2018 VCE Chemistry examination report

General comments

In the 2018 VCE Chemistry examination, Section A comprised 30 multiple-choice questions and Section B comprised 10 questions. In Section B, questions were a mix of short-answer and extended-answer questions, including questions with multiple parts.

It was evident that some students did not read questions carefully. For example, in Section B, Question 3, students were required to determine the molecular formula of the compound from the IR and NMR spectra provided; however, a number of students provided a molecular formula based on C, H and O. Students are reminded to read the introduction to a question carefully and make effective use of reading time to note specific details.

Specific 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 more or less than 100 per cent.
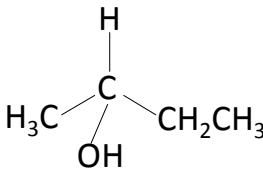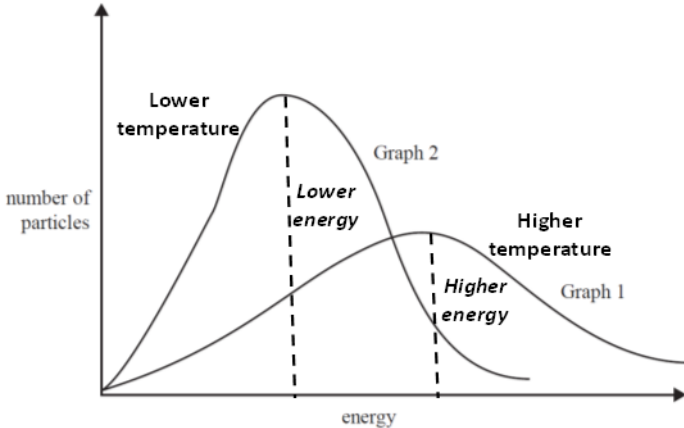
Section A – Multiple-choice questions

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

Question	% A	% B	% C	% D	% No answer	Comments
1	44	33	10	12	0	Electrochemical cells are broadly classified as galvanic, in which electrical energy is generated from chemical reaction(s), or electrolytic, in which electrical energy is used to drive chemical reaction(s). Primary cells and fuel cells show only galvanic action. Secondary cells show both galvanic and electrolytic action. Hence, not all galvanic cells are primary cells. Some secondary cells may have porous electrodes and they are generally more efficient (Li ion – 99%) than fuel cells. Hence, the correct answer was option A.

Question	% A	% B	% C	% D	% No answer	Comments
2	26	9	38	28	0	Aspartame is used as a sugar substitute because it has effectively the same energy content as sucrose (17 kJ g^{-1}) but is 200 times sweeter, so very small amounts are required. Aspartame molecules have a peptide link and an ester link. Aspartame is not a sugar; it is a methyl ester of a dipeptide. Aspartame is hydrolysed into two amino acids and an alcohol.
3	2	2	4	92	0	
4	5	75	11	10	0	Citric acid denatures the protein by disrupting hydrogen bonds holding its coiled (secondary) structure in place. The decrease in pH also causes protonation of some side groups.
5	81	6	6	7	0	
6	63	22	11	3	0	A water bath reduces the likelihood of ignition, and a fume hood reduces the chance of inhalation of ethoxyethane vapour. Option B was incorrect as it did not take into account that exposure to inhalation of organic vapours must be minimised.
7	7	59	9	25	0	• Option A: Vitamin D_2 has a formula $C_{28}H_{44}O$ and vitamin D_3 has a formula $C_{27}H_{44}O$. Hence, they are not structural isomers. • Option B: Vitamin D is non-polar and hence fat soluble. • Option C: Although one polar –OH group is present on each molecule, it is classed as (and behaves as) non-polar because of the extensive hydrocarbon region. • Option D: Vitamin D is manufactured in the body as long as there is some exposure to sunlight/ultraviolet radiation.
8	7	6	80	8	0	Option A: omega-6 Option B: omega-7 Option C: omega-3 Option D: omega-6
9	62	7	28	3	0	$NaCl(l) \rightarrow Na^+(l) + Cl^-(l)$ $Na^+(l)$ ions, cations, move to the cathode, where they are reduced according to $Na^+(l) + e^- \rightarrow Na(l)$ Option C was incorrect because $Cl_2(g)$ is produced at the anode as $Cl^-(l)$ is oxidised according to $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$
10	2	4	12	81	0	$n(CO_2) = 5.68/44.0 = 0.129$ mol $n(C_2H_5OH) = n(CO_2) = 0.129$ mol $m(C_2H_5OH) = 0.129 \times 46.0$ $= 5.94$ g
11	4	75	10	12	0	$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ $\qquad E^0 = 0.80$ V $Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$ $\qquad E^0 = -0.44$ V At the Fe electrode, Fe(s) is oxidised: $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$ At the Ag electrode, $Ag^+(aq)$ is reduced: $Ag^+(aq) + e^- \rightarrow Ag(s)$

