2011
Assessment
Report

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

2011 Chemistry GA 1: Written examination 1

GENERAL COMMENTS

A total of 9048 students sat the June 2011 Chemistry examination. Overall, students performed well. A score of just over 85 per cent was needed for an A^+, while a score of just over 79 per cent was needed to receive an A. The mean score for the examination was 60 per cent, which corresponded to the middle of the C^+ grade range. These statistics suggested that the examination proved to be slightly more challenging than the corresponding 2010 examination. However, the vast majority of students were able to finish the examination, to the best of their ability, within the allotted 90 minutes.

There were significant instances in which students did not make effective use of supplied data or information; for example, in Section A, Question 13. One of the aims of the study is that students are able to apply their understanding of chemistry to both familiar and new situations.

In Section A, there were 11 questions that more than 60 per cent of students answered correctly, and five questions that less than 50 per cent of students answered correctly.

Question 8 proved to be the most difficult question in this section. The majority of students proceeded along the carboxyl + amino → peptide path without considering the requirement that the product, ibuprofen lysine, needed to be **more** soluble in water than ibuprofen. The question required students to recognise that a deprotonated carboxyl group increases solubility, a point associated with 'soluble' aspirin.

For Question 9 it was decided that two responses could be correct since it was not made clear in the question that the ethanol would most likely be in excess. Even with this allowance, it was evident that the properties of the reactants, products and the catalyst in biodiesel production were not well understood.

While students would have performed titrations as part of their practical work throughout the unit, understanding of the 'equivalence point' was not strong. This was particularly evident in Question 11.

Question 13 emphasised the importance of not only reading the question carefully, but also using the supplied data effectively. The term 'heated to constant mass' may have encouraged many students to assume that all the water was driven off the sample. However, a quick check of $n(H_2O)$ removed showed that this was not the case.

The overall performance on Question 15 was surprising. Many students simply did not make the required use of the ratio $n(NaN_3)/n(N_2)$.

Question 18 challenged students to consider the key factors that determine the IR absorption band for a covalent bond. These factors include bond strength and the relative masses of the two atoms in the bond. Overall question performance showed that most students were drawn to electronegativity as the key factor. Understanding of the principles of spectroscopy is part of the study.

Question 20 showed that students' understanding of the effect of light from the light source on the metal atoms in the flame of an atomic absorption spectrometer could be improved. It suggested that many students did not make the distinction between oxidation and the transition of electrons to higher energy levels due to the absorption of energy.

As a part of their examination preparation, students should be encouraged to critically review multiple-choice questions on which they struggle. Teachers are encouraged to provide critical analysis and feedback to their students on their performance on multiple-choice questions.

Section B provided students with a mixture of question types and a wide variety of challenges.

Performance on Question 1d. reiterated the impression that biodiesel is a topic worth addressing. Question 1f., also linked to fatty acids, required students to recognise the need to use the ratio $n(Br_2)/n$(compound) to determine the number of C=C bonds present in each molecule and then identify which of the three fatty acids in the list qualified.

Responses to Question 2 demonstrated the challenges that descriptive responses pose for some students. It appears that the message about the need for a (+) charge on species causing peaks on a mass spectrum is not yet well known.

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Question 2aii. emphasised that interpretation of the supplied data, in this case the mass spectrum, in terms of the context of the question is a challenge for a significant proportion of students. Many misread or misunderstood the label on the *y*-axis, while others focused on the relative abundances of the atoms rather than the molecular ions. Question 2b. was well handled. Most students were able to link the information provided on the ^{1}H NMR spectrum to molecular structure. Students continued to respond well to questions on NMR spectroscopy.

In answering Question 3ci. most students focused on the truncated peak on the espresso coffee chromatogram and ignored the presence of the peak area in the data table. Students need to be aware that, when suggesting that a solution should be diluted, it is appropriate that parameters be set. For example, in Question 3c. 'to bring the peak area within the range of the calibration graph'.

Question 4a. was a stoichiometry question that included much data. The challenge for students was to identify the data relevant to getting to the solution most efficiently. Confusion resulted for those students who felt the need to use all the data. In preparing for examinations students should be encouraged to think through the calculation steps before beginning a solution, rather than just using the data in the order in which it appears. In Question 4b. most students interpreted the question as if the moisture in the original precipitate (in 4a.) had been an experimental error. The intent of the question was that both techniques, in 4a. and 4b., were valid, deliberate and accurate. Consequently, the calculated percentage P_2O_5 should have been the same for both techniques.

