2017 VCE Chemistry examination report

General comments

The 2017 Chemistry examination was the first examination for the *VCE Chemistry Study Design 2017–2020*.

Most of the questions in Section A were associated with calculations, interpretation of data and electrochemistry.

Students are reminded that data interpretation and associated calculations are important components of VCE Chemistry.

Many students struggled with questions in Section B, particularly Questions 8, 9 and 10. Particular issues associated with these questions are discussed in detail in the body of the report. Students should be aware that there is a fundamental requirement to be able to apply their learned knowledge and understanding to any context that appears on an examination.

Fundamental to chemistry is an understanding of structure and bonding. Overall performances on questions where students were required to discuss structure and bonding – namely Questions 2a., 3b. and 7a. – suggested that further attention to these areas is required.

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	1	0	3	96	0	
2	22	40	29	9	0	Around room temperature is most likely to provide the largest number of discharge cycles for a lithium-ion battery. Lithium-ion batteries do not charge as effectively at very high temperatures or very low temperatures, resulting in reduced discharge cycles.

Question	% A	% B	% C	% D	% No Answer	Comments
3	7	8	37	47	0	A hydrolytic reaction involves the reaction of water with a compound to produce two or more molecules smaller than the original compound. This is also commonly referred to as the process of hydrolysis. The formation of a dipeptide or a triglyceride is an example of a condensation reaction. Condensation reactions produce water. Reaction of water with the glycosidic bond in maltose produces two glucose molecules.
4	12	72	9	7	0	
5	5	84	7	5	0	
6	11	9	73	7	0	
7	7	81	9	3	0	
8	44	41	8	7	0	Both options A and B were accepted for this question. The capacity to distinguish between optical isomers is a characteristic of enzymes that is not evident with inorganic catalysts. As catalysts, enzymes also catalyse both forward and reverse reactions, as in the haemoglobin-O_2 equilibrium. The question did not specify a characteristic unique to enzymes.
9	4	24	36	35	0	Energy in a 45 g sample is determined from: 13.2 g protein → 13.2 g × 17 kJ g^{-1} = 224 kJ 16.3 g fat → 16.3 g × 37 kJ g^{-1} = 603 kJ 48.2 g carbohydrate → 48.2 × 16 kJ g^{-1} = 771 kJ Total available energy = 224 + 603 + 771 = 1598 kJ % energy from protein = (224/1598) × 100 = 14.0 % The selection of option D is consistent with the inclusion of the ‘indigestible’ dietary fibre in calculating the energy content of the muesli. Option B involved simply dividing the mass of protein by the mass of muesli.
10	9	7	22	63	0	
11	3	4	85	7	0	
12	62	11	18	9	0	Linolenic acid has the greatest number of C=C double bonds.
13	78	16	3	3	0	

Question	% A	% B	% C	% D	% No Answer	Comments
14	47	3	5	44	0	Impact on environment, i.e. $m(CO_2)$ produced per 100 km = fuel consumption (L/100 km) × $m(CO_2)$ per L of fuel The large number of students who selected option A overlooked the 100 km specification in the question.
15	3	23	61	13	0	Denaturation of proteins can have an impact on the secondary, tertiary and quaternary structures but not the primary structure. The bonds disrupted in the tertiary structure depend on the environment causing denaturation; for example, a change in pH will have an impact on the interaction between acidic and basic side groups but is unlikely to affect disulfide links. So, denaturation does not necessarily disrupt all bonds in the tertiary structure. However, alcohol denatures proteins by disrupting hydrogen bonds between side groups. New hydrogen bonds form between side groups capable of hydrogen bonding and the –OH group on alcohol molecules.
16	57	15	20	8	0	The key words in this question were ‘most effectively and safely’. While all options could in combination provide some increase in the levels of vitamin C and vitamin D, the most effective and safe combination year-round was indicated by option A.
17	14	20	51	15	0	Key peaks on the spectrum were at: 3300 cm–1 – this could be due to O–H (alcohols) or N–H 3000 cm–1 – consistent with C–H 1680 cm–1 – this could be due to C=C or C=O The only option consistent with that data was option C, amide.

