



GENERAL COMMENTS

Overall, students performed well on the June 2010 examination and the majority of students were able to finish the examination, to the best of their ability, within the allotted 90 minutes. A score of just over 89 per cent was needed to achieve an A⁺, while a score of 82 per cent was needed to receive an A. The mean score for the examination was 61.5 per cent, which corresponded to the middle of the C⁺ grade range.

Despite the overall strong student performance, analysis of performance on individual questions provided a number of general insights worth particular emphasis.

In Section A, Questions 4, 5, 9, 15, 18 and 20 all attracted correct responses by 50 per cent or less of the students. Performance on Questions 4, 5 and 18 indicated that many students did not correctly identify or use key mole ratios. In Question 18 the majority of students seemed to assume that the mole ratio oxalic acid: NaOH was 1:1, despite the given structure for oxalic acid clearly showing two carboxyl groups.

Question 9 suggested application of a 'learned' principle without full consideration of all the information supplied. While it is appropriate to identify an appropriate wavelength from the maximum absorbance on the absorption spectrum of a single compound, students should be aware that for a mixture of compounds the wavelength chosen is one at which the analyte absorbs strongly but other components of the mixture have minimal absorbance.

Question 15 reflected the 'different context' aspect of the study particularly well. Most students were well versed in the 'n-1 peptide links for n amino acids' principle of polypeptide chains but missed the significance of the 'two' individual chains in the question.

Responses to Question 20 indicated that students would benefit from more practice in deducing and identifying the monomers present when given the structure of a polymer chain.

In Section B the majority of students were successful on parts of every question. However, there are a number of issues which would seem to be worth particular emphasis in future VCE Chemistry classes.

In Question 1 many students applied inappropriate states in the required half equation and there was evidence of misunderstanding of what constitutes concordant titres.

In Question 2 students showed that they were very comfortable with the general interpretation of IR and NMR spectra; however, most were unable to provide a correct structure for the compound X, associated with the spectra. The prevalence of the structure for propanoic acid, despite the information that X did not react with a base, suggests that many students do not distinguish between -COOH and HCOO⁻ and may have thought that they were giving the structure of methyl ethanoate.

Question 3 indicated that students were not comfortable with some fundamental aspects of mass spectroscopy, notably the formation of a parent ion from the molecule and the assumption that the peaks shown are due to a species with charge of +1. Many students seemed unaware that the ionisation occurs in the gas state.

While Question 5 was generally well handled, students' answers suggested that questions requiring descriptive responses continue to provide particular challenges for many students.

In Questions 6a. and 6c., many students provided superficial answers. Given the reference to structure in the stem of the question, a better level of understanding should have been evident in students' responses. Consequently, the term 'denatured' in isolation was not acceptable in responses to 6c., and some indication of structural changes associated with the change in pH was required. In Question 6d., the combination of units proved challenging to most students.

There was a strong correlation between strong performance on Question 7 and high overall achievement. Question 7aii. required careful navigation through the variety of units, and a common error was the use of an incorrect molar mass, presumably due to the use of an incorrect formula for methanol. There were some inventive correct solutions to Question 7bi., but the formula of cernovic acid in Question 7bii. was poorly handled.

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In Question 8 many students displayed a casual regard for chemical correctness. Of particular significance was the incorrect use of chemical formulas, particularly the use of OH^- to represent the hydroxyl group and numerous incorrect variations on $\text{Cr}_2\text{O}_7^{2-}$ as the formula of the dichromate ion. Students should be aware that chemical symbols and formulas are the fundamental language of chemistry and must be used correctly. Responses to Question 8e. indicated that students had learned from a similar question on the 2009 exam. However, while the question was similar, some students missed the distinction and provided an incorrect answer.

While overall performance on Question 9 was not strong, there was little to suggest that lack of time was an issue. Significant numbers of students did not interpret the supplied information effectively and did not provide a coherent explanation of the role, and type, of intermolecular forces in determining the boiling points of different substances. Of particular concern was the confusion between intramolecular and intermolecular bonding and bond types, especially since many other aspects of Unit 3 require a clear understanding of fundamental bonding principles; for example, interactions with mobile and stationary phases in chromatography.

It was evident that most students found this to be an accessible examination. Given the general levels of performance on this examination, the number of issues of concern identified may seem surprising. Appropriate attention to these issues may be the key to improved performance by middle-range students in future years.

