuels: 8 mol for CH₄ and 6 mol for CH₃OH.</p>
23.	C	4	4	89	3	<p>2-methylpent-1-ene.</p> <p>The structural formula is:</p>  <p>Therefore, the semi-structural formula is $\text{CH}_3\text{CH}_2\text{CH}_2\text{C}(\text{CH}_3)\text{CH}_2$ or $\text{CH}_2\text{C}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{CH}_3$</p>
24.	A	61	9	23	7	<p>Half equations in a CH₃CH₂CH₂OH / O₂ fuel cell with acid electrolyte:</p> <p>Anode (-) $\text{C}_3\text{H}_8\text{O}(\text{l}) + 5\text{H}_2\text{O}(\text{l}) \rightarrow 3\text{CO}_2(\text{g}) + 18\text{H}^+(\text{aq}) + 18\text{e}^-$</p> <p>Cathode (+) $\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l})$</p> <p>Cations, H⁺(aq), flow through the electrolyte from the anode</p>

Question	Correct answer	% A	% B	% C	% D	Comments
						(-) to the cathode (+). Since there is a continuous supply of reactants, the voltage would not be expected to decrease. H ₂ O is formed at the positive electrode and CO ₂ is formed at the negative electrode. All reactants must have direct contact with the relevant electrodes.
25.	C	28	16	44	11	Galvanic cell: discharge Anode (-) $\text{Pb(s)} + \text{HSO}_4^-(\text{aq}) \rightarrow \text{PbSO}_4(\text{s}) + \text{H}^+(\text{aq}) + 2\text{e}^-$ Cathode (+) $\text{PbO}_2(\text{s}) + \text{HSO}_4^-(\text{aq}) + 3\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{PbSO}_4(\text{s}) + 2\text{H}_2\text{O(l)}$ Electrolytic cell: recharge Anode (+) $\text{PbSO}_4(\text{s}) + 2\text{H}_2\text{O(l)} \rightarrow \text{PbO}_2(\text{s}) + \text{HSO}_4^-(\text{aq}) + 3\text{H}^+(\text{aq}) + 2\text{e}^-$ Cathode (-) $\text{PbSO}_4(\text{s}) + \text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{Pb(s)} + \text{HSO}_4^-(\text{aq})$ H ⁺ ions react at the cathode in the galvanic cell. HSO ₄ ⁻ ions are produced at both electrodes in the electrolytic cell.
26.	B	21	50	20	9	There are three independent variables, since there are three things that would be altered by the student during the investigation: <ul style="list-style-type: none"> the type of oil – sunflower or canola the catalyst used – NaOH(aq) or KOH(aq) the alcohol used – methanol or ethanol
27.	B	17	45	19	18	The lower the flow rate of a biodiesel, the higher the viscosity; the higher the flow rate, the lower the viscosity. Using NaOH(aq) as a catalyst: The viscosity of canola oil is lower than the viscosity of sunflower oil for both methanol and ethanol. However, the viscosities of both sunflower oil and canola oil are lower when made from methanol, since the flow rates are higher than the flow rates using ethanol. Using KOH(aq) as a catalyst: <u>Methanol</u> : viscosity of canola oil is higher than the viscosity of sunflower oil <u>Ethanol</u> : viscosity of canola oil is lower than the viscosity of