Question	% A	% B	% C	% D	% No Answer	Comments
18	19	21	55	5	0	From the ‘rates’ perspective the temperature increase will cause the rates of both the forward and reverse reactions to increase since it increases the proportion of collisions with energy greater than the activation energy. From the ‘extent of reaction’ perspective, since the forward reaction is exothermic, the temperature increase will favour the endothermic reverse reaction, so there will be less NH_3 present at the higher temperature and the $[NH_3]$ will be lower. The rate of the forward reaction will continue to increase as the reaction returns to equilibrium since the reactant concentrations increase during that adjustment. The popularity of option C suggests that most students focused on the way the system compensated for the temperature increase and did not pay due attention to the rate of reaction implications.
19	17	1	11	71	0	It was necessary to select the option that would provide both quantitative and qualitative information.
20	5	24	15	56	0	Recharging involves the conversion of electrical energy to chemical energy. $2PbSO_4(s) + 2H_2O(l)$ $\rightarrow Pb(s) + PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq)$ Since $[H^+]$ increases, the pH decreases.
21	17	51	8	24	0	Attraction between the mobile phase and the stationary phase is minimised. Hence, since the stationary phase is non-polar, the mobile phase should be polar. Methanol, CH_3OH, is a better option than octanol, $C_8H_{17}OH$, because the larger non-polar hydrocarbon chain on octanol molecules will make them more attracted to the stationary phase than methanol molecules.
22	29	13	47	11	1	2400 units → *c*(caffeine) in diluted sample = 0.040 g L^{-1} The original sample had been diluted by a factor of 10. *c*(caffeine) in undiluted sample = 10 × 0.040 g L^{-1} = 0.40 g L^{-1} *m*(caffeine) in 350 mL = 0.40 × (350/100) = 0.14 g Many students overlooked the dilution factor.

Question	% A	% B	% C	% D	% No Answer	Comments
23	49	18	28	5	0	Consider the options: • Option A – correct, since this removes the error inherent in reading a thermometer • Option B – incorrect, energy per mole is inapproriate because crude oil is a mixture • Option C – incorrect, accuracy is dependent on technique, not the oil source. Also, different sources may have significantly different compositions • Option D – incorrect, the uncertainty may be directly linked to the procedure followed
24	18	17	48	17	1	Energy released from olive oil $= 2.97 \text{ g} \times 41.0 \text{ kJ g}^{-1}$ $= 121.8 \text{ kJ}$ Energy absorbed by water $= 121.8 - 28.0$ $= 93.8 \text{ kJ}$ $93.8 \times 10^3 \text{ J} = 4.18 \text{ J g}^{-1} \text{ °C}^{-1} \times 500.0 \text{ g} \times \Delta T$ $\Delta T = 93.8 \times 10^3/(4.18 \times 500.0)$ $= 44.9 \text{ °C}$ Final temperature $= 21.0 + 44.9$ $= 65.9 \text{ °C}$ (Alternatively $93.8 \text{ kJ} = 4.18 \text{ kJ kg}^{-1} \text{ °C}^{-1} \times 0.500 \times \Delta T$ $\Delta T = 93.8/(4.18 \times 0.500)$ $= 44.9 \text{ °C}$
25	50	7	37	5	0	The glycaemic index reflects the relative ease of digestion of carbohydates. Since amylopectin is more easily digested (because of its more open structure due to branching) than amylose, the lower the proportion of amylopectin realtive to amylose, the lower the GI value.
26	37	30	22	10	1	According to $pV = nRT$, i.e. $pV = (m/M)RT$ and since p, V, M and R do not change. $m_2T_2 = m_1T_1$ $m_2 = 11$ g CO_2, $T_2 = ?$ $m_1 = 10$ g CO_2, $T_1 = 30 \text{ °C} = 303 \text{ K}$ $T_2 = m_1T_1 / m_2$ $= 10 \times 303 / 11$ $= 275 \text{ K}$ As a result of adding one gram of CO_2, in order for the pressure to remain constant the temperature must decrease from 303 K (30 °C) to 275 K (2 °C), i.e by 28 K/28 °C. The temperature change is –28 °C.

Question	% A	% B	% C	% D	% No Answer	Comments
27	65	20	10	5	0	
28	13	42	31	14	1	Linking the electrochemical series data $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2\ H_2O(l)$ $E^0 = +1.23$ V $VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$ $E^0 = +1.00$ V $VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$ $E^0 = +0.34$ V $V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$ $E^0 = –0.26$ V The strongest reductant, $V^{2+}(aq)$, is oxidised to $V^{3+}(aq)$, which is both an oxidant and a reductant. Subsequently as the $[V^{2+}(aq)]$ decreases, the next strongest reductant, $V^{3+}(aq)$, is oxidised to $VO^{2+}(aq)$ by O_2. If the reaction is allowed to continue, since $VO^{2+}(aq)$ is also both an oxidant and a reductant, $VO^{2+}(aq)$ can be oxidised to $VO_2^+(aq)$ by $O_2(g)$. So $V^{2+}(aq)$ can be oxidised to $V^{3+}(aq)$, $VO^{2+}(aq)$ and $VO_2^+(aq)$.
29	3	10	6	80	0	The overall reaction M → P is endothermic – the products have a higher energy content than the reactants. Two intermediate reactions: M → N is endothermic. N → P is exothermic – the product has a lower energy content.