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	9	20	66	5	0	The starting pH of 10 is indicative of a weak base. The drop in pH to 1 would be due to titration with a strong acid; therefore, a strong acid was added to a weak base.																					
2	10	10	7	73	0	The titration curve suggests that the endpoint is around pH 4. Of the indicators listed, only bromophenol blue (3.0–4.6) would be suitable for identifying the endpoint.																					
3	67	22	9	3	1	$n(\text{C}) = 0.120 / 12.0 = 1.00 \times 10^{-2} \text{ mol}$ $n(\text{C}_{14}\text{H}_9\text{Cl}_5) = 1.00 \times 10^{-2} / 14$ $n(\text{Cl}) = 5 \times 1.00 \times 10^{-2} / 14$ $= 3.57 \times 10^{-3} \text{ mol}$ $m(\text{Cl}) = 3.57 \times 10^{-3} \times 35.5$ $= \mathbf{0.127 \text{ g}}$																					
4	13	18	45	24	0	$2\text{Cu}_3\text{FeS}_2 + 7\text{O}_2 \rightarrow 6\text{Cu} + 2\text{FeO} + 6\text{SO}_2$ <table style="margin-left: 20px;"> <tr> <td>Initial</td> <td>1.0</td> <td>1.0</td> <td></td> <td></td> <td></td> <td>mol</td> </tr> <tr> <td>Reacting</td> <td>$\frac{2}{7}$</td> <td>1.0</td> <td>$\frac{6}{7}$</td> <td>$\frac{2}{7}$</td> <td>$\frac{6}{7}$</td> <td>mol</td> </tr> <tr> <td>Final</td> <td>$\frac{5}{7}$</td> <td>-</td> <td>$\frac{6}{7}$</td> <td>$\frac{2}{7}$</td> <td>$\frac{6}{7}$</td> <td>mol</td> </tr> </table> <p>Hence, $\frac{5}{7}$ mol Cu_3FeS_2 is in excess.</p> <p>Overall performance on this question indicated that many students found the 2:7 mole ratio of Cu_3FeS_2 to O_2 difficult to handle. Since the equation indicated that 2 mol Cu_3FeS_2 reacts with 7 mol O_2, then for each 1 mol O_2 reacting, $\frac{2}{7}$ mol Cu_3FeS_2 will react. Students who selected option D probably realised this but did not follow through to calculate the amount of Cu_3FeS_2 in excess. The popularity of option B suggested that the question was not interpreted effectively by a significant number of students.</p>	Initial	1.0	1.0				mol	Reacting	$\frac{2}{7}$	1.0	$\frac{6}{7}$	$\frac{2}{7}$	$\frac{6}{7}$	mol	Final	$\frac{5}{7}$	-	$\frac{6}{7}$	$\frac{2}{7}$	$\frac{6}{7}$	mol
Initial	1.0	1.0				mol																					
Reacting	$\frac{2}{7}$	1.0	$\frac{6}{7}$	$\frac{2}{7}$	$\frac{6}{7}$	mol																					
Final	$\frac{5}{7}$	-	$\frac{6}{7}$	$\frac{2}{7}$	$\frac{6}{7}$	mol																					