Question	% A	% B	% C	% D	% No answer	Comments
12	6	6	49	40	0	Students could have eliminated the following answers: • Option A: Fuel cell electrodes are not reactive. • Option B: The porosity and catalyst impregnation make fuel cell electrodes more expensive to produce than solid electrodes such as graphite. • Option D: Fuel cell electrodes do not allow H_2 and O_2 to react directly. The function of a fuel cell is to convert chemical energy into electrical energy. If the H_2 and O_2 were able to directly react together, no electrical energy would be produced since chemical energy would be converted directly to thermal energy. Hence, option C was the best alternative because fuel cell electrodes have significantly higher surface area than solid electrodes.
13	2	6	9	83	0	
14	4	16	5	75	0	The heat of combustion of methanol was available in the Data Book (Table 11) $\Delta H_c(CH_3CH_2OH) = 726$ kJ mol^{-1} Since combustion is exothermic and there are 2 mol CH_3OH in the equation. $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$; $\Delta H_c = -1452$ kJ mol^{-1}
15	8	69	19	3	0	Fish • energy in 100 g = (8 × 37) + (29 × 17) = 789 kJ Bread • energy in 100 g = (50 × 16) + (4 × 37) + (8 × 17) = 1084 kJ ∴ energy in 80 g = 0.80 × 1084 = 867 kJ Cheese • energy in 100 g = (1 × 16) + (34 × 37) + (25 × 17) = 1699 kJ ∴ energy in 40 g = 0.40 × 1699 = 680 kJ Milk • energy in 100 g = (5 × 16) + (4 × 37) + (3 × 17) = 279 kJ ∴ energy in 258 g = 2.58 × 279 = 720 kJ
16	60	7	21	11	0	Recharging equation $ZnO + 2Ag \rightarrow Zn + Ag_2O$ Ag is oxidised to Ag_2O; ZnO is reduced to Zn. Oxidation at the anode: $2Ag + 2OH^- \rightarrow Ag_2O + H_2O + 2e^-$
17	56	13	26	4	1	$n(KMnO_4) = 0.0200 \times 21.7 \times 10^{-3}$ $\qquad = 4.34 \times 10^{-4}$ mol $n(H_2C_2O_4) = 5/2 \times n(KMnO_4)$ $\qquad = 5/2 \times 4.34 \times 10^{-4}$ $\qquad = 1.09 \times 10^{-3}$ mol $c(H_2C_2O_4) = 1.09 \times 10^{-3}/20.00 \times 10^{-3}$ $\qquad = 5.43 \times 10^{-2}$ mol L^{-1} Selection of option C reflected not using the ratio $n(C_2O_4^{2-})/n(MnO_4^-) = 5/2$ in the calculation of the $n(H_2C_2O_4)$.

| Question	% A	% B	% C	% D	% No answer	Comments
18	12	8	13	67	0	Pipettes and burettes should be rinsed with the solution being transferred from them. Flasks should be rinsed with distilled water. Only the conical flask was rinsed correctly.
19	5	7	71	16	0	A chiral carbon is bonded to four different atoms/groups of atoms.
20	41	14	9	36	0	Students who selected option D may not have considered the distribution curves closely enough. They may have overlooked either the relative positions of Graph 1 and Graph 2 (i.e. did not realise the change was right to left from the Graph 1 to Graph 2) or the fact that energy was on the horizontal axis.
21	6	78	3	13	0	Propan-1-ol and octan-1-ol both have a single –OH group and have both hydrogen bonding and dispersion forces as intermolecular attraction. Octan-1-ol has stronger intermolecular bonding due to its molecules having a larger hydrocarbon tail than propan-1-ol. Octan-1-ol has higher density and a higher boiling point than propan-1-ol.
22	8	13	70	9	0	Energy absorbed by water $= 4.18 \text{ J g}^{-1}\,^{\circ}\text{C}^{-1}$ $= 4.18 \times 1000 \times 60.0$ $= 2.51 \times 10^5 \text{ J}$ $= 251 \text{ kJ}$ Consider the options: Option A: $0.889 \text{ g H}_2 \rightarrow 0.889 \text{ g} \times 141 \text{ kJ g}^{-1} \rightarrow 125 \text{ kJ}$ Option B: $3.95 \text{ g C}_3\text{H}_8 \rightarrow 3.95 \text{ g} \times 50.5 \text{ kJ g}^{-1} \rightarrow 199 \text{ kJ}$ Option C: $0.282 \text{ mol CH}_4 \rightarrow 0.282 \text{ mol} \times 890 \text{ kJ g}^{-1} \rightarrow 251 \text{ kJ}$ Option D: $0.301 \text{ mol CH}_3\text{OH} \rightarrow 0.301 \text{ mol} \times 726 \text{ kJ g}^{-1} \rightarrow 219 \text{ kJ}$

For Question 19 comment:

For Question 20 comment:

Question	% A	% B	% C	% D	% No answer	Comments
23	15	6	6	73	0	Petrodiesel molecules are non-polar, whereas biodiesel molecules have a degree of polarity because of the carbonyl C=O in the ester group in each molecule. Consequently, petrodiesel is less hygroscopic than biodiesel. Intermolecular bonding in petrodiesel is only dispersion force attraction, but intermolecular attraction in biodiesel is a combination of dispersion force and dipole–dipole attraction. Consequently, petrodiesel is less viscous than biodiesel. Petrodiesel is derived from fossil fuels, whereas biofuels are produced from plant and animal fats and oils. Consequently petrodiesel is less biodegradable than biodiesel.
24	71	10	11	8	0	Temperature decrease will increase yield if the forward reaction is exothermic. Pressure increase will increase yield if there are fewer particles on the product side of the equation since the system responds to a pressure increase, and returns to equilibrium, by favouring the reaction, which reduces the total number of particles. Only option A was consistent with this behaviour.
25	9	57	16	18	0	$n(C_5H_{11}OH) = 10800 \times 10^3$ kJ / 3329 kJ mol^{-1} $= 3.244 \times 10^3$ mol $m(C_5H_{11}OH) = 3.244 \times 10^3$ mol $\times 88.0$ g mol^{-1} $= 2.85 \times 10^5$ g $= 285$ kg $= 0.285$ tonnes
26	11	23	30	34	1	Both the acid-base titration (to determine total acid concentration) and the redox-titration (to determine ascorbic acid concentration) are required. In the acid-base titration, the pH at the equivalence point will be above 7 since the weak acid is usually titrated with a strong base. Hence, the phenolphthalein is the most appropriate indicator from those suggested. Therefore, the best reponse was option D.
27	15	20	59	6	0	$Br_2(g) + I_2(g) \rightleftharpoons 2IBr(g)$ $\qquad K_c = 1.2 \times 10^2$ Reverse equation – take reciprocal of the value of the equilibrium constant $2IBr(g) \rightleftharpoons Br_2(g) + I_2(g)$ $\qquad K_c = 1 / 1.2 \times 10^2$ Double coefficients – square the value of the equilibrium constant $4IBr(g) \rightleftharpoons 2Br_2(g) + 2I_2(g)$ $\qquad K_c = (1 / 1.2 \times 10^2)^2$ $= 6.9 \times 10^{-5}$ Option B was incorrect because it was consistent with dividing by 2 rather that raising to the power of 2.