Question	% A	% B	% C	% D	% No Answer	Comments
30	13	35	31	20	1	Since all cells are operating for the same time at the same current, the n(e^-) passing through each cell is the same. $Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ $n(e^-) = 2 \times n(Pb) \quad = 2 \times 1.0/207.2$ $= 0.0097$ mol $Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$ $n(Cr) = 0.0097/3$ $m(Cr) = (0.0097/3) \times 52.0$ = 0.167 g $Ag^+(aq) + e^- \rightarrow Ag(s)$ $n(Ag) = 0.0097$ $m(Ag) = 0.0097 \times 107.9$ = 1.04 g $Au^{3+}(aq) + 3e^- \rightarrow Au(s)$ $n(Au) = 0.0097/3$ $m(Au) = (0.0097/3) \times 197.0$ = 0.634 g $Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$ $n(Sn) = 0.0097/2$ $m(Cr) = (0.0097/2) \times 118.7$ = 0.573 g Alternatively, the mass deposited under the same conditions is directly proportional to the charge on the ion. So the mass ratio Pb : Cr : Ag : Au : Sn is 207.2/2 : 52.0/2 : 107.9/1 : 197.0/3 : 118.7/2, i.e. 103.6 : 26.0 : 107.9 : 65.7 : 59.4.

Section B

Question 1a.

Marks	0	1	2	Average
%	17	46	37	**1.2**

$n(C_{12}H_{22}O_{11}) = 1.250 \times 10^3/342$

$= 3.65$ mol

$n(C_2H_5OH) = 4 \times 3.65 = 14.6$ mol

$m(C_2H_5OH) = 14.6 \times 46.0$

$= 673$ g (three significant figures)

Many answers were expressed to four significant figures, often due to students not using $M(C_{12}H_{22}O_{11}) = 342$ g mol^{-1}, as given in the question.

Question 1bi.

Marks	0	1	Average
%	39	61	0.6

$H_2O(g)$

Question 1bii.

Marks	0	1	Average
%	41	59	0.6

Addition reaction

Question 1c.

Marks	0	1	Average
%	49	51	0.5

Appropriate responses included: $Cr_2O_7^{2-}(aq)/H^+(aq)$; $MnO_4^-(aq)/H^+(aq)$; $K_2Cr_2O_7$, $KMnO_4$

Question 1di.

Marks	0	1	2	Average
%	24	34	42	1.2

$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightarrow CH_3COOCH_2CH_2CH_3(l) + H_2O(l)$

Question 1dii.

Marks	0	1	Average
%	38	62	0.6

Propyl ethanoate

Question 2a.

Marks	0	1	2	3	Average
%	27	43	25	6	1.1

Biodiesel has higher viscosity and so flows less easily than petrodiesel. This is due to stronger intermolecular attraction between biodiesel molecules than petrodiesel molecules due to:

- stronger dispersion forces because of the longer molecules/carbon chain
- dipole–dipole attraction due to the presence/polarity of the ester functional group.

Most students struggled to relate the higher viscosity of biodiesel to the key structural differences between the molecules of biodiesel and petrodiesel and the impact of these differences on intermolecular attraction.

Question 2b.

In both parts of this question some students tried to use the formulas of major components of biodiesel and/or petrodiesel in mole-related calculations, despite the fact that the question indicated that the fuels are not pure substances.

Question 2bi.

Marks	0	1	2	3	Average
%	26	8	17	48	1.9

Energy in 2.5 kg petrodiesel $= 2.5 \text{ kg} \times 43 \text{ MJ kg}^{-1}$
$= 1.08 \times 10^2$ MJ

m(biodiesel) $= 1.1 \times 10^2$ MJ/38 MJ kg^{-1}
$= 2.8$ kg

V(biodiesel) $= m/d$
$= 2.8$ kg/0.89 kg L^{-1}
$= 3.2$ L

Question 2bii.

Marks	0	1	Average
%	45	55	0.6

$m(CO_2) = 3.91 \text{ kg} \times 2.52 \text{ kg } CO_2\text{/kg}$

$= 9.85$ kg

Question 2c.

Marks	0	1	2	Average
%	22	36	42	1.2

Either:

- $C_{19}H_{32}O_2(l) + {}^{33}/_2\ O_2(g) \rightarrow 19CO(g) + 16H_2O(g/l)$
- $2C_{19}H_{32}O_2(l) + 33O_2(g) \rightarrow 38CO(g) + 32H_2O(g/l)$

Because temperature conditions were not specified, either (g) or (l) was accepted as the state for water. From a ‘point of combustion’ focus, (g) is acceptable as the state of the fuel.