Question 5a. assessed students' ability to write and combine half-equations. This is a skill that is regularly assessed and with which students are expected to be proficient. Many students who provided a correctly balanced oxidation half-equation in Question 5ai. did not accurately combine it with a given reduction half-equation in 5aii.

Question 5b. was a stoichiometry question that was handled much better than Question 4a. Students seemed more comfortable with titration-based calculations. With calculations related to back-titration, students should use labels such as 'supplied', 'excess/unreacted' and 'reacted/reacting' appropriately. In Questions 5bi. and 5bii. it was necessary to work out the number of mole of $Cr_2O_7^{2-}$ three times.

Question 7a. provided students with an organic reaction pathway. The associated questions revealed some significant issues. Question 7aii. required students to draw a structure of an alcohol produced from a chloroalkane. Errors included the incorrect number of carbon atoms and inappropriate representation of the bond between the hydroxyl group and carbon.

Questions 7aiii. and 7aiv. related to the use of correct systematic nomenclature. In the chemical name 3-methylbutan-1-ol (3-methyl-1-butanol), the numbers 1 and 3 are an essential part of the systematic name and are used because alternative locations of the methyl and/or hydroxyl groups would represent a different compound. On an ethanol molecule there is no other possible location but C-1 for the hydroxyl functional group so there is no number in the systematic name. Many students incorrectly included the number.

In Question 7av., while H_2SO_4 or $H_2SO_4(l)$ were acceptable as representing 'concentrated' sulfuric acid, $H_2SO_4(aq)$ was not.

Responses to Question 7b. suggested that, on seeing the words 'fractional distillation' in the question, many students immediately defaulted to the fractional distillation of crude oil and fractionating towers rather than addressing the fundamental principles of fractional distillation as it applies to a range of separations or, in this case in particular, the collection of an ester. Discussion of the method of collection of an ester and separation of an ester from water and unreacted acid and alcohol is a logical adjunct to coverage of ester production. This question tested students' ability to apply their understandings in different situations. The key factor determining different boiling temperature in a mixture of substances is intermolecular attraction.

Question 7c. proved challenging for a majority of students. The requirement to 'explain how the evidence provided by the spectra indicated that a complete separation of banana oil from the reaction mixture had been achieved' was not well interpreted. Some students were able to draws links between the alcohol IR spectrum and the banana oil IR spectrum to argue for separation from the alcohol, but few were able to effectively argue for separation from the acid. A useful ensuing discussion point might have been how the information on the ester spectrum alone shows separation from the acid and the alcohol.

In Question 8c. the main errors were not 'showing all bonds' and not showing the amino group as protonated.

SPECIFIC INFORMATON

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	**75**	5	13	7	0	Ethanol (CH_3CH_2OH), ethylamine ($CH_2CH_2NH_2$), and ethanoic acid (CH_3COOH) all dissolve in water via hydrogen bonding. Ethane (CH_3CH_3) is non-polar and is less soluble in water.
2	3	**80**	12	5	0	
3	2	2	**95**	1	0	
4	12	8	**73**	7	0	The molecular formula of 2,2,4-trimethylpentane is C_8H_{18}.
5	**76**	12	9	4	0	X is the bond between amino acid residues in the primary structure of the protein. This covalent bond between C and N in the linking peptide group is also known as an amide bond. Y is the bond formed when –SH on the side groups of cysteine molecules reacts in establishing the tertiary structure of the protein. The covalent S–S bond formed is also known as a disulfide bond.
6	15	19	8	**58**	1	All amino acids contain the amino, $–NH_2$, group, which is basic and would be expected to react with 1.0 M HCl(aq).
7	6	7	**79**	8	0	X – 1,1,2-trichloroethene Step 2 is a substitution reaction, H substituted by Br.
8	7	10	77	**6**	0	Ibuprofen lysine is more soluble in water than ibuprofen. So when ibuprofen reacts with lysine the product, ibuprofen lysine, must have a structure that enables it to dissolve in water more readily than ibuprofen. Option C would result from a condensation reaction between the –COOH group on ibuprofen and the $\alpha–NH_2$ group on lysine. The product would dissolve in water via hydrogen bonding. Option D would result from an acid-base reaction between the –COOH group on ibuprofen and the $\alpha–NH_2$ group on lysine. This product would dissolve in water via ion-dipole bonding and hydrogen bonding. The negative ion, formed when ibuprofen molecules donate H^+, dissolves via ion-dipole bonding. The positive ion, formed when lysine molecules gain H^+, dissolves via ion-dipole and hydrogen bonding. Since ion-dipole bonding is stronger than hydrogen bonding, option D best showed the structure of ibuprofen lysine.
9	**38**	31	17	**14**	0	The biodiesel ethyl stearate is produced via the reaction: canola oil + 3 ethanol $\rightarrow$3 ethyl stearate + glycerol in the presence of potassium hydroxide catalyst.