Question	Correct answer	% A	% B	% C	% D	Comments
						<p>sunflower oil.</p> <p>Again, the viscosities of both sunflower oil and canola oil are lower when made from methanol since the flow rates are higher than the flow rates using ethanol.</p> <p>Biodiesels made from methanol have a higher flow rate, and hence a lower viscosity, than biodiesels made from ethanol.</p> <p>The relative suitability of biodiesels and petrodiesel in cold climates cannot be deduced from the results presented.</p> <p>The flow rate of the biodiesel made from sunflower oil and methanol is lower when NaOH is used (4.8) than it is when KOH is used (4.9). In this instance the viscosity of the biodiesel is higher when NaOH(aq) is used than when KOH(aq) is used.</p>
28.	B	18	45	25	11	<p>The half-cell potentials relating to the cell are:</p> $\text{Mn}^{3+}(\text{aq}) + \text{e}^{-} \rightleftharpoons \text{Mn}^{2+}(\text{aq})$ <p style="text-align: center;">+1.56 V</p> $\text{SO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightleftharpoons \text{SO}_3^{2-}(\text{aq}) + 2\text{OH}^{-}(\text{aq})$ <p style="text-align: center;">-0.94 V</p> <p>The cell will produce 2.50 V as $\text{SO}_3^{2-}(\text{aq})$ is oxidised to $\text{SO}_4^{2-}(\text{aq})$, and $\text{Mn}^{3+}(\text{aq})$ is reduced to $\text{Mn}^{2+}(\text{aq})$.</p> <p>In both half-cells and in each half-equation, the oxidising and reducing agents are ions in solution and the electrodes on both cells will be unreactive conductors, in this case Pt, an inert metal. Mn would be inappropriate in an $\text{Mn}^{3+}(\text{aq})/\text{Mn}^{2+}(\text{aq})$ half-cell in any circumstance because it would be oxidised in the half-cell by $\text{Mn}^{3+}(\text{aq})$.</p>
29.	D	18	23	12	46	<p>In mass spectrometry molecules are ionised as result of bombardment with high-energy electrons. The positive ions produced are deflected in a magnetic field according to their m/z ratios.</p> <p>The relative molecular mass of a compound is determined from the significant peak with highest m/z ratio.</p> <p>The base peak is associated with the most abundant species formed during fragmentation / the base peak represents the most abundant fragment produced and the relative height of the peak at that m/z ratio is set at 100.</p> <p>The base peak represents the most common fragment produced during the impact of the electron beam on the parent molecule ion cation. It can also be formed from fragments larger than itself.</p> <p>The major peaks on a mass spectrum occur at the m/z ratios of the different fragments / ions produced in the mass spectrometer. The very small peaks, usually one m/z unit</p>

Question	Correct answer	% A	% B	% C	% D	Comments
						<p>higher, may be associated with different isotopes.</p> <p>The heights of peaks on the mass spectrum are all relative to the height of the base peak, which is set at 100.</p>
30.	C	26	11	48	15	<p>The relative locations of the species $\text{H}_2\text{O}_2(\text{aq})$, $\text{Fe}^{3+}(\text{aq})$ and $\text{Fe}^{2+}(\text{aq})$ on the electrochemical series:</p> $\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l}) \quad +1.77 \text{ V}$ $\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq}) \quad +0.77 \text{ V}$ $\text{O}_2(\text{s}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}_2(\text{aq}) \quad +0.68 \text{ V}$ $\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Fe}(\text{s}) \quad -0.44 \text{ V}$ <p>$\text{H}_2\text{O}_2(\text{aq})$ is both the strongest oxidising agent and the strongest reducing agent present.</p> <p>The equation for the redox reaction occurring will be $2\text{H}_2\text{O}_2(\text{aq}) \rightarrow \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$.</p> <p>So, the concentration of $\text{H}_2\text{O}_2(\text{aq})$ decreases.</p> <p>The reaction cannot produce a voltage because it is not in an electrochemical cell.</p> <p>The reaction is exothermic, so the temperature of the contents increases.</p>

Section B

Question 1a.

Marks	0	1	Average
%	0	1	1

This question contained conflicting information; therefore, the decision was made to award all students the mark for this question.

0% was the correct answer if the name linoleic acid was used.

2% was potentially also a correct answer if the chemical formula was used, as this formula matched that of linolenic acid which is an omega-3 fatty acid.

Question 1b.

Marks	0	1	Average
%	0.4	0.6	0.6

The mark was awarded for stating either of:

- 'Coconut oil consists of mainly saturated fatty acids.'
- 'Coconut oil consists of very few molecules with C=C present.'

A clear reference to the degree of unsaturation being linked to oxidative rancidity was required.

Question 1c.

Marks	0	1	Average
%	0.4	0.6	0.6

Glycerol

Question 1d.

Marks	0	1	Average
%	0.8	0.2	0.3

$C_{27}H_{50}O_6$

Students found it difficult to reassemble this triglyceride from its components.

Question 1e.

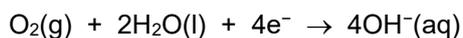
Marks	0	1	2	Average
%	0.5	0.4	0.1	0.7

The first mark was awarded for recognising that both vitamin E and coconut oil are non-polar compounds.

The second mark was awarded for recognising that the vitamin E would then dissolve in coconut oil because of the dispersion forces that would form between these two compounds.