Students should be aware that fuels are supplied to diesel engines as liquids. The use of (aq) in this equation was inappropriate.

Question 3ai.

Marks	0	1	Average
%	44	56	0.6

Glycogen

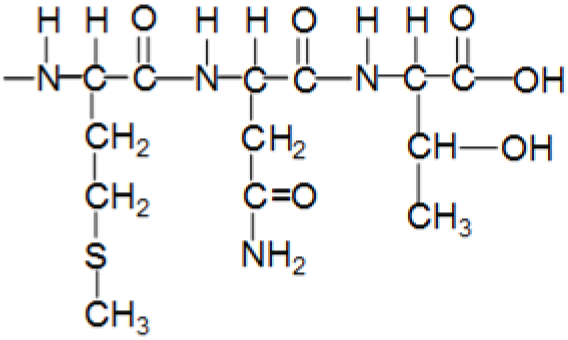
Question 3aii.

Marks	0	1	Average
%	36	64	0.7

Glycosidic/Covalent bond

Question 3bi.

Marks	0	1	2	3	Average
%	23	21	31	26	1.6



One mark each was awarded for:

- all three Z groups correctly represented
- open bond on first N and terminal COOH shown as complete
- both peptide groups correct.

Question 3bii.

Marks	0	1	2	3	Average
%	32	22	38	8	1.3

Primary structure: Covalent bonds between C and N in the peptide links between amino acids

Secondary structure: Hydrogen bonds between O (–C=O) and H (–N–H) on different peptide groups in the α-helix (β-sheet).

While most students correctly identified appropriate bond types, the description of the bonds was less well done. Some simply stated 'covalent bonding' or 'hydrogen bonds', without indicating whether the answer referred to the primary or secondary structure. Also, a significant number of students included incorrect bond types, seeming to confuse secondary and tertiary structures.

Students should be encouraged to see the distinction between 'identify/name' and 'describe' when discussing chemical bonding.

Question 3c.

Marks	0	1	2	Average
%	20	10	70	1.5

Serine and glutamine (non-essential amino acids) can be manufactured in the body. Histidine and threonine (essential amino acids) cannot be manufactured in the body and must be part of our diet.

Question 4a.

Marks	0	1	2	3	4	Average
%	26	12	14	14	34	**2.2**

	$2SO_2(g)$	+	$O_2(g)$	⇌	$2SO_3(g)$
Initially	2.00 mol		2.00 mol		–
Reacting	1.66 mol		0 .83 mol	→	1.66 mol
Equilibrium	0.34 mol		1.17 mol		1.66 mol

$K = [SO_3]^2 / \{[SO_2]^2[O_2]\}$

$[SO_3] = 1.66/4 = 0.415$ M

$[SO_2] = 0.34/4 = 0.085$ M

$[O_2] = 1.17/4 = 0.293$ M

$K = 0.415^2 / (0.085^2 \times 0.293)$

$= 81\ M^{-1}\ (L\ mol^{-1})$

One mark each was awarded for correct:

- $n(SO_2)/[SO_2]$ at equilibrium
- $n(O_2)/[O_2]$ at equilibrium
- equilibrium law using correctly calculated concentrations
- answer and unit.

Question 4b.

Marks	0	1	2	3	4	Average
%	15	14	14	16	41	**2.6**

Temperature should be decreased. The forward reaction is exothermic and is favoured at lower temperature, hence the yield of SO_3 will increase.

Volume should be decreased. Smaller volume causes the concentrations/pressure to increase. As the system moves to partially compensate for this change, the side of the equilibrium with fewer molecules is favoured so the yield of SO_3 will increase.

One mark each was awarded for:

- temperature change
- explanation of why temperature change shifts the reaction to the right
- volume change
- explanation of why volume change shifts the reaction to the right.

While this question was generally well answered, many students missed out on a mark because they did not mention the impact of the volume change on concentration or pressure as part of their explanation of the effect on SO_3 yield.

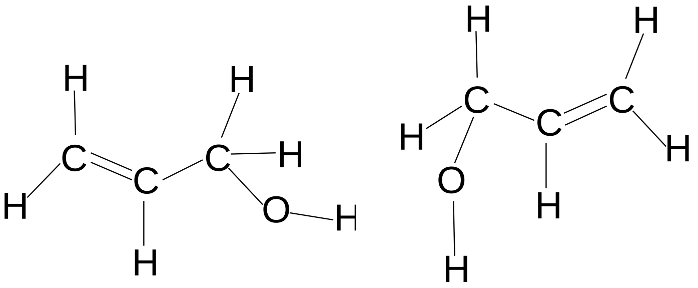
Question 5ai.