Question	% A	% B	% C	% D	% No Answer	Comments
						Since the ethyl stearate is collected in layer A, layer B must contain glycerol, potassium hydroxide and unreacted ethanol. This separation reflects the non-polar nature of the biodiesel as distinct from the polar ethanol and glycerol, and ionic KOH. On this basis, the correct answer was option D. Ideally, the ethanol should be in excess to ensure complete reaction of the canola oil. However, this was not made clear in the question, and it was possible that students may have assumed that the ethanol and canola oil were present in the exact stoichiometric ratio for complete reaction. In this case, layer B would contain only glycerol and potassium hydroxide. Hence, option A was also accepted as correct.
10	8	56	27	10	0	Consider the amounts of CH_4 and CO_2 produced starting from 1 mol $C_6H_{12}O_6$. Step 1: products are 2 mol CH_3CH_2OH + $\underline{2\text{ mol }CO_2}$ Step 2: all the CH_3CH_2OH from step 1 is converted to CH_3COOH, hence 2 mol $CH_3CH_2OH \rightarrow$ 2 mol CH_3COOH Step 3: 2 mol CH_3COOH $\rightarrow$ 1 mol $Ca(CH_3COO)_2$ + $\underline{1\text{ mol }CO_2}$ Step 4: 1 mol $Ca(CH_3COO)_2$ $\rightarrow$ $\underline{2\text{ mol }CH_4}$ + $\underline{1\text{ mol }CO_2}$ Total $n(CO_2)$ produced = 4 mol $n(CH_4)$ produced = 2 mol Ratio $n(CH_4)$ produced : $n(CO_2)$ produced = 2:4 = 1:2 Since the CH_4 and the CO_2 may be assumed to be collected at the same temperature and pressure, the ratio $V(CH_4)$ produced: $V(CO_2)$ produced equals 1:2.
11	17	45	32	6	0	When a strong base such as NaOH(aq) is added to an acid, weak or strong, the key factor influencing the amount of NaOH(aq) required to reach the equivalence is the $n(H^+)$ available from the acid. Since there was 25.0 mL of both acids, and both were 0.10 Mn(acid) present $= 0.10\times25.0\times10^{-3}$ $= 2.0\times10^{-3}$ mol Both acids are monoprotic, so the $n(H^+)$ available for titration is the same for each acid. Hence, the same amount of 0.20 M NaOH(aq) is required to reach the equivalence point for both acids. Representing the acids by the general formula HA(aq), the equation for the titration reaction in both cases is $HA(aq) + NaOH(aq) \rightarrow NaA(aq) + H_2O(l)$ Since the n(HA) is the same for both acids, the n(NaOH) required is the same for both acids.
12	12	15	61	12	0	This question required students to make effective use of the information in Table 11 of the Data Book (Acid-base Indicators). According to the information in the table: Thymol blue is yellow above pH = 2.8