Question	% A	% B	% C	% D	% No answer	Comments
28	21	11	57	11	0	α-amino acid molecules have the $-NH_2$ (amino) and $-COOH$ (carboxyl) groups bonded to the same C atom. The side groups are also attached to that same C atom. A peptide bond forms when the α-COOH group of one amino acid (cysteine) molecule reacts with the α-NH_2 group of another amino acid (methionine) molecule. Option C was the only option in which the dipeptide was formed from the reaction between an α-NH_2 group and an α-COOH group. Option A would be formed from two α-amino acids. However, the amide group was formed by reaction between the α-NH_2 group on alanine and the side chain $-COOH$ on aspartic acid. Options B and D both contained one amino acid in which the $-NH_2$ and $-COOH$ groups were separated by two carbons rather the one carbon characteristic of α-amino acids.
29	7	10	61	23	0	In each half-cell, electrons move from the (−) electrode to the (+) electrode. So in each cell the E^0 value of the half-cell containing the (−) electrode is lower than the E^0 value of the half-cell containing the (+) electrode. So, for the three cells shown: $E^0(Q/Q^{2+}) < E^0(G/G^{2+})$ $E^0(J/J^{2+}) < E^0(Q/Q^{2+})$ $E^0(R/R^{2+}) < E^0(J/J^{2+})$ From this, the order of increasing E^0 values can be deduced to be $E^0(R/R^{2+}) < E^0(J/J^{2+}) < E^0(Q/Q^{2+}) < E^0(G/G^{2+})$ Option D showed the correct sequence of half-cells but in order of decreasing E^0 values.
30	11	53	23	12	0	Consider the options: • Option A was incorrect: water is a reactant, not a product, in hydrolysis reactions. • Option B was correct: $n(CO_2) = 3.3 \text{ g}/44.0 \text{ g mol}^{-1} = 0.075 \text{ mol}$ From equation 32 mol $ADP^{2-} \rightarrow$ 6 mol CO_2 $n(ADP^{2-}) = 32 \times 0.0075/6$ $= 0.40 \text{ mol}$ • Option C was incorrect: the stem of the question stated 'energy is used in the production of ademine triphosphate, ATP^{3-} from ADP^{2-}, and inorganic phosphate, PO_4^{3-}'. • Option D was incorrect: $n(C_6H_{12}O_6) = 9.5/180 = 0.0538 \text{ mol}$ $n(ATP^{3-}) = 32 \times 0.0538 = 1.7 \text{ mol}$

Section B

Question 1ai.

Marks	0	1	Average
%	22	78	0.8
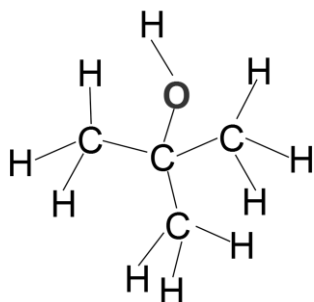
The most common error was not showing the O–H bond. Missing and/or extra H atoms was also relatively common.

Question 1aii.

Marks	0	1	Average
%	26	74	0.8

C_4H_6

The molecular formula shows the symbol and numbers of atoms of each element present in the molecule only. Structural or semi-structural formulas were not appropriate.

Question 1aiii.

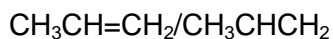| Marks	0	1	Average
%	73	27	0.3

2,3-dibromo-4-methylhexane

The following logical steps in determining nomenclature proved challenging for many students:

* longest carbon chain – 6 – hence, hexane
* number carbons to give functional groups lowest possible numbers – 2,3-dibromo; 4-methyl

This question was not answered well, suggesting that systematic naming of compounds is an area needing further attention.

Question 1bi.

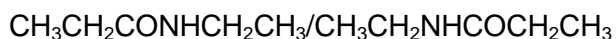| Marks	0	1	Average
%	46	54	0.6

$CH_3CH=CH_2/CH_3CHCH_2$

Question 1bii.

Marks	0	1	Average
%	52	48	0.5

- $Cr_2O_7^{2-}(aq)/H^+(aq)$
- $K_2Cr_2O_7(aq)/H^+(aq)$
- $MnO_4^-(aq)/H^+(aq)$
- $KMnO_4(aq)/H^+(aq)$

While most students were aware that acidified dichromate or acidified permanganate was the required reagent, a significant number of students provided incomplete or inaccurate formulas.

Question 1biii.

Marks	0	1	Average
%	53	47	0.5

$CH_3CH_2CONHCH_2CH_3/CH_3CH_2NHCOCH_2CH_3$

Common errors included incorrect representation of the amide group and the inclusion of extra O or H atoms.

Question 2a.

Marks	0	1	2	3	Average
%	13	25	40	21	1.7

The following are the key points for which marks were awarded:

- increase in rate
- increase in temperature increases the average kinetic energy of all molecules, leading to increased frequency of collisions/increased number of collisions per second and increased energy of collisions
- increase in temperature leads to an increased proportion (percentage/ratio) of (total) collisions that are successful, i.e. collisions with energy greater than the activation energy.

This question was generally well answered. Many responses that were not awarded full marks did not make the 'time' link and simply referred to an increased number of collisions rather than increased frequency of collisions.

The increased proportion of collisions that are successful is a significant factor in the effect of temperature increase on reaction rate. Other factors such as increased concentration and surface area also increase the frequency of collisions that are successful, but only increased temperature and the introduction of a catalyst increase the proportion of collisions that are successful.