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Question	% A	% B	% C	% D	% No Answer	Comments
5	10	27	50	12	1	<p>According to the equation, the explosion of 2 mol of $C_7H_5N_3O_6$ produces 20 mol of gaseous products (12 mol CO + 5 mol H_2 + 3 mol N_2). Hence 1 mol $C_7H_5N_3O_6 \rightarrow 10$ mol gases. $V(\text{gas}) = n(\text{gas}) \times RT / p$ $= 10 \times 8.31 \times (27+273) / 1.00 \times 10^2$ $= 249 \text{ L}$</p> <p>Option B (22.7 L) was 249 L divided by 11, suggesting that students who chose this option realised that there was 10 mol of gases produced from 1 mol TNT, but then divided the total volume by 11 because there was a total of 11 mol of products formed for each 1 mol of TNT reacting. Option A was consistent with using Pa rather than kPa for pressure, while option D assumed 11 mol of gas, overlooking that carbon was a solid.</p>
6	60	3	25	11	0	<p>The most polar substance will be most strongly attracted to the polar stationary phase, and hence will move least along the stationary phase and will have the lowest R_f value. $R_f(X) = 0.80 / 2.75 = 0.29$</p> <p>Students who chose option C may have assumed that the species being referred to was the one least attracted to the stationary phase. This suggests the need for better understanding of the link between the principles of chromatography and bonding.</p>
7	66	3	23	8	0	<p>Isotopes are separated and quantified by mass spectroscopy.</p> <p>The popularity of option C suggested that some students did not distinguish between the use of atomic absorption spectroscopy to determine the amount of a specific metallic element in a sample, and the use of mass spectroscopy to determine the amounts of different isotopes of an element.</p>
8	2	82	4	11	0	
9	1	45	51	3	0	<p>The best wavelength to use is one where Red No. 2 dye absorbs strongly but no other dye in the mixture does, i.e. 500 nm.</p> <p>According to the absorption spectra provided, Red No. 2 absorbs most strongly at 540 nm. However, because Blue No.1 dye also absorbs significantly at 540 nm, it is not the best wavelength to use.</p> <p>Students who chose option B may have focused solely on the maximum absorption of Red No. 2 dye.</p>
10	13	4	70	12	0	
11	79	7	10	4	0	
12	19	11	17	53	0	<p>H_2NCH_2COOH will react with both dilute $HCl(aq)$ and dilute $NaOH(aq)$ because the amino group, NH_2, is basic and the carboxyl group, $COOH$, is acidic.</p> <p>This question was less well done than might have been expected. Students should be aware that amino acids have both basic and acidic character.</p>



Question	% A	% B	% C	% D	% No Answer	Comments
13	4	63	21	12	0	All the reactions represented, albeit incorrectly in option B, should have been familiar to students. Option B was incorrect because when HCl reacts with an unsaturated hydrocarbon the H and Cl add at opposite ends of the C=C double bond. Some students may have been drawn to option C because the other product of the reaction, H ₂ O, was not shown.
14	5	11	14	69	0	The first sentence in this question was the key. Students needed to recognise that it was the side chain on the first amino acid that had reacted, and that this side chain would have to be CH ₂ CH ₂ COOH. Effective use of Table 8 in the Data Book would have allowed identification of the amino acid as glutamic acid.
15	8	38	48	6	0	A single protein chain consisting of n amino acids will contain n – 1 peptide links. So a single protein chain of 51 amino acids will contain 50 peptide links. However, the 51 amino acids in insulin are arranged in two individual chains, containing 21 and 30 amino acids respectively. Hence the total number of peptide links present is (21 – 1) + (30 – 1) = 49. The popularity of option C suggests that most students did not pick up on the significance of the ‘two individual chains’.
16	6	11	79	4	0	Disulfide bridges are formed when –SH (thiol) groups on the side chains of two cysteine molecules react together.
17	8	25	9	58	0	Reaction 1 represented fermentation and product A was CO ₂ . Reaction 2 represented a condensation reaction in which a disaccharide is produced from a monosaccharide. Product B was H ₂ O. Since one reactant in reaction C was C ₆ H ₁₂ O ₆ (aq), and the products were CO ₂ and H ₂ O, it is perhaps most readily recognised as respiration $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ Respiration and combustion reactions are very similar; the main difference in the combustion equation being that C ₆ H ₁₂ O ₆ would normally be shown as C ₆ H ₁₂ O ₆ (s). Because it occurs at a low temperature, respiration may be referred to as ‘slow’ combustion . The popularity of option B suggested that many students were relatively unfamiliar with fermentation, a process which would generally be covered when discussing the production of the biofuel ethanol.



Question	% A	% B	% C	% D	% No Answer	Comments
18	6	30	5	59	0	<p>When oxalic acid HOOC-COOH reacts completely with a strong base it acts as a diprotic acid, according to the equation</p> $\text{HOOC-COOH(aq)} + 2\text{NaOH(aq)} \rightarrow \text{NaOOC-COONa(aq)} + \text{H}_2\text{O(l)}$ $n(\text{oxalic acid}) = \frac{1}{2} \times n(\text{NaOH})$ $= \frac{1}{2} \times 2.50 \times 15.0 \times 10^{-3}$ $= 0.01875 \text{ mol}$ $c(\text{oxalic acid}) = 0.01875 \text{ mol} / 25.0 \times 10^{-3} \text{ L}$ $= 0.750 \text{ M}$ <p>The fact that most students selected option D suggests that they simply assumed a 1:1 mole ratio between oxalic acid and NaOH, did not take note of the supplied structure of oxalic acid and so did not recognise the significance of the two carboxyl groups.</p>
19	8	12	75	4	0	
20	21	47	11	20	1	<p>To identify the two alkenes/monomers it was necessary to identify the 'repeating' units in the section of copolymer chain shown.</p> <p>This suggests the copolymer was formed by reaction between but-2-ene, $\text{CH}_3\text{CH}=\text{CHCH}_3$ and propene, $\text{CH}_3\text{CH}=\text{CH}_2$.</p>

Section B – Short-answer questions

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

Question 1a.