Question	% A	% B	% C	% D	% No Answer	Comments
						Methyl red is yellow above pH = 6.3 Phenolphthalein is colourless below pH = 8.3 This suggests that the pH of the solution was above pH = 6.3 and below pH = 8.3, i.e. between pH = 6.3 and pH = 8.3. Overall performance on this question suggested that a significant number of students were unable to effectively interpret the information in Table 11 of the Data Book. Teachers should ensure that students use the Data Book throughout the study.
13	33	38	14	14	1	$n(CaSO_4.2H_2O)$ = 172.1/172.1 = 1.000 mol The loss in mass during heating was due to the release of H_2O. $n(H_2O)$ released = 27.0/18.0 = 1.50 mol The ratio $n(CaSO_4.2H_2O)$ reacting: $n(H_2O)$ released = 1:1.5 = 2:3 So the coefficients of $CaSO_4.2H_2O$ and H_2O in the equation must be in the ratio 2:3. Alternatively, 1 mol $CaSO_4.2H_2O$ releases 1.5 mol H_2O, leaving 2 – 1.5 = ½ mol H_2O remaining in the hydrated compound, so the chemical formula of the product of the reaction must be $CaSO_4.½H_2O$. This is consistent with the equation $2CaSO_4.2H_2O(s) \rightarrow 2CaSO_4.½H_2O(s) + 3H_2O(l)$.
14	6	14	18	61	1	d(gas) = 2.86 grams per litre at STP Volume of 1 mol gas at = 22.4 L Hence the M(gas) = 2.86 × 22.4 = 64.1 g mol^{-1} $M(\mathbf{SO_2})$ = 64.1 g mol^{-1}
15	28	59	10	3	1	The inflation of the airbag to 62.0 L was due to the release of $N_2(g)$; i.e. the $V(N_2)$ present at 100 kPa and 36.6°C = 62.0 L $n(N_2)$ produced = $P(N_2) \times V(N_2)/RT$ = 100 × 62.0/[8.31 × (36.6+273)] = 2.41 mol According to the equation for the reaction $n(NaN_3)/n(N_2)$ = 10/16 = 5/8 Hence $n(NaN_3)$ = (5/8) × $n(N_2)$ = (5/8) × 2.41 = 1.51 mol $m(NaN_3)$ = $n(NaN_3) \times M(NaN_3)$ = 1.51 × 65.0 = 97.9 g
16	2	69	25	3	0	If the starch molecule is formed from 500 $C_6H_{12}O_6$ molecules, 499 H_2O molecules will be produced during the condensation polymerisation reaction. M(starch) = 500 × $M(C_6H_{12}O_6)$ – 499 × $M(H_2O)$ = 500 × 180.0 – 499 × 18.0 = 90000 – 8982 = 81018 g mol^{-1} Option C (90 000 g mol^{-1}) overlooked the

Question	% A	% B	% C	% D	% No Answer	Comments
						condensation nature of the formation of starch from glucose.
17	71	11	6	12	0	In thin-layer chromatography, the stronger the adsorption to the stationary phase, the smaller the distance travelled up the stationary phase and the lower the R_f value.
18	51	20	17	11	1	At ordinary temperatures covalent bonds vibrate, and the vibrational energies of molecules have defined energy (quantum) levels (states) in the same manner as electronic energy levels. Transitions between vibrational energy levels depend on absorption of infrared radiation of energy matching the difference between vibrational energy levels. The energy absorbed is proportional to the frequency of the IR radiation, which is proportional to the wavenumber. Covalent bonds in molecules are not rigid, but may be compared to stiff springs that can be stretched and bent. The exact frequency (wavenumber) at which a given vibration occurs is determined by the strength of the bonds involved and the masses of the atoms in the bond. C–H bonds (bond energy 410 kJ mol^{-1}) are stronger than C–O bonds (bond energy 326 kJ mol^{-1}). The mass effect can be attributed to the ‘different’ atom in the C–O and C–H bonds. The lighter H atom produces a higher vibration frequency, so the IR radiation required to bring about the transitions to higher vibrational energy levels in C–H bonds will be of higher wavenumber than for C–O bonds. So, the lower IR wavenumber for bond stretching in a C–O bond can be attributed to larger atomic mass of oxygen atoms compared to hydrogen atoms.
19	26	6	5	62	0	A mixture of hydrocarbon molecules would be quite volatile and most effectively separated into its component compounds by gas chromatography. Each component could then be identified by mass spectroscopy.
20	12	40	29	18	0	Aqueous solutions containing the Cu2+(aq) ion are blue because in the presence of white light they absorb wavelengths in the red region of the visible spectrum, and so transmit wavelengths in the blue region. When $CuSO_4$(aq) is introduced into an atomic absorption spectrometer, the sample is atomised in the high temperature flame. As the light from the Cu lamp passes through the flame, electrons in the Cu atoms in the flame absorb energy and are promoted to higher energy levels, but are not lost from the atoms. As excited electrons return to lower energy levels, energy emitted is in the green region of the visible spectrum. Because the absorption of energy by the Cu atoms in the flame from the light source does not cause

Question	% A	% B	% C	% D	% No Answer	Comments
						loss of electrons from the atoms, oxidation does **not** occur.

Section B – Short answer questions

For each question, an outline answer (or answers) is provided. In some cases the answer given is not the only answer that could have been awarded marks.

Question 1

With the exception of Questions 1d. and 1f., this question was well done.

1a.

Marks	0	1	Average
%	10	90	**0.9**

A

1b.