Some students attempted to apply equilibria and Le Chatelier's principle to answer this question, despite the reaction being irreversible and being directed to answer the question in terms of collision theory. This was linked to students trying to incorporate the exothermic nature of the reaction into their responses.

Question 2b.

Marks	0	1	Average
%	8	92	0.9

MnO_2 acts a catalyst/lowers activation energy.

Question 2c.

Marks	0	1	2	Average
%	47	31	22	0.8

1.00 L $H_2O_2(aq) \rightarrow$ 10.0 L O_2 at standard laboratory conditions

$n(O_2)$ = 10.0/24.8

$\quad$ = 0.403 mol

$n(H_2O_2)$ = 2 × $n(O_2)$ = 0.806 mol

$m(H_2O_2)$ = 0.806 × 34.0

$\quad$ = 27.4 g

$c(H_2O_2)$ = 27.4 g L^{-1}

This question proved challenging for some students, who did not take into account the stated fact that '1.00 L of this solution produces 10.0 L of O_2'.

Common calculation errors included overlooking the mole ratio $2H_2O_2(aq) \rightarrow O_2(g)$ indicated in the equation, assuming there was 1000 g H_2O_2 in 1.00 L of $H_2O_2(aq)$ and not using V_m at standard laboratory conditions, as well as incorrect molar mass for H_2O_2 and incorrect concentration units.

Question 2d.

Marks	0	1	2	3	Average
%	43	24	22	11	1

Effective responses to this question included:

- using a known amount of H_2O_2 solution
- an appropriate quantity measured at time intervals or over a set time
- how the quantity was measured at time intervals or over a set time.

For example:

- Take a known amount (mass or volume) of H_2O_2 solution.
- Measure the $V(O_2)$ produced over time.
- Use gas syringe or appropriate gas collection apparatus.

Such a method would provide a qualitative indication of the rate of decomposition, but the amount of O_2 produced could be used to calculate the $n(H_2O_2)$ reacted over a set time to determine a quantitative rate of decomposition.

Other methods might include:

- measure the change in mass of a known amount of $H_2O_2(aq)$ using electronic balance
- measure the change in pH of $H_2O_2(aq)$ using a pH meter.

The methods listed above were all based on the temperature being a controlled variable. Some students interpreted the question as 'determining how quickly the solution decomposes at different temperatures', which was incorrect.

High-scoring responses also described graphing the quantity change against time and using the gradient of the graph as an indication of the rate of decomposition.

Question 3a.

Marks	0	1	Average
%	14	86	0.9

2956 cm^{-1} C–H

3376 cm^{-1} N–H

Some students identified one of the bonds as O–H despite the question stating 'a chemical contains carbon, C, nitrogen, N, and hydrogen, H'.

Question 3bi.

Marks	0	1	2	Average
%	21	22	57	1.4

$C_4H_{11}N$

The highest m/z (mass/charge) ratio on the spectrum is 73; hence, the parent ion has a relative mass of 73, consistent with parent molecule $C_4H_{11}N$.

A significant number of students did not refer to the m/z ratio of 73 on the mass spectrum. Some were not awarded a mark for the molecular formula because they included a positive charge.

Question 3bii.
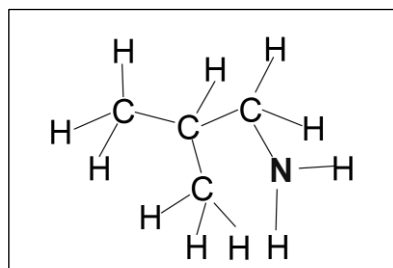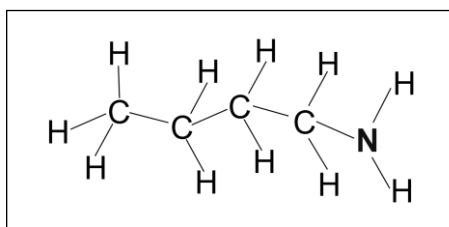
Marks	0	1	Average
%	50	50	0.5

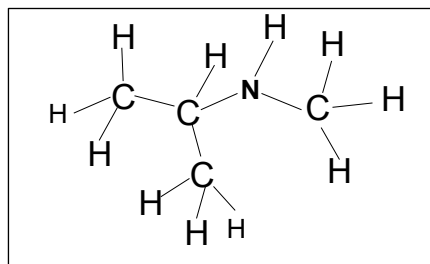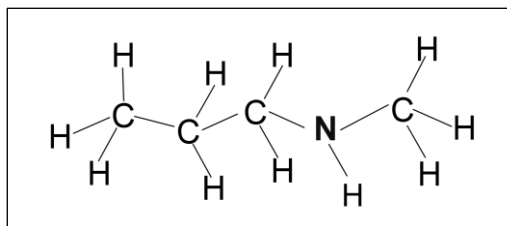$[CH_2NH_2]^+$/$CH_2NH_2^+$/CH_4N^+, etc.

Incorrect responses to this question indicated that some students could not distinguish between the base peak and the parent ion peak. The lack of a positive charge on the formula of the fragment was also relatively common.

Question 3biii.

Marks	0	1	2	Average
%	22	7	70	1.5

Possible structural formulas included:

This question was generally answered well. Most students were able to present two structures but some were missing atoms, some included the incorrect numbers of atoms and some repeated structures.

Question 3ci.

Marks	0	1	2	Average
%	12	31	57	1.5

20.0 $R-CH_3$ / $R-CH_2-R$

50.2 R_3C-NH_2 / R_3C-NR

This question was answered well by many students. However, some did not link the chemical shift to the presence of nitrogen in the compound.

Question 3cii.