Marks	0	1	2	Average
%	30	14	55	1.3

Either of:

- $\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O(l)}$
- $\text{MnO}_4^-(\text{aq}) + 8\text{H}_3\text{O}^+(\text{aq}) + 5\text{e}^- \rightarrow \text{Mn}^{2+}(\text{aq}) + 12\text{H}_2\text{O(l)}$

Two marks were awarded for a correct balanced equation with all states correct, one mark was awarded for a correct balanced equation with one or more states missing or incorrect, and no marks were awarded for an incorrect equation.

This was a half equation commonly used in examples of balancing reduction half equations and so might have been expected to be handled better. Electrons with an (aq) state and H^+ ions with a (g) state were unexpectedly common.

Question 1b.

Marks	0	1	Average
%	51	49	0.5

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$$(22.03 + 21.97 + 21.99)/3 = 22.00 \text{ mL}$$

A number of students who identified the three concordant titres did not access the mark because they truncated the average (21.997) to 21.99. A significant proportion of students simply averaged all four titres, not recognising that 20.25 was not concordant with the other three titres.

Question 1c.

Marks	0	1	Average
%	21	79	0.8

$$n(\text{MnO}_4^-) = 0.0400 \times 22.00 \times 10^{-3} \\ = 8.80 \times 10^{-4} \text{ (mol) or } 0.000880$$

Consequential marks were applied throughout this question. The mark for this question was awarded if the answer to Question 1b. was correctly converted to the number of mol.

There was a significant number of errors associated with not converting the volume to mL, and not expressing the answer to the correct number of decimal places.

Question 1d.

Marks	0	1	2	Average
%	15	20	65	1.5

$$n(\text{Fe}^{2+}) \text{ in } 20 \text{ mL aliquot} = 5 \times n(\text{MnO}_4^-) \\ = 5 \times 8.80 \times 10^{-4} \text{ *} \\ = 4.40 \times 10^{-3} \text{ (mol)} \\ n(\text{Fe}^{2+}) \text{ in } 250 \text{ mL flask} = 4.40 \times 10^{-3} \times (250/20) \\ = 5.50 \times 10^{-2} \text{ * (mol)}$$

The marks were awarded for accurately multiplying the answer to Question 1c. by 5 and by (250/20). Some students used their titre value rather the 20.00 mL aliquot in determining the amount present in the 250 mL volumetric flask.

Question 1e.

Marks	0	1	2	3	Average
%	14	6	33	46	2.1

$$n(\text{Fe}) \text{ in } 80.50 \text{ g alloy} = 5.50 \times 10^{-2} \text{ (mol)} \\ m(\text{Fe}) \text{ in } 80.50 \text{ g alloy} = 5.50 \times 10^{-2} \times 55.9 \text{ *} \\ = 3.07 \text{ (g)} \\ \% \text{ Fe in alloy} = (3.07 / 80.50) \times 100 \text{ *} \\ = 3.82 \% \text{ (3.81) *}$$

The most common error was not expressing the answer to the required 3 significant figures. Students should also be reminded to use the molar masses as supplied (as relative atomic masses) in the Data Book.

Many students who incorrectly answered Question 1b. still obtained full consequential marks for Questions 1c., 1d. and 1e. A common final answer was 3.74 %, consistent with using all four titres in 1b.

Students should be reminded that severe rounding of data in early parts of a question, for example, 0.0009 for 0.00088 in Question 1c., can have a significant impact on the accuracy of their final answer.

Students should be aware of the difference between 'truncating' and 'rounding off' an answer. In Question 1a., correctly rounding off 21.997 to 4 significant figures gives the answer as 22.00, not 21.99.

Question 2a.

Marks	0	1	Average
%	7	93	0.9

Either of:

- C=O

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- carbon, oxygen with double covalent bond.