Marks	0	1	Average
%	14	86	**0.9**

H

1c.

Marks	0	1	2	Average
%	10	28	63	**1.6**

D and E

1d.

Marks	0	1	Average
%	64	36	**0.4**

F

Most students overlooked the fact that biodiesel is generally a methyl ester of a fatty acid. Structure F was the only ester in the table of structures provided. Structure E was chosen by many students, indicating that they did not realise that while glycerol is a product of the production of biodiesel by transesterification it is **not** a component of biodiesel.

1e.

Marks	0	1	Average
%	15	85	**0.9**

B

1f.

Marks	0	1	Average
%	65	35	**0.4**

F

Students needed to realise that to react with Br_2, the substance had to contain C=C bonds; that is, carbon-carbon double bonds. $n(Br_2)$ reacting = 0.320/160.0 = 0.002 mol. Since 0.001 mol of the substance reacts **completely** with 0.002 mol Br_2, each molecule of the substance must contain two C=C bonds. A similar calculation was required on the 2009 examination.

There were three fatty acids in the table; options D, F and G (see below) . Saturated fatty acids have the general formula $C_nH_{2n+1}COOH$ or $C_nH_{2n}O_2$. Unsaturated fatty acids with the same number of C atoms as a saturated fatty acid have two fewer H atoms for each C=C present. Therefore,

D. $C_{13}H_{27}COOH$ – saturated
F. $C_{17}H_{31}COOH$ – polyunsaturated with 2 C=C bonds
G. $C_{17}H_{29}COOH$ – polyunsaturated with 3 C=C bonds

Question 2
2**ai.**

Marks	0	1	Average
%	42	58	**0.6**

$[CH_3CH_2]^+$/$CH_3CH_2^+$/$C_2H_5^+$

Students did not perform as well as expected on this question. Students need to be aware that the species producing peaks on a mass spectrum carry a positive charge. This issue has also arisen on previous examinations.

2aii.

Marks	0	1	2	Average
%	33	25	43	**1.1**

One mark was awarded for a description of relative abundances (either of):
- the relative abundances of the ^{79}Br and ^{81}Br isotopes are approximately equal
- the ^{79}Br isotope is slightly more abundant than the ^{81}Br isotope.

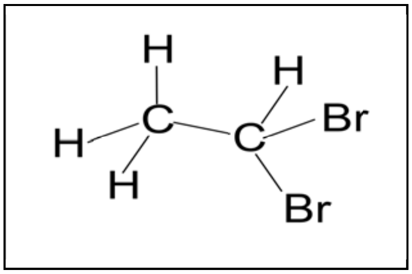
One mark for reference to the molecular ion peaks (either of):
- the peaks at $m/z = 108$, i.e. $[C_2H_5{}^{79}Br]^+$ and $m/z = 110$, i.e. $[C_2H_5{}^{81}Br]^+$ are approximately the same height
- the peak at $m/z = 108$, i.e. $[C_2H_5{}^{79}Br]^+$ is slightly higher than the peak at $m/z = 110$, i.e. $[C_2H_5{}^{81}Br]^+$.

Performance on this question suggested that many students struggled to effectively interpret and/or use the information given about the molecular ion peaks. Fundamentally, this was about the different peak heights with the higher peak height at m/z=108 indicating a greater abundance of the lighter molecule – the one with the lighter Br atom.
A number of students focused on the peaks for ^{79}Br and ^{81}Br rather than the molecular ion peaks. Expressions such as the peak at m/z = 108 being 60 per cent abundant suggested that the 'relative abundance' scale in the context of mass spectroscopy where the most abundant species is set at relative abundance 100 was not well understood.

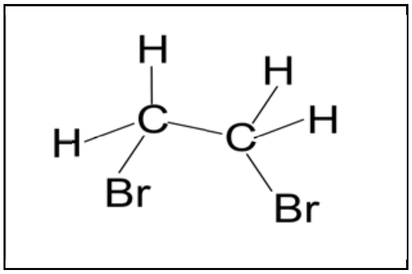
2bi.

Marks	0	1	2	Average
%	4	7	89	**1.9**

Structure 1



Structure 2



This question was well done.

2bii.

Marks	0	1	2	3	Average
%	14	6	23	58	2

One mark each was awarded for:

- circling the correct structure in Question 2bi. (Structure 1)
- appropriate reference to the signals on the ^1H NMR spectrum
- a description of the different H environments in the two compounds.