Question 1fi.

Marks	0	1	Average
%	0.7	0.3	0.3



Students were required to present this equation, with correct states (available in the Data Book), using a single-headed arrow.

This was a challenging question for students, demonstrating the difficulty they continue to have with interpreting redox questions.

Question 1fii.

Marks	0	1	Average
%	0.5	0.5	0.5

The design feature of the cathode could have been any of the following concepts:
porous / high surface area / catalyst added to surface.

Question 1g.

Marks	0	1	Average
%	0.5	0.5	0.5

Students were required to link the concept of higher efficiency being associated with the fuel cell when compared with direct combustion.

Question 1h.

Marks	0	1	2	Average
%	0.8	0.1	0.1	0.4

Students were required to provide a viable *reason* and then link this to the *practical application* of a fuel cell.

Typical examples included:

'Coconut oil is viscous (reason) and this means that it may be difficult for the fuel to then flow effectively through the cell (application).'

'Coconut oil is non-polar and therefore not soluble in water (reason) and this means that it may be difficult for the fuel to effectively interact with the aqueous alkaline electrolyte (application).'

Many students believed that fuel cells require gaseous fuels to be able to operate; however, this is not a requirement of a fuel cell. There are numerous applications where the fuel is a liquid or a solute present in a solution.

Question 2a.

Marks	0	1	Average
%	0.2	0.8	0.8

Glycosidic link

Question 2bi.

Marks	0	1	2	Average
%	0.4	0.3	0.3	0.9

The first mark was awarded if the student conveyed the concept that the glycaemic index is a measure of the rise in the blood glucose levels after a food is eaten.

For the second mark, students were then required to provide one piece of additional material from the following list:

- Relative to glucose.
- Glucose has a GI value of 100 (reference compound).
- The blood glucose levels should be measured 2 hours after the ingestion of food.
- GI is linked to the rate at which the food is being metabolised to produce glucose.

Question 2bii.

Marks	0	1	Average
%	0.5	0.5	0.5

A glucose molecule is produced when lactose is hydrolysed / metabolised / broken down.

Significant issues arose with this question where students incorrectly believed that the hydrolysis of lactose produced two glucose units rather than glucose and galactose.

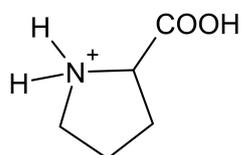
Question 2ci.

Marks	0	1	Average
%	0.2	0.8	0.9

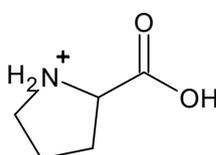
Proline can be synthesised in the body.

Question 2cii.

Marks	0	1	Average
%	0.6	0.4	0.4



or



To gain this mark, students must have shown the correct number of hydrogens on the nitrogen atom and the nitrogen atom must also be shown with an associated positive charge.

A mark was not awarded if the charge was associated with the hydrogens in this structure.

Question 2ciii.

Marks	0	1	2	Average
%	0.5	0.2	0.4	0.9

Any two of the following statements were awarded marks.

Proline can:

- undergo condensation reactions to form proteins/enzymes
- be formed from hydrolysis reactions of proteins/enzymes
- undergo oxidation reactions as it is broken down into smaller molecules.

Question 2civ.

Marks	0	1	2	Average
%	0.5	0.2	0.3	0.8

The first mark was awarded for recognition that proline contains a chiral carbon.

The second mark was awarded when the student did one of the following:

- identified the chiral carbon in the molecule
- described how it could be identified by having four different groups attached
- stated that the two optical isomers formed were non-superimposable mirror images (enantiomers).

Question 2cv.

Marks	0	1	2	Average
%	0.6	0.2	0.2	0.7

The first mark was awarded for recognition that the incorrect optical isomer of proline would alter the primary structure of the enzyme (wrong conformation) and cause the active site of *lactase* to change shape.

The second mark was awarded for recognition that with a changed active site in the *lactase*, the lactose substrate would then no longer have the correct conformation/shape to match. Hence the lactose in milk would not be as effectively digested.

A significant number of students failed to distinguish that the proline was part of the primary amino acid sequence of the enzyme and instead referred to proline as the substrate in this reaction.

Question 3ai.