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

CH_3COCH_3

Question 5aii.

Marks	0	1	Average
%	38	62	0.6



Question 5bi.

Marks	0	1	Average
%	42	58	0.6

$[CH_3CH_2]^+$/$[CHO]^+$

$[COH]^+$ was also accepted.

Students should be aware that representation of mass spectrum species should include a positive charge.

Question 5bii.

Marks	0	1	2	3	Average
%	39	10	25	27	1.4

Propanal

Only CH_3CH_2CHO can readily be fragmented to produce $[CH_3CH_2]^+$ and/or $[CHO]^+$. Neither the alkenol nor the ketone can readily be fragmented to produce $[CH_3CH_2]^+$ or $[CHO]^+$. The two fragments $[CH_3CH_2]^+$/$[CHO]^+$ are consistent with the base peak at m/z = 29.

One mark each was awarded for:

- propanal
- explaining from the fragments why this spectrum is for propanal
- a valid reason why the spectrum is unlikely to be that of the alkenol or the ketone, or the significance of propanal giving two fragments with m/z = 29.

Many responses to this question suggested that students were influenced by their responses to Questions 5ai. and 5aii. and had overlooked the fact that propanal was also given in the stem of the question. Some students who identified $[COH]^+$ as the species with m/z = 29 argued for prop-2-en-2ol (which has its base peak at m/z = 57), not recognising the fact that this would require multiple fragmentations.

Question 5c.

Marks	0	1	2	3	Average
%	20	7	20	54	2.1

Propanone/CH_3COCH_3

It is a symmetrical molecule and end C atoms are equivalent, therefore it has 2 C environments and 2 peaks on the ^{13}C spectrum, or the peak at chemical shift of 205 ppm on the ^{13}C spectrum is consistent with a ketone (R_2CO).

It has 1 H environment since all H atoms are equivalent, therefore it has 1 peak on the ^{1}H NMR spectrum or the peak at chemical shift of 2.2 ppm is consistent with a ketone ($RCOCH_3$).

The spectra showing 2 C environments and 1 H environment cannot be of the alkenol or the aldehyde since they both have 3 C environments and multiple H environments.

- One mark was awarded for identifying the ketone.
- Two marks were awarded for either:
  - identifying that propanone has 2 C environments and 1 H environment and linking that information to the spectra
  - explaining why, according to the spectra, it could not be the alkenol or the aldehyde isomers.

Question 6ai.

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

Either:

- carry current between the electrodes by the movement of cations (+ ions) towards the cathode and anions (– ions) towards the anode
- complete the circuit by allowing the flow of charged particles through the cell.

Most students overlooked the importance of electrolytic conduction in the operation of the cell.

Question 6aii.

Marks	0	1	Average
%	39	61	**0.6**

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

Question 6aiii.

Marks	0	1	2	Average
%	29	51	21	**0.9**

Appropriate responses included:

- controlling possible ignition sources since hydrogen is highly flammable and explosive in the presence of a spark in air
- ensuring storage vessels are appropriate since hydrogen is stored under pressure
- using hydrogen release detectors
- regular maintenance of hydrogen containers
- safe storage/location of hydrogen containers
- following appropriate hazardous materials guidelines.

Many students interpreted the question as needing the specification of properties of hydrogen that demand its safe storage and simply stated the properties of hydrogen that required safe storage instead of describing the safe storage conditions.

Question 6bi.

Marks	0	1	2	Average
%	20	47	33	1.2

Appropriate responses included:

- no toxic/environmentally hazardous products from PEM fuel cell
- fuel cells are more efficient
- high energy density of H_2 means less fuel needs to be carried
- PEM fuel cell generates less heat
- less noise generated from PEM cell
- water produced in PEM could be used in the submarine.

While the expectation in this question was that students would focus on the advantages of water as the only product and higher efficiency, many responses were focused on submarine issues and did not make reference to the energy sources.

Question 6bii.

Marks	0	1	2	Average
%	73	22	5	0.4

Electrolysis of water (seawater) using energy from the diesel engine or solar energy.

Most students did not include both components of this response.

A small number of students provided a method of generation and were awarded one mark. Examples included:

- reduction of water according to $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$
- decomposition of water according to $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$.

Question 7a.