Possible responses included:

- the NMR spectrum of CH_3CHBr_2 shows two sets of peaks/two signals
- the NMR spectrum of CH_3CHBr_2 shows a doublet and a quartet
- this is consistent with the structure because there are the two different hydrogen environments – one for the three hydrogen atoms on CH_3 attached to CH_2Br, and one for the H on $CHBr_2$ attached to CH_3
- this is not consistent with CH_2BrCH_2Br structure in which all H atoms are in the same environment
- the splitting pattern is consistent with the different hydrogen environments on the CH_3CHBr_2 structure, – a doublet for three hydrogen atoms on CH_3 attached to CH_2Br, and a quartet for H on $CHBr_2$ attached to CH_3.

Overall performance on this question was strong, aided in part by the fact that it was possible to access full marks without referring to the splitting pattern on the spectrum. Many students who did refer to the signal splitting explained it very well. Students continue to do well on NMR-related questions.

Question 3a.

Marks	0	1	Average
%	33	67	0.7

128 ppm (126–129 ppm was accepted)

Most errors on this question were associated with inaccurate reading of the graph.

3b.

Marks	0	1	Average
%	12	88	0.9

There is no peak at the retention time of caffeine/no peak at 96 seconds.

3ci.

Marks	0	1	Average
%	71	29	0.3

The caffeine peak area is beyond the range of the calibration graph. Extrapolation outside the range of the standard solutions may not be accurate.

Many incorrect responses referred to the caffeine peak on the chromatogram rather than the calibration graph and argued that since the top of the peak was not visible, the peak area could not be measured. However, the peak area of the largest peak (caffeine) for espresso coffee was given in the results summary table.

3cii.

Marks	0	1	Average
%	82	18	0.2

Dilute the espresso coffee sample (either of):

- to bring its caffeine concentration within the range of the calibration curve
- by a factor > 12.

While many responses referred to dilution, the term on its own was not sufficient. Students were expected to either state the purpose of the dilution with respect to using the calibration curve, or suggest a dilution factor that would bring the caffeine concentration within the range of the calibration graph. Responses to such questions should not be superficial.

Question 4a.

Marks	0	1	2	3	4	Average
%	24	20	21	22	13	1.8

n($MgNH_4PO_4.6H_2O$) $= 4.141$ g / 245.3 g mol^{-1}
$= 1.688\times10^{-2}$ mol
n(P_2O_5) = ½ × n($MgNH_4PO_4.6H_2O$)
$= 8.441\times10^{-3}$ mol
m(P_2O_5) $= 8.441\times10^{-3}$ mol × 142.0 g mol^{-1}
= 1.199 g
% P_2O_5 = (1.199 / 3.256) × 100
= 36.81 %

One mark each was awarded for:

- correctly calculating n($MgNH_4PO_4.6H_2O$)
- accurately calculating n(P_2O_5)
- accurately calculating the m(P_2O_5)
- accurately calculating the percentage P_2O_5 to four significant figures.

Many students struggled to correctly identify the data relevant to the calculations and attempted to use all data. The key to an efficient response was realising that all the P in 3.256 g of fertiliser ends up in 4.141 g of $MgNH_4PO_4.6H_2O$.

Correctly calculating the n(P_2O_5) was particularly challenging, with most students not linking it to n($MgNH_4PO_4.6H_2O$). Since n(P) = n($MgNH_4PO_4.6H_2O$) and n(P_2O_5) = ½ × n(P)
then n(P_2O_5) = ½ × n($MgNH_4PO_4.6H_2O$).

Some students did not gain full marks because their final answer was not given to four significant figures. This was expected because all data that needed to be used in the calculations was given to four significant figures.

4b.

Marks	0	1	2	Average
%	72	6	22	0.5

The same, because:

- no P is lost on heating the precipitate
- the mass of the precipitate is divided by the M($MgNH_4PO_4$) in calculating the percentage P_2O_5.

The key point in this question was that the precipitate collected had been deliberately heated above 100 °C to completely convert the precipitate to $MgNH_4PO_4$ before weighing. The implication was that it was known that the precipitate collected was now $MgNH_4PO_4$. So while the mass of precipitate collected will be lower, the calculated n($MgNH_4PO_4$) will be the same as the n($MgNH_4PO_4.6H_2O$) in 5a. because the mass of precipitate is divided by a lower molar mass. This question was intended to test the more able students.

Question 5ai.