Marks	0	1	2	Average
%	60	29	11	0.5

One of:
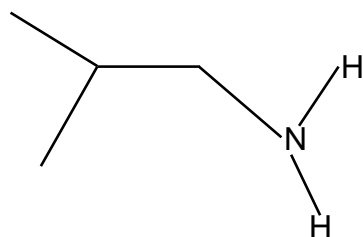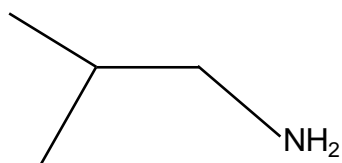
Students were awarded marks for:

- a skeletal structure with four C atoms
- the presence of three C environments including two CH_3 groups.

Most students struggled to produce a structure that was both skeletal and consistent with the information given in the question, notably the presence of 4 C atoms in the molecular formula and 3 carbon environments as suggested by the ^{13}C spectrum.

Students should be able to represent organic molecules in any of the four forms shown in Table 8 of the Data Book.

Some responses indicated that some students thought there was an extra C atom in the —NH_2 link, i.e. seeing it as C—CNH_2 rather than C—NH_2.

Students should be able to deduce the skeletal structure from the semi-structural formula $(CH_3)_2CHCH_2NH_2$ and vice versa.

Question 4a.

Marks	0	1	Average
%	72	28	0.3
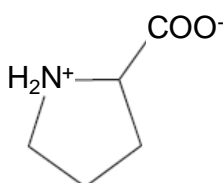
This question was not answered well. Many students struggled to correctly utilise the structure of proline, with attempts to draw out its full structure unnecessary and generally unsuccessful.

Converting the amino acid to its zwitterion involves protonating the amino group and deprotonating the carboxyl group. In proline this involves converting NH to $^+NH_2$ and COOH to COO^-. Many students seemed unsure how to deal with the NH.

Some who did protonate the NH did not show that the positive charge was on the N atom as in $^+NH_2$.

Question 4b.

Marks	0	1	2	3	Average
%	36	24	27	13	1.2

• Vitamin C binds to the surface of the inactive enzyme (protein) and changes the shape of the active site.
• The substrate is now able to attach to the active site and the reaction can be catalysed.
• In this synthesis ascorbic acid is oxidised during oxidation and reformed during reduction steps; hence, acting as an electron carrier/acts as a reductant by donating electrons to the enzyme substrate complex to facilitate reaction.

This question was challenging for some students. The question specifically referred to the 'physical and chemical interactions of vitamin C with the enzyme', but responses generally showed that this requirement was not interpreted well.

Reiteration of words in the stem of the question, for example, 'electron donor', was not an appropriate response for chemical interactions. Most students could not link this to redox activity/reducing behaviour or electron carrier properties of vitamin C.

While many students stated that that the coenzyme binds to the enzyme or active site of the enzyme, they did not elucidate the effect on the active site or substrate attachment. An annotated diagram might have been quite effective.

Question 4ci.

Marks	0	1	Average
%	52	48	0.5

Optical isomers are:

- two or more forms of a compound that have the same structure but are mirror images of each other and differ in optical activity
- forms of a compound that have the same bonds but have non-superimposable mirror images/are enantiomers
- compounds with the same semi-structural formula but that rotate plane polarised light in different directions
- compounds with the same semi-structural formulas that contain chiral carbons and are non-superimposable/rotate plane of polarised light to different extents
- compounds that have structures that are mirror images of each other and show opposite optical activity/rotate (the plane of) polarised light in opposite directions.

While students generally answered this question well, there was room for improvement in general understanding of types of isomers and associated structure variations.

Some students gave incorrect responses such as isomers that exist as cis or trans, molecules that have double bonds or molecules that rotate when light is present.

Structural isomers have different bonds. Optical isomers and geometric isomers (e.g. cis and trans) that are stereoisomers have the same bonds but different arrangements, but only optical isomers show optical activity.

Question 4cii.

Marks	0	1	2	Average
%	51	23	27	0.8

- The ability of the coenzyme to attach to the enzyme (active site) depends on the coenzyme having a (complementary) shape that allows it to bind to the original shape of the active site.
- The enzyme has a specific shape (spatial geometry) that only matches up with L-ascorbic acid.
- Different optical isomers have different spatial arrangement of the atoms and so do not match up with the enzyme.
- The arrangement of atoms that allows for effective binding to the surface of the enzymes in the body is not present in the other optical isomers (mirror images) of ascorbic acid.

This question assessed understanding that molecular shape/geometry was integral to the suitability of a substance to act as a coenzyme for a particular enzyme. While many students provided high-scoring responses, others struggled to provide an explanation beyond an initial statement such as 'L-ascorbic acid has a specific structure'. These students did not frame their answer in terms of the L-ascorbic acid being able to bind to the original shape of the active site, while other isomers were unable to bind because of the variation in their shape geometries.

Question 4d.

Marks	0	1	2	Average
%	41	32	27	0.9

Unsaturated fats contain C=C double bonds (compared to saturated fats, which contain only single C–C bonds). Hence, unsaturated fats are more reactive (than saturated fats)/oxidise more

readily/can produce (propagate) free radicals in the presence of oxygen. Vitamin C inhibits this reactivity.

High-scoring responses referred to unsaturated fats containing carbon-to-carbon double bonds, and the susceptibility of these bonds to undergo oxidation or oxidative rancidity more readily than saturated fats that contained carbon-to-carbon single bonds. Many students stated that unsaturated fats contain double bonds without specifying C=C double bonds. Students should be aware that fats also contain C=O double bonds.

Some students confused reactivity with melting point, i.e. they thought the 'kinks' in the unsaturated molecules prevented them from close packing and so made them more likely to require vitamin C as the 'bonds were easier to break'.

Question 5a.

Marks	0	1	2	Average
%	14	60	26	1.2

Q – glucose, R – glycerol

The fact that glucose and galactose had retention times only 0.9 minutes apart, the fact that peak Q leaned slightly to the left and the limited number of indications on the horizontal axes all added a significant challenge to the identification of the substance causing peak Q. Students should be aware that to determine retention time, a vertical line should be drawn from the top of the peak to the horizontal axis. A ruler may be useful in such determinations.