Marks	0	1	2	3	4	Average
%	15	19	21	25	20	2.2

- Stearic and palmitic acids are both saturated fatty acids but palmitic acid molecules ($CH_3(CH_2)_{14}COOH$) have shorter hydrocarbon chains than stearic acid molecules ($CH_3(CH_2)_{16}COOH$).
- Palmitic acid thus has weaker dispersion force attraction between its molecules, hence a lower melting point, or stearic acid has a higher molecular mass than palmitic acid and hence stronger intermolecular dispersion forces and a higher melting point. Stearic acid molecules are saturated and linoleic acid molecules are unsaturated, or stearic acid has no C=C double bonds and linoleic acid has 2 C=C double bonds.
- Kinks in the linoleic acid hydrocarbon chains (due to the cis conformation) at the C=C double bonds prevents the linoleic molecules from packing together as effectively as stearic acid molecules, hence the intermolecular forces are much weaker than in stearic acid and linoleic acid has a lower melting point.

One mark each was awarded for:

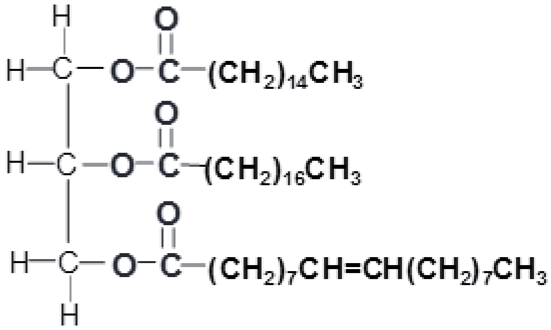
- comparison of size/hydrocarbon chain length of stearic acid and palmitic acid molecules
- relating molecule size/chain length to strength of intermolecular attraction
- distinguishing between the structures of stearic and linoleic acid molecules

- clearly explaining the impact of C=C double bonds on the intermolecular attraction and melting points of stearic and linoleic acids.

Students' ability to coherently distinguish between the fatty acids in each pair in terms of both structure and bonding varied.

Question 7bi.

Marks	0	1	2	Average
%	39	20	41	1



One mark each was awarded for:

- three correct ester links
- correct fatty acid chains, in any order.

Some students drew out a full structure showing all bonds, but there was no indication in the question that all bonds needed to be shown.

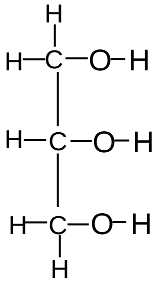
Question 7bii.

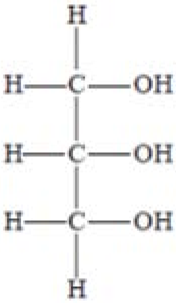
Marks	0	1	Average
%	36	64	0.7

3H_2O

Question 7biii.

Marks	0	1	Average
%	32	68	0.7





Question 7c.

Marks	0	1	2	Average
%	35	50	15	0.8

Either:

- Coenzymes are organic molecules that become part of the active site of an enzyme and modify its shape, thus enabling the enzyme to catalyse a reaction. A coenzyme may also act as an electron, atom or molecule carrier to facilitate the reaction being catalysed by the enzyme.
- A coenzyme assists the enzyme to catalyse a reaction by providing an alternative reaction pathway with lower activation energy.

One mark each was awarded for:

- appropriate description of the interaction of a coenzyme at the active site
- appropriate reference to electron/atom/molecule carrier role of coenzyme or link to an alternative reaction pathway.

While most students could appropriately describe the interaction between the coenzyme and the enzyme, many students did not seem to appreciate the link between coenzymes, enzymes and an alternative reaction pathway.

Question 8

Students handled Question 8e. – calculations associated with electrochemistry – very well. However, students struggled with much of Question 8. The majority of students did not come to terms with HF as a solvent and the role of the diaphragm. Responses to Question 8d. showed that students struggled to provide meaningful explanations of the impact of a change in the material used as the anode.

Question 8a.

Marks	0	1	Average
%	37	63	0.7

(–) iron electrode; (+) carbon electrode

Students should be aware that in an electrolytic cell, electrons flow from the (+) electrode to the (–) electrode.

Question 8b.

Marks	0	1	Average
%	78	22	0.2

Either:

- $2F^{-}_{(HF)} \rightarrow F_2(g) + 2e^{-}$
- $2HF_{(HF)} \rightarrow F_2(g) + 2H^{+}_{(HF)} + 2e^{-}$.

The main error in responses was the use of $F^{-}(aq)$ in the half-equation. Half-equations that did not include states but were otherwise correct were accepted. However, use of the incorrect (aq), given the context of the question, was not rewarded.

Question 8c.