Marks	0	1	Average
%	0.3	0.7	0.7

Heat of combustion is 50.5 kJ g^{-1}

Therefore $50.5 \times 140 = 7.07 \times 10^3 \text{ kJ}$ ($7.06 \times 10^3 \text{ kJ}$ was also a valid response).

Incorrect units such as kJ g^{-1} were commonly seen but could not be awarded marks.

Question 3a.ii.

Marks	0	1	2	Average
%	0.2	0.3	0.5	1.3



Either kJ mol^{-1} or kJ were accepted as viable units for ΔH .

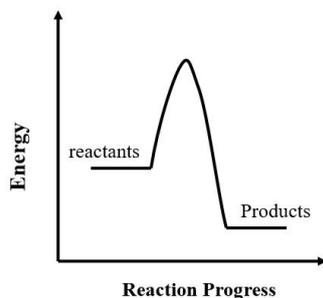
The first mark was awarded for a correctly balanced chemical equation with correct states.

The second mark was awarded for the correct ΔH value with correct units.

This question was well done, although some students were still attempting to use $\Delta\text{H} = -50.5 \text{ kJ g}^{-1}$, which is not applicable for a thermochemical equation. Since the question explicitly stated at SLC, the states had to be (g) for propane and (l) for water, and this also was not always recognised.

Question 3a.iii.

Marks	0	1	Average
%	0.2	0.8	0.8



The mark was awarded for the correct exothermic profile being shown.

Question 3a.iv.

Marks	0	1	2	Average
%	0.6	0.4	0.1	0.5

The first mark was awarded for recognising that the products of incomplete combustion needed to have a higher energy than shown for the complete combustion (but still below the reactants).

The second mark was awarded when the student identified this as being due to the incomplete oxidation of the reactants, which is the reason for less energy being released.

Students commonly tried to explain the reason for the energy difference as being due to the 'incomplete combustion' rather than incomplete oxidation, but as this term was already stated in the stem of the question, this was not an acceptable approach.

Question 3bi.

Marks	0	1	2	3	Average
%	0.1	0.1	0.2	0.6	2.3

The first mark was awarded for the correct calculation of $n(\text{ethanol}) = 96.0/46.0 = 2.09 \text{ mol}$

The second mark was awarded for the correct calculation of $n(\text{CO}_2) = 2 \times 2.09 = 4.17 \text{ mol}$

The third mark was awarded for the correct calculation of the volume with units.

$$V(\text{CO}_2) = (4.17 \times 8.31 \times 288) / 100 = 99.9 \text{ L}$$

Question 3bii.

Marks	0	1	2	3	Average
%	0.2	0.2	0.3	0.3	1.7

The first mark was awarded for stating that the flashpoint of ethanol is higher than the flashpoint of propane.

The second mark was awarded when the student clearly recognised the structural component of either ethanol and/or propane that was the major factor affecting the flashpoint. Typically, students referred to the presence of the hydroxyl group as being the major factor in the structure of ethanol.

The third mark was awarded for discussion around the need for a greater amount of energy and/or the higher temperature that would be required to break the intermolecular bonds in ethanol.

Question 4ai.

Marks	0	1	Average
%	0.3	0.7	0.7

Addition or hydration

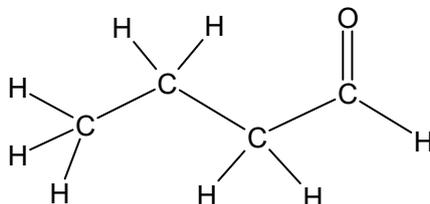
Question 4aii.

Marks	0	1	Average
%	0.5	0.5	0.5

Butan-2-ol or 2-butanol

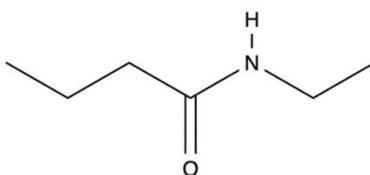
Question 4b.

Marks	0	1	Average
%	0.4	0.6	0.6



Question 4c.

Marks	0	1	2	Average
%	0.5	0.3	0.2	0.8



The first mark was awarded for showing a correct amide linkage.

The second mark was awarded for the correct skeletal representation of the final molecule.

Question 4d.

Marks	0	1	2	Average
%	0.2	0.2	0.6	1.5

The first mark was awarded for the % atom economy formula being applied:

$$\frac{M(\text{Desired product } (116))}{M(\text{All reactants } (134))} \times 100$$

The second mark was awarded for the correct value of 86.6% (87% or 86.57%). This was not a significant figure question.