A number of students identified bonds associated with each of the three significant peaks but did not specifically indicate which of those bonds was associated with the peak labelled A. Occurrences of C=C suggested some issues with judgment along the horizontal axis.

Question 2b.

Marks	0	1	Average
%	7	93	1

Three

Question 2c.

Marks	0	1	Average
%	14	86	0.9

Three

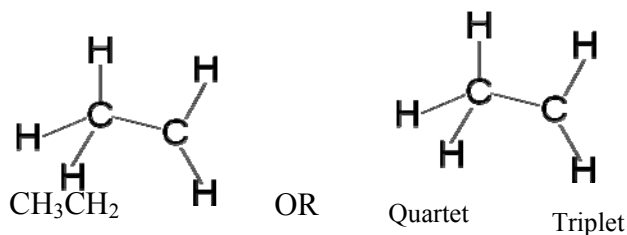
Question 2di.

Marks	0	1	Average
%	17	83	0.8

Two

Question 2dii.

Marks	0	1	Average
%	47	53	0.6



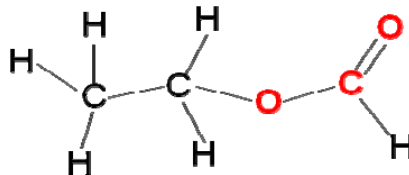
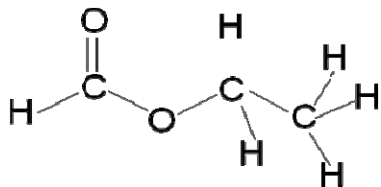
It was evident that many students did not interpret the term 'gives rise to' as intended and instead described the splitting pattern of the peaks of the two groups of H atoms, i.e. labelled CH₃ with 'triplet' and CH₂ as 'quartet', rather than the impact on the neighbouring equivalent H atoms.

The random use of R in structures, for example, CH₃CH₂R, suggested that many students do not realise that R represents an alkyl group, and so would also have an impact on the splitting pattern.



Question 2e.

Marks	0	1	2	Average
%	68	4	28	0.6



This question proved challenging for most students. A large number provided the structure of propanoic acid, CH₃CH₂COOH, despite the question stating that 'X does not react with a base'. Some of these students may have recognised that it was an ester but confused HCOO⁻ in the structure with -COOH, given that there was no evidence on the IR spectrum of a broad O-H absorption band (2500-3300 cm⁻¹) consistent with carboxylic acids.

Question 3a.

Marks	0	1	Average
%	78	22	0.2

Any of:

- CH₃CH₂OH(g) + e⁻ → [CH₃CH₂OH]⁺(g) + 2e⁻
- CH₃CH₂OH(g) → CH₃CH₂OH⁺(g) + e⁻
- C₂H₆O(g) → [C₂H₆O]⁺(g) + e⁻
- NO₂(g) + e⁻ → [NO₂]⁺(g) + 2e⁻
- NO₂(g) → NO₂⁺(g) + 2e⁻.

This question was not well answered. Many students struggled to provide an appropriate balanced equation, particularly with respect to the correct location of the electron(s). The differences between 'ionisation' and 'fragmentation' in mass spectroscopy should be made clear to students. Of significant concern was the use of (aq) as the state for the species included in the equation.

Question 3b.

Marks	0	1	2	Average
%	14	17	69	1.6

Either of:

- Spectrum A
- Peaks at $m/e = 45$ (or 31 or 29 or 27) will not result from fragmentation of NO₂ or NO₂, since molecules with only three atoms cannot produce as many fragmentation peaks.

Students argued successfully from both the ethanol and nitrogen dioxide perspectives. Identification of specific peaks, for example, 31 – CH₂OH⁺, 30 – NO⁺ was a component of many correct responses.

Students should be reminded that when associating peaks with the 'loss of H' during fragmentation, it is H atoms that are lost, **not** H⁺ ions.

Question 3c.

Marks	0	1	Average
%	55	45	0.5

[NO]⁺ or NO⁺ or NO^{•+}

Students did not perform as well as expected on this question. Some students referred to species from spectrum A rather than spectrum B, or incorrect, or lack of, charge.

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Question 4a.

Marks	0	1	2	Average
%	16	19	66	1.5

(A) B C (D) E F

If three or more answers were circled, one mark was deducted for each incorrect alternative.