Question 5b.

Marks	0	1	2	3	Average
%	47	24	20	9	0.9

- Retention time reflects the relative attraction of an analyte (molecule) to the stationary and mobile phases/interaction between the molecule and the mobile and stationary phases.
- Retention time is dependent on the ability of a compound to adsorb to the stationary phase and desorb into the mobile phase.
- The stronger the attraction between the analyte and the stationary phase (or the lower its solubility in the mobile phase), the higher the retention time.

Difference in retention times may be due to:

- a larger molecule will be more strongly attracted (dispersion forces) to a non-polar stationary phase and have a higher retention time than a smaller molecule
- a polar analyte will be more strongly attracted to a polar stationary phase than a non-polar analyte
- a compound with multiple –OH groups would be more strongly attracted to a polar stationary phase and have a higher retention time than a compound with a single –OH group.

This question proved to be challenging for most students. Many students tried to relate the question specifically to the data provided on retention times and struggled more than those who focused on the general principles of chromatography with respect to retention times.

Question 5ci.

Marks	0	1	2	3	Average
%	37	25	23	15	1.2

m(cellulose) = 0.37 × 1000 = 370 kg

m(ethanol) produced = 0.79 g mL^{-1} × 144 × 10^3 mL

$$= 1.14 \times 10^5 \text{ g}$$

$$= 114 \text{ kg}$$

% yield ethanol = (114 / 370) × 100

$$= 31 \text{ \%}$$

The wide range of errors on this question suggested that assimilation of the data provided posed a significant challenge for many students. Common errors included assuming 1000 kg glucose, assuming 144 L of ethanol was equivalent to 144 kg, inconsistent units when calculating m(CH$_3$CH$_2$OH) using its density, inaccurate use of the density when using m = d × V and not presenting the final answer to three significant figures.

Students should be aware that they may encounter different contexts, but the fundamental calculation skills should be familiar.

Question 5cii.

Marks	0	1	Average
%	58	42	**0.4**

Energy = 114 × 10^3 g × 29.6 kJ g^{-1} or 114 kg × 29.6 × 10^3 kJ kg^{-1}

$$= 3.4 \times 10^6 \text{ kJ}$$

Question 5d.

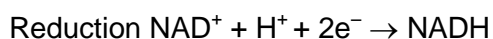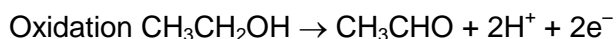| Marks	0	1	2	Average
%	51	23	26	**0.8**

Both:

- Ethanol molecules contain polar –OH groups, hence there is hydrogen (dipole–dipole) bonding between ethanol molecules, which is stronger than dispersion forces between non-polar petrol molecules.
- The inclusion of ethanol and its stronger intermolecular bonds increase fuel viscosity or The attraction of ethanol molecules to both petrol (by dispersion force attraction) and other ethanol molecules (by hydrogen bonding) increases viscosity.

Many students recognised the significance of the presence of the –OH group in ethanol molecules, but struggled to link that to the higher viscosity of E10.

Question 6ai.

Marks	0	1	2	Average
%	49	13	38	**0.9**

Oxidation CH$_3$CH$_2$OH $\rightarrow$ CH$_3$CHO + 2H$^+$ + 2e$^-$

Reduction NAD$^+$ + H$^+$ + 2e$^-$ $\rightarrow$ NADH

Question 6aii.

Marks	0	1	Average
%	32	68	0.7

CH_3CH_2OH/ethanol

Students should have been aware that CH_3CH_2OH is oxidised to CH_3CHO. Consequently, NAD^+ to NADH had to be reduction. Students should be aware of the steps in balancing half-equations.

Question 6bi.

Marks	0	1	Average
%	13	87	0.9

(+) Cu electrode, (–) Zn electrode

Question 6bii.

Marks	0	1	Average
%	19	81	0.8

1.10 V

Question 6biii.

Marks	0	1	Average
%	27	73	0.8

Left to right

Question 6biv.

Marks	0	1	2	Average
%	24	27	49	1.3

Acceptable responses included two of:

- Zn electrode decreases in size
- Cu electrode increases in size (is coated)
- Cu^{2+} solution becomes less blue (paler blue)/fades
- voltage or current drops.

Mass changes were a relatively common response but were not considered to be 'visible'.

Some responses indicated issues with effective use of the electrochemical series in identifying what was happening in the half-cells.

Question 6c.

Marks	0	1	2	Average
%	45	42	13	0.7

- The two half-cells are separated so that electrons can flow through the connecting wire.
- The two half-cells are connected via a salt bridge to complete the circuit and allow electrons to flow through the connecting wire.

While most students could identify the separation of the half-cells and the role of the salt bridge as a key design feature, few were able to identify another. A significant number did not consider half-cell separation even though this is essential to getting electrical rather than heat energy. Responses such as 'has an anode and a cathode' or 'oxidation occurs at the anode', while correct statements, are not design features unique to this galvanic cell.

Question 7a.

Marks	0	1	2	3	Average
%	26	17	28	29	**1.6**

- The gas mixture goes darker brown.
- The forward reaction is exothermic ($\Delta H < 0$), hence the reverse reaction is favoured at higher temperatures.
- As the reverse reaction is favoured, $[NO_2]$ increases and so the equilibrium mixture is darker at higher temperature.

This question was generally answered well. Some students interpreted $\Delta H < 0$ to mean that the forward reaction was endothermic and argued consequently that the colour would go a lighter brown. Such responses, if coherent, could access partial marks. Statements such as the colour of the gas mixture turns brown, becomes brown, changes from colourless to brown, etc., were not acceptable because the initial equilibrium mixture contains both the brown NO_2 and the colourless N_2O_4.