Marks	0	1	Average
%	75	25	0.3

Acceptable responses included:

- If the products H_2 and F_2 can mix they will react explosively.
- The diaphragm keeps the products of the electrolysis, $H_2(g)$ and $F_2(g)$, from coming in contact.

Many responses to this question suggested that the safe operation of the cell was not the key focus. The significance of the structure of the diaphragm – solid in the gas collection region, but porous in the electrolyte – was missed by many students.

Question 8d.

Marks	0	1	2	3	Average
%	50	24	17	9	0.9

Distinct points that could have been made were:

- iron is a stronger reducing agent than $F^-_{(HF)}$ and would be preferentially oxidised at the anode
- no F_2 would be produced
- $Fe(s) \rightarrow Fe^{2+}_{(HF)} + 2e^-$.

This proved to be one of the more challenging questions on the examination. Students should have considered the likelihood of the change of electrode having an impact on the reaction occurring at the anode. The implication of the change given the purpose of the cell was the production of fluorine. While predictions based on the electrochemical series are most accurate at standard conditions, it was still a valid point of reference.

There was evidence that many students struggled to interpret the supplied information effectively.

Question 8e.

Marks	0	1	2	3	Average
%	23	8	23	46	2

$$2F^-_{(HF)} \rightarrow F_2(g) + 2e^-$$

$$Q = It = 1.50 \times 2.00 \times 60 \times 60$$
$$= 1.08 \times 10^4 \text{ C}$$
$$n(e^-) = Q / F$$
$$= 1.08 \times 10^4/96\,500$$
$$= 0.112 \text{ mol}$$
$$n(F_2) = ½ \times 0.112$$
$$= 0.0560 \text{ mol}$$
$$V(F_2) = 0.0560 \times 24.8$$
$$= 1.39 \text{ L}$$

One mark each was awarded for correct calculation of:

- $n(e^-)$
- $n(F_2)$, i.e. appropriate mole ratio
- volume of F_2 (units needed to be included).

This question was generally well answered, with the most common errors being incorrect conversion of time units, incorrect mole ratio $n(e^-)$:$n(F^-)$, and inaccurate use of molar volume or the general gas equation.

Question 9a.

Marks	0	1	Average
%	66	35	0.4

There were two assumptions that students may have made in this question. If it were assumed that the tartaric sample was uniform, there was no independent variable in the analysis. However, if it were assumed that the tartaric sample was not uniform, the independent variable would be the percentage purity of the tartaric acid or the concentration of tartaric acid as these could vary for the analysis of different 30.0 g samples.

The Advice to Teachers defines an independent variable as 'the variable for which quantities are manipulated (selected or changed) by the experimenter, and assumed to have a direct effect on the dependent variable'. Difficulty in identifying the independent variable may have affected some students' responses in the remainder of the question.

Question 9b.

Marks	0	1	2	Average
%	19	27	55	1.4

Appropriate responses included:

- aliquot size – allows for concordant titres and reproducible results
- *c*(NaOH) – allows for consistent titre volume
- amount of indicator – to achieve consistent endpoint colour for different titrations.

Controlled variables are variables that are kept throughout the analysis so that they do not have an impact on the dependent variable. Temperature and choice of indicator might also be considered controlled variables in this exercise.

Question 9c.

Marks	0	1	2	Average
%	37	25	38	1

Calculation of the average titre was appropriate because it involved three concordant titres that differed by less than 0.1 mL (0.05 mL)/were within a range of 0.1 mL.

Some students endeavoured to frame an argument for four titres, identifying 14.96 as the outlier; however, such responses needed to link that argument to an appropriate concordance value.

Question 9d.

Marks	0	1	2	3	4	Average
%	33	11	27	11	17	1.7

Acceptable responses could have been based on:

- The impact of inappropriate rinsing of glassware, for example:
  - if the 500 mL volumetric flask was not rinsed with deionised water, impurities may have an impact on the $c(C_4H_6O_6)$, decreasing the accuracy and reliability of results
  - if the burette was rinsed with water instead of 0.1 M NaOH(aq), the *c*(NaOH) will be decreased, as will the accuracy and reliability of results
- Improper preparation of tartaric acid solution, for example:

  - if the $C_4H_6O_6$ was not fully dissolved before the 500 mL flask was topped up to the calibration mark, some may remain undissolved, thus decreasing the accuracy and reliability of results
  - inadequate mixing of the 500 mL volumetric flask contents, leading to variation in the $c(C_4H_6O_6)$ in different aliquots and so decreasing the accuracy and reliability of results

- NaOH issues, for example:
  - if the NaOH(aq) was not standardised prior to the titrations its concentration would be unreliable due to reaction with atmospheric CO_2, thus the decreasing accuracy of results
  - the *c*(NaOH) was only stated to one significant figure, the fewest significant figures, and hence the least accurate of all the data in the exercise. This reduces the accuracy and reliability of results

- Titration issues, for example:
  - 3 concordant titres were obtained; this increases the accuracy of results
  - 4 drops of phenolphthalein were used in each titration; this increases the likelihood of getting a consistent endpoint colour and so increases the accuracy and reliability of results

Two marks were awarded for each of two steps. Within each step, one mark was awarded for the method point and one mark was awarded for why it has an impact on accuracy/reliability.