Question 4bi.

Marks	0	1	Average
%	17	83	0.9

Hydrogen* bonding

Question 4bii.

Marks	0	1	2	Average
%	17	24	59	1.4

A B (C) D E (F)

The majority of students were well versed in key structural and bonding aspects of DNA. A reasonable number of students also identified the hydroxyl groups at either A and or D as sites for hydrogen bonding, perhaps not focusing on 'between the two strands' as stated in the question.

Question 5ai-ii.

Marks	0	1	2	Average
%	12	31	57	1.5

While these questions were generally well handled, some students did not distinguish between the two parts and provided a similar response to both. In Question 5a.ii. a surprising number of students seemed to miss the link between the retention time of 0.9 for ethanol and the determination of blood alcohol content. Some gave a detailed description of 'how' the chromatogram could be used to determine the percentage of alcohol in the blood rather than why the peak at 0.9 was measured.

5ai.

Acceptable responses included:

- ethanol has a unique retention time/peak
- each chemical produces a distinct peak on the chromatogram.

5a.ii.

Acceptable responses included:

- the analysis is to determine the amount of ethanol in blood
- 0.9 is the retention time of ethanol, the alcohol in blood which is analysed.

Question 5b.

Marks	0	1	Average
%	16	84	0.9

0.220(%)

Question 6a.

Marks	0	1	Average
%	42	58	0.6

Acceptable responses included:

- enzyme function is determined by the shape of the active site
- enzyme shape is complementary to a specific substrate
- 'lock and key' effect – the substrate (reactant) is the 'key' and the active site of the enzyme is the 'lock'

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- an enzyme's active site has a shape allowing access only to particular molecules.

To obtain the mark for this question, students needed to indicate their understanding that the 'specificity' of an enzyme is related to the shape of the enzyme's active site, or the complementary relationship between an enzyme and the substrate. If referring to the 'lock and key' effect, students were expected to relate that terminology to the active site and substrate.

Question 6b.

Marks	0	1	2	Average
%	1	15	84	1.9

Temperature 55*(°C), pH 5*

Question 6c.

Marks	0	1	Average
%	66	34	0.4

Acceptable responses included:

- the tertiary structure of the enzyme changes with change in pH
- change in $[H^+]$ may change the charge on side chain groups
- the enzyme is denatured so the shape of the active site changes.

To access the mark for this question, students needed to indicate that the change in pH affects the enzyme/active site structure and/or charge. Denaturing in isolation was not accepted; some appropriate link to change in enzyme structure was required.

Question 6d.

Marks	0	1	2	Average
%	63	2	34	0.7

$$n(C_6H_{12}O_6) = 300 \times 10^{-3} \text{ mol mg}^{-1} \times 1.00 \times 10^{-1} \text{ mg}$$

$$m(C_6H_{12}O_6) = 3.00 \times 10^{-2} \times 180.0$$

$$= 5.40^* \text{ g}^* \text{ or } 5.40 \times 10^3 \text{ mg or } 5400 \text{ mg}$$

One mark was awarded for correctly calculating the mass of glucose, i.e. correctly working out the number of mole of glucose and multiplying by the molar mass. One mark was awarded for the correct mass unit.

Effective interpretation of the data proved challenging for most students, perhaps confused by having the mass of invertase in grams but the activity in mmol glucose/mg invertase. A significant proportion of students used an incorrect conversion factor in changing g to mg or vice versa.

Some astute students realised that mmol glucose/mg invertase equates to mol glucose/g invertase and obtained the correct answer via $300 \times 1.00 \times 10^{-4} \times 180$.

Question 7ai.

Marks	0	1	Average
%	48	52	0.5

3 or 3:1

This question required students to recall that during the production of biodiesel, three fatty acid molecules from each molecule of the triglyceride are converted to methyl ester molecules. Hence for one mole of POP, 3 moles of methanol were required.

Question 7aii.