Question 5a.

Marks	0	1	Average
%	0.2	0.8	0.9

Any one of the following:

organic waste matter / biomass / coal seam gas / cattle / biogas / anaerobic respiration / fossil fuels / natural gas / fracking.

Question 5bi.

Marks	0	1	Average
%	0.2	0.8	0.8

$$\frac{[H_2]^4[CO_2]}{[H_2O]^2[CH_4]}$$

Question 5bii.

Marks	0	1	2	3	4	Average
%	0.2	0.1	0.1	0.2	0.4	2.4

	CH ₄	H ₂ O	CO ₂	H ₂
Initial (n)	25.0	25.0	0.00	0.00
Change	-x (-1.530)	-2x (-3.060)	+x (+1.530)	+4x (+6.120)
Equilb (n)	23.47	21.94	1.530	6.120
Equilb conc (M)	0.2347	0.2194	0.0153	0.0612

$$K = \frac{[0.0612]^4[0.0153]}{[0.2194]^2[0.2347]} = 1.90 \times 10^{-5} \text{ M}^2$$

The first mark was awarded for the correct equilibrium amounts.

The second mark was awarded for the correct equilibrium concentrations.

The third mark was awarded for the correctly calculated value for K .

The fourth mark was awarded for the correct units being shown.

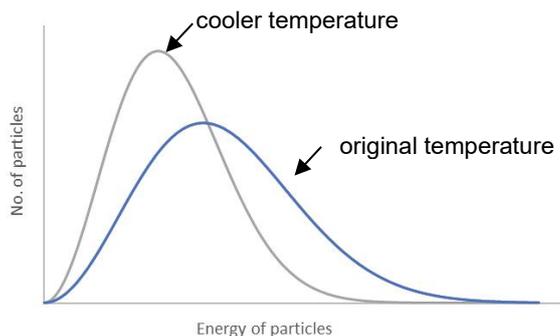
This question was generally well done, with clear structured responses that allowed for easy allocation of consequential marks.

Question 5c.

Marks	0	1	Average
%	0.5	0.5	0.5

'Narrower' and 'taller/higher' were required to be mentioned in any written response.

Students could have shown this change with a clearly annotated plot.



Question 6a.

Marks	0	1	Average
%	0.2	0.8	0.8

chemical energy → electrical energy

Question 6b.

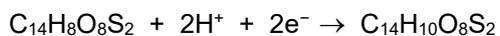
Marks	0	1	2	Average
%	0.4	0.3	0.3	0.9

The first mark was awarded for either $\text{Fe}_2(\text{SO}_4)_3$ or Fe^{3+} as the oxidising agent.

The second mark was awarded for indicating that the oxidation number for iron changed from +3 to +2 during this process and hence why Fe^{3+} was the oxidising agent.

Question 6ci.

Marks	0	1	Average
%	0.5	0.5	0.5



Question 6cii.

Marks	0	1	Average
%	0.5	0.5	0.5

Negative

Question 6ciii.

Marks	0	1	2	Average
%	0.7	0.2	0.1	0.4

The first mark was awarded for the recognition that the electrode polarity does not change when the system is changed from discharge to recharge. The relative reductive and oxidative strength of the chemicals present in the galvanic cell is what determines the polarity, and this is fixed for both the discharge and recharge processes.

The second mark was awarded for the recognition that the external power source causes the *process* to change at each electrode. This means that during the recharge the positive electrode becomes the anode and oxidation occurs here. This reversal of processes means that the original chemicals can be re-formed and hence the cell is recharged.

Students frequently referred to the electrode polarity 'swapping' during recharge and this is an incorrect statement.

Question 7ai.

Marks	0	1	2	Average
%	0.3	0.1	0.6	1.3

The first mark was awarded for the correct molecular formula of $C_5H_{10}O$.

The second mark was awarded for reference to the parent ion being located at $m/z = 86$, and hence the molar mass of the compound must have been 86 g mol^{-1} .

Question 7aii.

Marks	0	1	Average
%	0.4	0.7	0.7

The peak at $m/z = 87$ is an isotopic peak caused by a ^{13}C isotope being present in the molecule.