Some students correctly noted that increasing the temperature at constant volume would increase the pressure in the sealed tube. They then tried to argue, using Le Chatelier's principle, that the system would favour the forward reaction to try to decrease the pressure. This argument is invalid since the concentration fraction is initially unaffected by the change. The system is out of equilibrium because the increased temperature has decreased the value of the equilibrium constant and hence it is no longer equal to the concentration fraction. The system favours the back reaction in order to decrease the concentration fraction. Le Chatelier's principle only applies to a pressure change if it is a result of a change to the volume of the system.

Question 7bi.

Marks	0	1	2	Average
%	22	48	30	**1.1**

$K = [N_2O_4] / [NO_2]^2$

$\quad = 1.5 \times 10^{-2}/(5.0 \times 10^{-2})^2$

$\quad = 6.0 \ M^{-1}$

Most students identified the equilibrium law but many either misread the concentrations from the graph or did not include the appropriate unit for the value of the equilibrium constant. The ability to read graphical data accurately is a fundamental skill.

Question 7bii.

Marks	0	1	2	3	Average
%	30	28	20	21	**1.4**
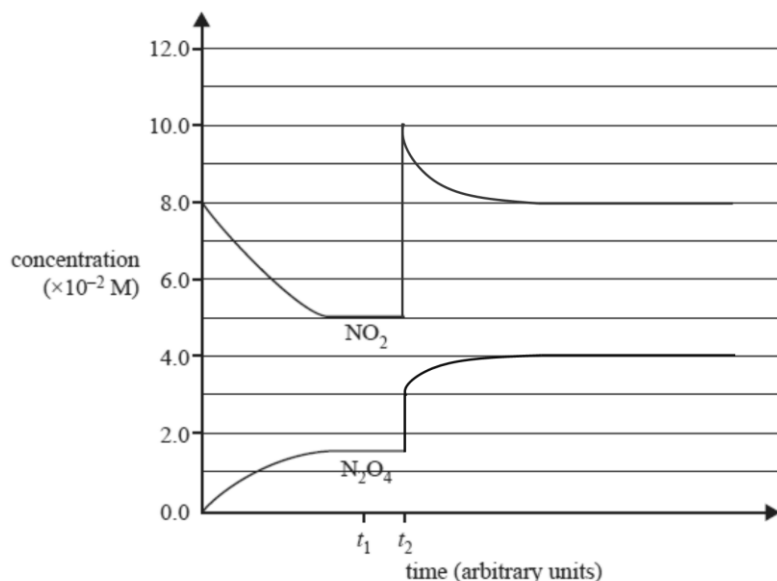
Students were awarded one mark each for:

- showing $[NO_2]$ doubled to $10.0(\times 10^{-2})$ M and $[N_2O_4]$ doubled to $3.0(\times 10^{-2})$ M
- showing subsequent adjustments in correct directions, NO_2 decrease and N_2O_4 increase
- showing change in $[NO_2]$ double that of N_2O_4 during return to equilibrium.

Students were not expected to determine the exact concentrations at which the system returned to equilibrium.

Question 8ai.

Marks	0	1	Average
%	41	59	**0.6**

Negative/(–)

Many students did not make the link between H_2 in the fuel cell where it is oxidised at the negative electrode and the 'like connects to like' connection to the electrolysis cell. Also, in the electrolysis of water, reduction (to produce H_2) occurs at the negative electrode.

Question 8aii.

Marks	0	1	Average
%	66	34	**0.4**

$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$
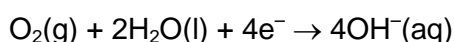
The frequency of the half-equation for an acidic environment suggested that many students copied the first O_2 reduction half-equation on the electrochemical series rather than considering the significance of the alkaline electrolyte.

Even though equilibrium arrows were shown on the electrochemical series – to indicate that, depending on the combination of oxidant and reductant, both directions are possible – they are not appropriate for cell-specific half-equations.
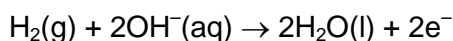
Question 8bi.

Marks	0	1	2	3	Average
%	19	21	49	12	**1.6**

$Q = It = 5.20 \times (8 \times 60 \times 60) \times 4$

$\qquad = 5.99 \times 10^5$ C

$\quad n(e^-) = Q / F = 5.99 \times 10^5/96\ 500$

$\qquad\qquad = 6.21$ mol

$H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$

$n(H_2) \quad = 6.21/2$

$\qquad\quad = 3.10$ mol

Marks were awarded for the accurate calculations of Q, n(e⁻) and n(H₂⁻).

Common errors associated with solutions to this question included:

- ignoring the fact that there were 4 solar cells
- not converting time into seconds in the calculation of Q
- assuming, incorrectly, that the n(H₂) was the same as the n(e⁻).

The eight-hour period indicates that this quantity was not a factor in determination of the appropriate number of significant figures. The current of 5.20 A was the determining factor in the answer having three significant figures.

Question 8bii.

Marks	0	1	Average
%	45	55	**0.6**

$p = nRT / V$

$\quad = 3.10 \times 8.31 \times 298/10.0$

$\quad = 769$ kPa

The most logical approach to this question was to calculate the pressure exerted at 25 °C in a 10.0 L container by 3.10 L of H₂ using the general gas equation.

Question 8ci.

Marks	0	1	2	Average
%	38	34	28	**0.9**

m(petrodiesel) at 100 per cent efficiency

$\qquad\qquad = 3553$ kJ/45 kJ g^{-1}

$\qquad\qquad = 79$ g

At 35% efficiency:

m(petrodiesel) $= 79$ g/0.35

$\qquad\qquad = 2.3 \times 10^2$ g

Alternatively:

Energy = 3553/0.35

$$= 1.02 \times 10^4 \text{ kJ}$$

m(petrodiesel) = 1.02×10^4/45.0

$$= 2.3 \times 10^2 \text{ g}$$

Students needed to accurately divide the energy by 0.35 (or 35/100) and 45. While most students were able to execute one of these requirements, a significant number did not realise that kJ/kJ g^{-1} gives the mass in grams.