Marks	0	1	2	3	Average
%	29	21	20	30	1.5

$$n(\text{POP}) = 10.0 \times 10^3 / 833$$

$$= 12.0^* \text{ mol}$$

$$n(\text{CH}_3\text{OH}) = 3 \times 12.0$$

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$$\begin{aligned}
 &= 36.0 \text{ mol} \\
 m(\text{CH}_3\text{OH}) &= 36.0 \times 32.0 \\
 &= 1.15 \times 10^3 \text{ g} \\
 V(\text{CH}_3\text{OH}) &= m(\text{CH}_3\text{OH})/d(\text{CH}_3\text{OH}) \\
 &= 1.15 \times 10^3 \text{ g} / 0.79 \text{ g mL}^{-1} \\
 &= 1.46 \times 10^3 \text{ mL} \\
 &= 1.5 \text{ L (range accepted 1.46–1.5)}
 \end{aligned}$$

One mark each was awarded for:

- correctly calculating $n(\text{POP})$
- calculating $m(\text{CH}_3\text{OH})$, i.e. multiplying $n(\text{POP})$ by ratio from Question 7ai. and by 32.0
- accurately converting calculated $m(\text{CH}_3\text{OH})$ into volume in litres.

Common errors included:

- not converting 10.0 kg to g
- not using, or using incorrectly, the stoichiometric ratio from 7ai.
- incorrectly calculating the molar mass of methanol – 31 and 46 were common
- not converting the calculated volume to litres.

Question 7bi.

Marks	0	1	2	3	Average
%	20	11	18	52	2

$$\begin{aligned}
 n(\text{I}_2) &= 0.300 \times 20.00 \times 10^{-3} \\
 &= 6.00 \times 10^{-3} \text{ mol}
 \end{aligned}$$

$$\begin{aligned}
 n(\text{cervonic acid}) &= 0.328 / 328 \\
 &= 1.00 \times 10^{-3} \text{ mol}
 \end{aligned}$$

$$\text{Ratio } n(\text{I}_2) / n(\text{cervonic acid}) = 6 / 1$$

Hence **6*** (C=C) **double bonds**.

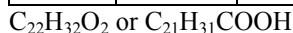
There were some quite intuitive approaches to this question. Some students calculated the $n(\text{cervonic acid})$ and then determined what its molar mass would be if the I_2 :cervonic acid mole ratio was 1:1. They then used the ratio of the actual molar mass 328 g mol^{-1} to the calculated molar mass to deduce the number of C=C double bonds.

Some students also deduced that since there are 22 C atoms in cervonic acid, if it was saturated ($\text{C}_{22}\text{H}_{44}\text{O}_2$ or $\text{C}_{21}\text{H}_{43}\text{COOH}$) its molar mass would be 340 g mol^{-1} . Since the actual molar mass is 12 less, then each cervonic acid molecule has 12 fewer H atoms than a saturated fatty acid with 22 C, indicating the presence of 6 C=C double bonds.

Some students interpreted the lead-in to the question to mean the ‘total’ number of double bonds, including the C=O double bond in the carboxyl. Seven double bonds was also an acceptable answer.

Question 7bii.

Marks	0	1	Average
%	69	31	0.3



It was surprising that many students who correctly calculated the number of C=C double bonds in Question 6bi. did not effectively combine that with the information that there are 22 carbon atoms in a molecule of cervonic acid to deduce the formula of cervonic acid, based on the principle that for each C=C double bond, a cervonic acid molecule contains 2 fewer H atoms than a saturated fatty acid with 22 C atoms ($\text{C}_{22}\text{H}_{44}\text{O}_2$).

Question 8a.

Marks	0	1	Average
%	30	70	0.7

ether or glycosidic linkage

The most common error was identifying the linkage as an ester linkage.

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Question 8bi.

Marks	0	1	Average
%	29	71	0.7

Any of:

- monosaccharides
- carbohydrates
- sugars
- hexoses.

The most common error on this question was identifying the compound rather than the 'group of biomolecules' to which it belongs. Polysaccharides was an unexpectedly common and incorrect answer.

Question 8bii.

Marks	0	1	Average
%	22	78	0.8

OH or -OH

Students need to be aware of the difference between a hydroxyl group -OH, and an hydroxide ion OH⁻.

Question 8ci.

Marks	0	1	Average
%	46	54	0.6

oxidation or redox

The reaction involves the conversion of -CH₂OH on salicyl alcohol to -COOH, which students should recognise as being consistent with the oxidation of a primary alcohol to a carboxylic acid.

Some students identified the process as a condensation reaction, suggesting that there is a need for clarification of the distinction between condensation reactions (such as between alcohols and acids where water is a product) and the broader range of reactions in which water is a product; for example, combustion or the overall reaction between acidified dichromate and a primary alcohol.

Question 8cii.