There was evidence of uncertainty in students' understanding of the terms 'accuracy' (proximity to true value), and 'reliability' (ability to reproduce data).

Some students framed a complete answer based on the calculations.

Question 9e.

Marks	0	1	2	Average
%	51	24	25	**0.8**

Possible responses included:

- The conclusion is based on the results of one experimental group, so even though concordant titres were obtained there may have been an error in either $c(C_6H_4O_6)$ or *c*(NaOH), which limits reliability. This could be checked by either collating results from a number of groups or repeating the procedure with fresh solutions.
- The percentage purity calculated depends on, and its reliability is limited to some degree by, the accuracy of identification of the colour change at the endpoint. This could be remedied by using a digital pH meter to record endpoint pH.
- Percentage purity 92.5% is quoted to three significant figures, yet the [NaOH] used in its calculation only has one significant figure. This could be addressed by standardising the NaOH to three significant figures.
- The sample tested may not have been truly representative of the manufacturer's product. This could be addressed by testing a sample from a different container.
- One student's results cannot be conclusive; there may have been a consistent error in the technique. This could be addressed by using a different analytical technique such as HPLC.

Question 9f.

Marks	0	1	2	Average
%	22	49	28	**1.1**

Preparing the $C_4H_6O_6$ solution: fume hood or breathing apparatus or equivalent/safety goggles/ gloves

Conducting the titration: safety goggles/gloves

Given that the question listed three specific areas of irritation, it was appropriate that these be addressed where needed when identifying PPE. While protection against respiratory irritation was necessary for solution preparation, i.e. when handling the powder, it was not required for the titration.

Question 10a.

Marks	0	1	2	3	4	Average
%	31	22	27	15	5	**1.5**

Points of reference in assessing the relative feasibility of using biofuels to meet the energy needs of a colony on Mars included:

- the severe atmospheric conditions would make it necessary to establish a self-sustaining biosphere for biofuel production or regeneration
- the source material for extended biofuel production must be producible, for example, plant material for biofuel production
- while CO_2 and sunlight are available for photosynthesis, energy must be expended in extracting and melting water
- the combustion of biofuels requires oxygen, which is not only extremely limited in supply but is critical to the survival of the colonists
- oxygen needed for combustion and human survival could be generated by electrolysis of water using solar energy
- water from combustion of the biofuels needs to be recycled to maximise energy usage
- biological organisms required for biofuel production must not only survive on Mars but also survive the trip to Mars
- all the source material for the initial production of biofuels must be transported from Earth, this will greatly increase payloads to be carried into space
- production of biofuels may have an impact on the space available for food production and other activities
- some biofuels – bioethanol and biodiesel – can be stored as liquids, reducing the need for pressurised containers in the residential biosphere
- biodiesel viscosity increases as the temperature decreases, so adequate fuel flow issues would need to be addressed for use in outside vehicles
- biological organisms and chemical reactions may be less effective due to low temperatures.

This question challenged many students. Many students did not pick up on the emphasis on the chemistry of biofuels and focused mainly on the severe conditions on Mars and the impact on life.

Question 10b.

Marks	0	1	2	Average
%	59	24	18	**0.6**

Possible responses included:

- Using batteries would mean that large amounts of fuel for use in establishing the colony would not have to be transported to Mars. This may allow for transport of other requirements for the settlement.
- Oxygen would not be required for energy production, hence there would be less pressure on supplies of oxygen for residents.
- Batteries could be used on the journey to Mars, reducing the amount of journey fuel to be carried and the overall weight of transport.

- More biomass produced in the colony could be used for food supplies. This reduces the pressure on supplies/colony viability/population size.
- Less demand for the production of fuel reduces the extent of infrastructure dedicated to meeting energy needs.
- Batteries are more efficient than biofuels for electrical energy production, meaning less waste of energy/fewer products released to the atmosphere.

Most students focused on the advantages of access to solar energy rather than another advantage of the use of batteries as an alternative energy source to biofuels. It seemed that many focused on the word ‘advantage’ and its link to solar energy in the stem of the question rather looking at the advantage of the suggestion to use batteries.