Marks	0	1	Average
%	34	66	0.7

Either of:

- $TeO_2(s) + 2H_2O(l) \rightarrow H_2TeO_4(aq) + 2H^+(aq) + 2e^-$
- $TeO_2(s) + 2H_2O(l) \rightarrow TeO_4^{2-}(aq) + 4H^+(aq) + 2e^-$.

Most errors with this equation were associated with the location and number of H^+(aq) and e^-.

5aii.

Marks	0	1	Average
%	56	44	0.5

$\mathbf{3}TeO_2(s) + \mathbf{1}Cr_2O_7^{2-}(aq) + \mathbf{8}H^+(aq) \rightarrow \mathbf{3}H_2TeO_4(aq) + \mathbf{2}Cr^{3+}(aq) + \mathbf{1}H_2O(l)$

Many of the students who had provided the correct answer for 5ai. did not combine the two half-equations effectively. An incorrect coefficient for $H_2O(l)$ was quite common. Further attention should be paid to the combination of half-equations to give the overall redox equation.

5b. and 5bii.

Marks	0	1	2	3	4	Average
%	14	8	12	16	50	**2.8**

Many students were confused about the classifications of dichromate ions – 'supplied', 'in excess' and 'reacting with the tellurite'. While most students handled the mathematics of such questions efficiently, logical sequencing proved challenging for some.

5bi.

$n(Fe^{2+})$ = 0.0525×19.71 x 10^{-3}
= 1.035×10^{-3} mol [1.035×10^{-3}]
$n(Cr_2O_7^{2-})$ in excess (unreacted) = $n(Fe^{2+})/6$
= $1.035\times10^{-3}/6$
= $\mathbf{1.72\times10^{-4}}$ mol

5bii.

$n(Cr_2O_7^{2-})$ supplied = $0.03052 \times 50.00\times10^{-3}$
= $\mathbf{1.526\times10^{-3}}$ mol
$n(Cr_2O_7^{2-})$ reacting = $1.526\times0^{-3} - 1.72x10^{-4}$
= $\mathbf{1.354\times10^{-3}}$ mol

5biii.

Marks	0	1	2	Average
%	35	19	46	**1.1**

$n(TeO_2)$ = $\underline{\mathbf{3}} \times n(Cr_2O_7^{2-})$ reacting
= $3 \times 1.354\times10^{-3}$
= 4.062×10^{-3} mol
$m(TeO_2)$ = 4.062×10^{-3} mol × 159.6 g mol^{-1}
= **0.6482 g** ... (units needed to be included)

Students needed to multiply the $n(Cr_2O_7^{2-})$ reacting as calculated in 5bii. by the mole ratio for $TeO_2/Cr_2O_7^{2-}$ from the equation in 5aii. Some students used an incorrect molar mass, that of H_2TeO_4, which was surprising since $M(TeO_2)$ was given at the beginning of the question.

Question 6ai.

Marks	0	1	Average
%	6	94	1

G	A	T	A	C
C	T	A	T	G

6aii.

Marks	0	1	Average
%	26	74	0.8

12 hydrogen bonds

Many students were either not aware of or did not apply the fact the there are three hydrogen bonds in each G–C link and two hydrogen bonds in each A–T link.

6b.

Marks	0	1	2	3	Average
%	8	4	13	76	2.6

All of:

- phosphoric acid/phosphate
- deoxyribose
- adenine.

Students who did not gain full marks on this question often did not correctly name all the reactants. The general groups ‘sugar’ and ‘nitrogen base’ were given instead of the specific compounds ‘deoxyribose’ and ‘adenine’.

Question 7ai.

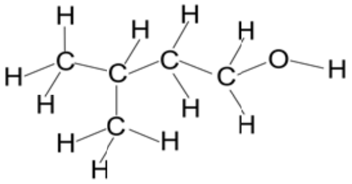
Marks	0	1	Average
%	20	80	0.8

Any of:

- OH^-
- NaOH
- potassium hydroxide.

7aii.

Marks	0	1	Average
%	37	63	0.7



Given that the question asked for a structure rather than the structure showing all bonds, it was not necessary to show all bonds. However, it had to be clear that it is the O end of the OH that is bonded to C, and that there were two CH_3 groups bonded to carbon number 3.

Since the pathway showed that that B was an alcohol produced from $ClCH_2CH_2CH(CH_3)_2$, and so had to be $HOCH_2CH_2CH(CH_3)_2$, it was surprising that many students showed a structure with the incorrect number of carbon atoms.