Question 8cii.

Marks	0	1	2	Average
%	38	14	48	**1.1**

n(C$_{12}$H$_{24}$) = 2.3×10^2/168

$$= 1.34 \text{ mol}$$

n(CO$_2$) $= 12 \times n$(C$_{12}$H$_{24}$) $= 12 \times 1.34$

$$= 16.1 \text{ mol}$$

m(CO$_2$) $= 16.1 \times 44.0$

$$= 709 \text{ g (640 g)}$$

Students were required to calculate the n(CO$_2$) from the m(petrodiesel) determined in part ci. A significant number did not recognise that 1 mol C$_{12}$H$_{24}$ will produce 12 mol CO$_2$.

Question 8ciii.

Marks	0	1	Average
%	34	66	**0.7**

The amount of CO$_2$ from the combustion of petrodiesel is greater since the H$_2$-O$_2$ fuel cell does not produce CO$_2$.

Question 9a.

Marks	0	1	Average
%	49	51	**0.5**

Calibration method

Question 9b.

Marks	0	1	Average
%	57	43	**0.5**

An error associated with calibration or inaccuracy of voltmeter/ammeter/power supply (voltage), etc., or with electrical connections

The question specified a systematic error that applies only to the electrical method of calibration. These were errors associated with reading of the current or voltage where it was consistently inaccurate, or obtaining a current or voltage below/above the required value due to faulty wires. No marks were awarded if students referred to an error common to both calibration methods such as the reading of the stopwatch or timer, or the reading of the same thermometer.

Question 9c.

Marks	0	1	2	Average
%	70	22	8	0.4

Possible limitations that affect accuracy but not reliability included:

- temperature not stabilised before KNO_3 added
- no indication of how long to record temperature
- purity of KNO_3
- not all KNO_3 may have been transferred
- limitations that affect reliability
- only one set of data collected
- the exercise was not repeated.

Reliability would be improved by repeating the exercise or sharing data.

Students were awarded marks for:

- identifying a relevant limitation
- explaining how the limitation affects reliability or stating that reliability will improve if the experiment is repeated.

This question was challenging for many students. Most responses referred to the accuracy of the results but few demonstrated understanding of what makes results reliable. The large number of students who referred to limitations of the electrical calibration suggested that chemical calibration of a calorimeter was a relatively unfamiliar procedure.

Question 9d.

Marks	0	1	2	Average
%	15	47	37	1.2

Differences

- Student A (25 °C) reached a higher maximum temperature than Student B (24 °C).
- Student A reached maximum temperature later (450 s) than Student B (390 s).
- Student A heated water for longer than Student B.

Reasons

- Student A turned the power/current/voltage off later that Student B, so reached higher temperature.
- Student B turned the power/current/voltage off earlier than Student A, so reached lower temperature.
- Different calorimeters were used so there were different levels of energy absorption by components.

Marks were awarded for one clear difference between the graphs and a valid variation in technique that accounts for difference.

This question was generally answered well.

Question 9e.

Marks	0	1	2	3	Average
%	24	28	21	26	1.5

$n(KNO_3) = 3.0/101.1$

$= 0.030$ mol

Energy released $= 0.030 \times 35$

$= 1.04$ kJ or 1.04×10^3 J

$\Delta T = 23.6 - 22.0 = 1.6$ °C

Calibration factor $= 1.04$ kJ/1.6 °C^{-1} or 1.04×10^3 J/1.6 °C^{-1}

$= 0.649$ kJ °C^{-1}

$= 649$ J °C^{-1}

$= 6.5 \times 10^2$ J °C^{-1}

A significant proportion of students defaulted to the electrical calibration and used E = VIt to determine the energy released. This was further evidence that many students were unfamiliar with chemical calibration.

$\Delta T = 23.5 - 22.0 = 1.5$ °C, giving calibration factor 6.9×10^2 J °C^{-1}, was also accepted.

Question 10a.

Marks	0	1	2	3	4	Average
%	37	20	25	15	3	1.3

Triglyceride structure
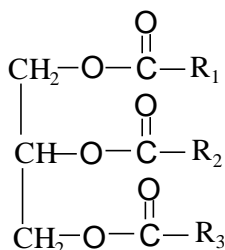
R_1, R_2, R_3 are from associated fatty acids.

Reaction types – metabolism of fats and oils

Digestion/Hydrolysis

- hydrolysis reaction in which water reacts with ester groups on triglycerides to produce glycerol and three fatty acids: R_1COOH, R_2COOH, R_3COOH (in the presence of lipase)

Condensation

- Fats formed (in the liver) for storage.
- Glycerol reacts with three fatty acid molecules to produce fat molecules and water.

Oxidation

- Energy is released when fatty acids are oxidised to produce CO_2 and H_2O.
- Bile is used to emulsify fats so that the triglycerides can undergo hydrolysis as the first step in the metabolism.

To access full marks students needed to address both dot points in the question.

The triglyceride structure was not well represented, with many students unable to show the correct structure and/or location of the ester groups. Many students were able to identify the types of

reactions, but did not fully demonstrate their knowledge of the chemistry by indicating the changes that occur in those reactions.

Question 10b.

Marks	0	1	2	3	Average
%	32	28	27	14	1.3

Larger pieces have the lower glycaemic index (GI).

- Glycaemic index is based on how readily glucose is released into/accessed by the body/blood. The more quickly the glucose is released, the higher the GI.
- GI is higher for shredded coconut because the high surface area provides greater access for H_2O molecules and enzyme action, and so increases the rate of digestion. Hence, large pieces of coconut have lower GI.

Students who attempted this question generally answered parts of it well. Many responses overlooked the significance of surface area in the release of glucose and hence GI. There were indications that some students assumed that the form in which the coconut was consumed was not a factor.