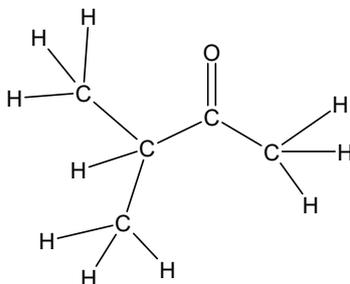
Question 7b.

Marks	0	1	Average
%	0.5	0.5	0.5

The doublet seen in the spectrum is formed according to the $n+1$ rule and is due to the presence of a single non-equivalent hydrogen located on an adjacent carbon atom.

Question 7c.

Marks	0	1	2	3	Average
%	0.4	0.3	0.1	0.3	1.3



The first mark was awarded for any structure drawn that was a valid isomer of $C_5H_{10}O$.

The second mark was awarded if this structure then had either four carbon environments or three hydrogen environments (i.e. was consistent with the patterns seen in the NMR spectra).

The third mark was awarded only if the student produced a correctly drawn, full structural diagram for the compound 3-methylbutanone.

Question 7d.

Marks	0	1	2	3	Average
%	0.3	0.5	0.1	0.1	0.9

The first mark was awarded for the recognition that the different bonds, or the functional groups, are what is causing the absorption of different frequencies of infrared radiation.

The second and third marks could be obtained from discussion of any two of the following possibilities: strength of bonds / mass of atoms attached to bonds / bond length / bond dipoles / electronegativity differences / different types of molecular vibrations (i.e. stretching, wagging, flexing, etc.).

Question 8a.

Marks	0	1	2	Average
%	0.1	0.3	0.6	1.5

The first mark was awarded for recognising that the surface area of the beans was increased.

The second mark was awarded for reference to any one of the following:

increasing the rate of reaction / ensuring complete combustion / ensuring greater efficiency of combustion.

Question 8b.

Marks	0	1	Average
%	0.5	0.5	0.5

Any of the following: energy content / temperature change of water / final temperature of water.

Just stating 'temperature' was not sufficient to be awarded the mark.

Question 8c.

Marks	0	1	2	Average
%	0.1	0.1	0.9	1.8

The first mark was awarded for the student referring to a step in the procedure and listing the precaution undertaken.

The second mark was awarded for explaining the risk that was being mitigated by that precaution.

For example:

Step 4 – where the precaution was the use of a heatproof mat. The mitigation of risk was explained as the use of a heatproof mat to reduce the chance of the laboratory catching fire.

or

Step 8 – where the precaution was allowing the water to cool to below 30 °C. The mitigation of risk was explained as waiting for the water to cool down to reduce the chance of scalding/burns.

Question 8d.

Marks	0	1	2	3	4	Average
%	0.1	0.2	0.4	0.3	0.03	2.1

The first mark was awarded for the correct calculation of ΔT being $32.1 - 25.0 = 7.1$ °C.

The second mark was awarded for converting the volume of water into a mass of water:

$$m(\text{water}) = 300 \times 0.997 = 299.1 \text{ g}$$

The third mark was awarded for correctly calculating the energy change in the water:

$$q = mC\Delta T = 299.1 \times 4.18 \times 7.1 = 8.88 \text{ kJ}$$

The fourth mark was awarded for correctly calculating the energy content, stated to two significant figures:

$$\text{energy content} = 8.88/1.11 = 8.0 \text{ (kJ g}^{-1}\text{)}$$

Question 8ei.

Marks	0	1	2	Average
%	0.2	0.2	0.6	1.5

The first mark was awarded for correctly calculating the energy content from data:

$$\text{Energy content per 100 g} = (36 \times 17) + (20 \times 37) + (29 \times 16) = 1816 \text{ kJ}$$

The second mark was for awarded for converting this value into kJ g^{-1} :

$$\text{Energy content} = 1816 / 100 = 18 (\text{kJ g}^{-1})$$

A significant number of students incorrectly quoted the energy content as being 1816 kJ g^{-1} , not realising that the masses given were the average quantity per 100 g.

Careful reading of the information given in the stem of a question is always essential.

Question 8eii.

Marks	0	1	2	Average
%	0.7	0.1	0.2	0.5

The first mark was awarded for correctly stating any justifiable error that the student may have made that would produce a higher-than-expected energy content.