7aiii.

Marks	0	1	Average
%	48	52	**0.5**

3-methylbutan-1-ol or 3-methyl-1-butanol

The performance data for this part of the question indicated that many students who had the correct structure in 7aii. did not provide a correct name for the compound. Many students referred to a dimethyl option rather than identifying the longest chain of C atoms.

7aiv.

Marks	0	1	Average
%	44	56	**0.6**

Ethanol

Ethan-1-ol or 1-ethanol was a relatively common response for this question; however, this is not the systematic name. There is no other option for the –OH functional group but to be on C-1, hence the number is not part of the systematic name.

7av.

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

Any of:

- H_2SO_4
- sulfuric acid
- $H_2SO_4(l)$.

This question was poorly done. Sulfuric acid is used as a catalyst in ester production. A relatively common error was to give the answer as $H_2SO_4(aq)$ or dilute sulfuric acid.

7avi.

Marks	0	1	Average
%	15	85	**0.9**

Reaction II

Ethanoic acid is produced from ethanol by oxidation.

7b.

Marks	0	1	2	Average
%	31	42	26	**1**

Compounds in the mixture are separated according to their boiling temperatures/intermolecular attraction and (any of):

- the most volatile compound (lowest boiling temperature) will be collected first (at the lowest temperature)
- the least volatile compound (highest boiling temperature) will be collected last (at the highest temperature)
- the compounds are collected in order of increasing boiling temperature.

Many responses to this question focused on the fractional distillation of crude oil with emphasis on the fractionating tower and collection of hydrocarbon fractions at different levels in the tower with minimal appropriate, in the context of the question, reference to the role of boiling temperature or intermolecular attraction. Given that the production of esters is the endpoint of chemical pathways covered in this unit, awareness of the technique by which an ester is separated from other compounds present in the reaction mixture is a reasonable expectation. Students should be aware that the key factor that influences boiling temperature is the strength of intermolecular attraction, not molecular mass.

7c.

Marks	0	1	2	Average
%	46	50	4	**0.6**

Both of:

- compound B has a distinct O–H (alcohol) absorption band around 3300 cm^{-1} (3200–3550 cm^{-1}). This is not present on the spectrum of banana oil
- the IR spectrum of banana oil does not show an O–H (acid) (2500–3300 cm^{-1}) absorption band.

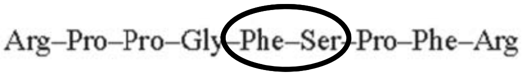
Students were required to explain how the evidence provided by the spectra supported the claim that ‘complete separation of banana oil from the reaction mixture’ had been achieved. Since the reaction mixture would have contained ethanoic acid and 3-methylbutan-1-ol, it was necessary to indicate how the spectra showed the lack of the acid or the alcohol in the final banana oil product.

While slightly more than half the students were able to argue effectively that there was no alcohol present, few were able to explain how the banana oil spectrum showed that the acid was not present. Many students gave reasons how the banana oil spectrum showed that banana oil was an ester, but that was not relevant to the question.

There was some confusion around the absorption band near 3100 cm^{-1} on the banana oil spectrum, with a significant number of students suggesting that it was an O–H (acid) band. Students should have been able to recognise the characteristic broad shape of an O–H (acid) band.

Question 8a.

Marks	0	1	Average
%	21	79	**0.8**



Arg–Pro–Pro–Gly–Phe–Ser–Pro–Phe–Arg

The side groups on the bradykinin molecule section should have enabled students to identify the amino acids from Table 8 of the Data Book.

8b.

Marks	0	1	2	Average
%	18	20	62	**1.5**

Both of:

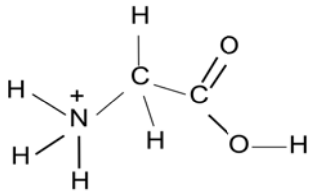
- carboxyl or COOH
- amino, NH_2 or NH_3^+.

It was decided that either the name or the chemical formula of the functional groups was a reasonable response to ‘identify’ the two functional groups. NH_3^+ was accepted because in 6 M HCl it is fair to assume that the NH_2 group on the amino acids would be protonated.

Students should be aware that the hydrolysis of proteins converts peptide groups in amino and carboxyl groups.

8c.

Marks	0	1	Average
%	59	41	**0.4**



A surprising number of students did not show the O–H bond, despite the instruction in the question to show all bonds. Other common errors included missing atoms and either not including the positive charge or showing it as an H^+.