Marks	0	1	Average
%	45	55	0.6

- Cr₂O₇²⁻(aq), Cr₂O₇²⁻(aq)/H⁺(aq), acidified dichromate or potassium dichromate
- MnO₄⁻(aq), MnO₄⁻(aq)/H⁺(aq), acidified permanganate or potassium permanganate
- O₂(g) or oxygen

Overall performance on this question suggested that students were familiar with the reagents generally used in the oxidation of primary alcohols. However, many responses were inaccurate. Students are reminded that accuracy in chemical formulas is essential. The variety of incorrect representations of the dichromate ion suggests that this point needs to be strongly emphasised. Charge on ions is **not** an optional extra.

Question 8d.

Marks	0	1	Average
%	52	48	0.5

ethanoic acid or ethanoic anhydride

Step 3 involved the conversion of salicylic acid to aspirin. This reaction is specifically covered in the study, and the preparation of aspirin is a common practical exercise, so stronger student performance on this question might have been expected.

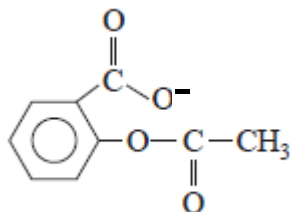
While there was some leniency in the marking, in that correct chemical formulas were accepted instead of the name, students must not presume this will always be the case when the 'name' of substance is asked for. 'Acetic' was an acceptable alternative for 'ethanoic'.

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Question 8e.

Marks	0	1	Average
%	45	55	0.6



Most students identified that the carboxyl group on aspirin loses H^+ in the reaction. However, many omitted the (-) charge on the final structure. A number of students, perhaps having used the 2009 paper for practice, showed a structure for sodium salicylate. This was not accepted as it was not consistent with the equation as given in the question.

Question 9ai.

Marks	0	1	Average
%	45	55	0.6

Methanol or ethanol

Responses to this question suggested two distinct interpretations of the 'mixture'. Students who identified methanol or ethanol interpreted the question as intended, i.e. the mixture of alkanols added to the distillation flask. Many students stated that butan-1-ol (or pentanol-1-ol) could not be present, presumably thinking of the mixture as the 'fraction' collected at $97.2^\circ C$ in a fractionating tower.

Question 9aii.

Marks	0	1	Average
%	52	48	0.5

Any of:

- if methanol (ethanol) had been present in the mixture it would have condensed as the first fraction at $64.5^\circ C$ ($78.3^\circ C$)
- the boiling temperature of methanol (ethanol) is below $97.2^\circ C$
- methanol (ethanol) has boiled off before the first fraction is collected.

Most students who identified methanol or ethanol in Question 9ai. provided an appropriate response to this question.

Question 9b.

Marks	0	1	Average
%	49	51	0.5

Flammability of alkanol vapours or risk of fire or explosion

The difficulty of controlling temperature using a Bunsen burner was also accepted.

The emphasis in this question was on why a Bunsen burner **should not** be used. While just over 50 per cent of students received the mark this was more a reflection of mention of or reference to 'temperature control' rather than common recognition of the risk factor.

Many students simply stated that the Bunsen burner was 'too hot'. This was not accepted.

Question 9c.

Marks	0	1	2	3	Average
%	41	18	12	29	1.3

The three marks for this question were awarded for:

- correctly describing the bonding (dispersion force attraction) between butane molecules
- correctly describing the bonding (hydrogen bonding) between propan-1-ol molecules

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- indication that the higher boiling point of propan-1-ol is because the hydrogen bonding between propan-1-ol molecules is stronger than the dispersion forces bonding between butane molecules.

Some responses showed good understanding of bonding and included points such as the relative polarity of butane and 1-propanol molecules, and the role of the –OH group in hydrogen bonding between 1-propanol molecules. However, overall performance on this question suggested that many students were perhaps not expecting a ‘bonding’-related question.

While the boiling point of butane as stated in the question, -138.4°C , is its melting temperature (the correct boiling temperature is -0.5°C), this did not affect student performance.

Common errors included:

- reading the data as butane having the higher boiling point
- relating the boiling point to the bonds within the molecules
- describing the hydrogen bonding in propan-1-ol as the bond between O and H in the hydroxyl group
- referring to hydrogen bonding between propan-1-ol and water.

There was clear evidence that many students were not familiar with, or were confused by, the term ‘intermolecular’.