The second mark was awarded for explaining how this error would have caused the energy content calculation to be too high. Since energy content is calculated from $\Delta T/\text{mass}$, this could only be achieved if the student mentioned specifically that the error caused the ΔT value being used to be too high, or that the mass used was too low. Some students failed to make this key link.

Typical examples of good responses from students:

'The thermometer may have been resting on the bottom of the can and therefore became much hotter than it should have. This caused the change in temperature to be too high and hence the energy content to be calculated too high.'

'There is no evidence/mention of any stirring taking place and this could have caused localised hot spots resulting in a calculated change of temperature that was too high. This then caused the calculated energy content to be too high.'

Question 8f.

Marks	0	1	2	Average
%	0.4	0.4	0.3	0.9

The first mark was awarded for correctly describing an improvement that had the potential to increase the accuracy of the final answer.

The second mark was awarded for how this improvement would produce a final answer closer to the true value.

Typical examples of good responses from students:

'An improvement could be to ensure better insulation was used on the outside container. This would allow for more energy to be effectively transferred to the water and thus allow for a more accurate ΔT and hence a final energy content that would be closer to the true value.'

'An improvement could be to conduct multiple trials so that outliers could be removed from the data set. This would allow for a final energy content to be calculated that would be closer to the true value.'

Quite a few students incorrectly referred to 'removing the holes in the can', or 'sealing the can to stop heat being lost.' This type of response failed to recognise that this would cause incomplete combustion to occur and would actually decrease the accuracy of the final answer.

Question 8g.

Marks	0	1	Average
%	0.3	0.7	0.7

Any response that referred correctly to the relationship between the energy content of the soybeans and broad beans. A typical correct response was:

'The energy content of the soybeans was higher than the energy content of the broad beans.'

An acceptable answer could have been related to the student recognising the error that had occurred with the soybeans and therefore a valid conclusion could also have been:

'No valid conclusion can be drawn from this experiment due to the experimental error that occurred with the soybean trial.'

Question 9a.

Marks	0	1	2	3	4	5	Average
%	0.3	0.4	0.2	0.1	0.04	0.01	1.2

The first mark was awarded for a correct definition of electrolysis. For example, 'Electrolysis involves passing an electric current through an electrolyte so that a (non-spontaneous) redox reaction can occur.'

The second mark was awarded for the recognition of the redox processes occurring at the impure anode based on the ECS. For example, 'Zn and Pb metals are stronger reductants than Cu and will preferentially undergo oxidation to form $\text{Zn}^{2+}(\text{aq})$ and $\text{Pb}^{2+}(\text{aq})$ ions.'

The third mark was awarded for the recognition that Au(s) would not undergo oxidation. For example, 'As Cu(s) is a much stronger reductant than Au(s), the Cu(s) would be preferentially oxidised to form $\text{Cu}^{2+}(\text{aq})$. (Resulting in the Au(s) falling from this electrode and collecting as anode 'mud'.)

The fourth mark was awarded for the recognition of the redox processes occurring at the cathode based on the ECS. For example, ' $\text{Zn}^{2+}(\text{aq})$ and $\text{Pb}^{2+}(\text{aq})$ ions are weaker oxidants than $\text{Cu}^{2+}(\text{aq})$ and so only the $\text{Cu}^{2+}(\text{aq})$ would be reduced, providing a pure layer of copper metal to be deposited onto the cathode.'

The fifth mark was awarded for the recognition of the voltages needed for these reactions to take place. For example, 'During electrolysis the voltage supplied needs to be high enough for the oxidation of copper metal to occur but less than what would be needed for the oxidation of gold to occur.'

Question 9b.

Marks	0	1	2	3	Average
%	0.4	0.2	0.2	0.2	1.2

The first mark was awarded for the recognition that the charge in coulomb passing through a system is calculated by multiplying the current and time (i.e. $Q = It$).

The second mark was awarded for the recognition that Faraday's constant is used to determine the amount, in mol, of electrons by dividing the charge by Faraday's constant (i.e. $n(\text{e}^-) = Q/F$).

The third mark was awarded for the recognition that for one mole of bromine to be produced two mole of electrons are required, and so $n(\text{Br}_2) = \frac{1}{2} n(\text{e}^-)$. (i.e. $2\text{Br}(\text{l}) \rightarrow \text{Br}_2(\text{g}) + 2\text{e}^-$)