



2012

Chemistry GA 1: Written examination 1

GENERAL COMMENTS

This examination was the final Unit 3 June examination for the *VCE Chemistry Study Design*. From 2013, a single examination covering both Units 3 and 4 will be held in November.

Overall, students performed very well on the 2012 June Chemistry examination.

Section A was generally very well handled, with the majority of questions answered correctly by most students. Questions 5, 13 and 14 proved to be the most difficult for students. Responses to Question 5 showed that, while students were aware that the secondary structure of proteins involves peptide groups, knowledge of where the hydrogen bonding between these groups occurs needs improvement. Responses for Question 13 suggested that many students did not read the question properly as many treated the volume of water added during dilution as if it were the same as the volume of diluted acid. Responses to Question 14 showed that many students continue to find unit manipulation and conversion challenging.

Other areas of concern with Section A included the following.

- Many students did not accurately distinguish between IR spectra of an ester and a carboxylic acid (Question 11).
- Many students did not correctly use the O:C ratio in Taxol[®], C₄₇H₅₁NO₁₄, when determining the mass of oxygen present in a sample containing a given mass of carbon (Question 15).
- Some students selected an oxidation half-equation when asked to identify a reduction half-equation (Question 20).

The majority of questions in Section B were generally well handled, and students seem to have managed their time well.

There was an emphasis on equation writing throughout Section B, with balanced equations required in Questions 1aii., 1aiii., 1bi., 1biii., 4b., 7ai. and 8aii. In all but one of those instances, states were required.

Specific Information

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	2	92	3	2	0	
2	12	11	66	11	0	1-chlorobutane, CH ₃ CH ₂ CH ₂ CH ₂ Cl 2-chlorobutane, CH ₃ CH ₂ CHClCH ₃ 1-chloro-2-methylpropane, (CH ₃) ₂ CHCH ₂ Cl 2-chloro-2-methylpropane, (CH ₃) ₃ CCl
3	7	2	1	90	0	
4	5	88	4	3	0	
5	27	12	10	51	0	The primary, secondary and tertiary structures were accurately described in statements I, II and III respectively. The choice of option A suggested that many students were not aware that the hydrogen bonding in the secondary structure that occurs between peptide, –CONH–, groups, in the secondary structure of proteins is between the H atom on peptide group and the O atom on a peptide group further along the chain.



Question	% A	% B	% C	% D	% No Answer	Comments
6	70	19	7	3	0	All amino acids contain the $-\text{NH}_2$ and $-\text{COOH}$ functional groups. Overall polarity therefore depends on the polarity of the side chains. Of the amino acids listed, only glutamic acid (option A) has a polar group ($-\text{COOH}$) in its side chain. Students could have checked this in the Data Book.
7	9	3	83	5	0	
8	11	4	15	71	0	In reaction 1, salicylic acid was converted to the ester methyl salicylate by reaction with methanol (reagent X). In reaction 2, salicylic acid was converted to acetylsalicylic acid (aspirin) (compound Y) by reaction with ethanoic anhydride.
9	83	5	9	2	0	
10	82	6	6	7	0	
11	61	31	4	3	0	The compound in question, ethyl propanoate, contains the ester group, so its IR spectrum will lack broad absorption bands at $2500\text{--}3300\text{ cm}^{-1}$ (O–H acids) and $3200\text{--}3550\text{ cm}^{-1}$ (O–H alcohols), but will show a distinct absorption band at $1670\text{--}1750\text{ cm}^{-1}$ (C=O).
12	4	7	83	6	0	
13	3	48	46	3	0	$n(\text{HCl}) \text{ present} = 10.0\text{ mol L}^{-1} \times 15.0 \times 10^{-3}\text{ L}$ $= 1.50 \times 10^{-3}\text{ M}$ Volume of diluted acid = $15.0 + 60.0$ $= 75.0\text{ mL}$ $c(\text{diluted acid}) = 1.50 \times 10^{-3}\text{ mol} \div 75.0 \times 10^{-3}\text{ L}$ $= 2.00\text{ M}$ Alternatively, since the volume of the acid increases by a factor of 5 (15.0 mL to 75.0 mL) the concentration decreases by a factor of 5 from 10.0 M to 2.00 M. Option B is consistent with calculating the concentration of the diluted acid based on the volume of diluted solution being 60.0 mL.
14	7	49	16	27	1	$V(\text{water}) \text{ produced} = 200 \times 10^9\text{ L}$ $m(\text{B}) \text{ permitted} = 0.5\text{ mg L}^{-1} \times 200 \times 10^9\text{ L}$ $= 100 \times 10^9\text{ mg}$ $= 100 \times 10^9 \div 10^3\text{ g}$ $= 100 \times 10^6\text{ g}$ $= 100 \times 10^6 \div 10^3\text{ kg}$ $= 1 \times 10^5\text{ kg}$ Option C resulted from adding an incorrect and irrelevant step – multiplying the $m(\text{B})$ as calculated in kilograms by the molar mass of B (10.8). Option D was consistent with a unit manipulation error – either not, or incorrectly, converting milligrams to grams and/or grams to kilograms.



Question	% A	% B	% C	% D	% No Answer	Comments
15	18	66	11	5	1	<p>Taxol[®] C₄₇H₅₁NO₁₄ $n(\text{C}) \text{ present} = 0.157 \text{ g} \div 12.0 \text{ g mol}^{-1}$ $= 0.0131 \text{ mol}$ $n(\text{Taxol}^{\text{®}}) = n(\text{C}) \div 47$ $n(\text{O}) \text{ present} = 14 \times n(\text{Taxol}^{\text{®}})$ $= 14 \times n(\text{C}) \div 47$ $= 14 \times 0.0131 \div 47$ $= 0.00390 \text{ mol}$ $m(\text{O}) \text{ present} = 0.00390 \times 16.0$ $= 0.0624 \text{ g}$</p> <p>Option A was consistent with using the 14/47 ratio to calculate the m(O) directly from the m(C). Students should know that ratios deduced directly from a formula, or an equation, are mole ratios not mass ratios. Option C was consistent with overlooking the 14/47 ratio in calculating the n(O) from the n(C).</p>
16	10	6	82	2	0	<p>$V = nRT \div p$ $n(\text{He}) = pV \div RT$ $= (10.2 \times 101.3) \times 5.65 \div (8.31 \times 298)$ $= 2.36 \text{ L}$</p> <p>Option A was consistent with not converting the pressure to Pa.</p>
17	7	16	12	65	0	<p>The solution to be titrated was 0.100 M HCl, so the pH at the start of the titration was 1 as indicated on graphs B and D. As 0.100 M NaOH is added beyond the endpoint – that is, after 0.010 L (10 mL) NaOH has been added – the solution becomes increasingly basic and the pH approaches 13 (the pH of 0.100 M NaOH). Hence option D was correct. After 0.020 L (20 mL) of 0.100 M NaOH has been added, there will be 0.0010 mol OH⁻ in excess in 30 mL of solution ∴ [OH⁻] = 0.033 M ∴ pH = 12.5</p> <p>Options A and C were not consistent with a starting solution of 0.100 M HCl.</p>
18	6	10	75	8	1	<p>Since each molecule contains only one C=C $n(\text{alkene}) = n(\text{Br}_2)$ $= 8.0 \div 160.0$ $= 0.050 \text{ mol}$ $M(\text{alkene}) = 2.1 \text{ g} \div 0.050 \text{ mol}$ $= 42 \text{ g mol}^{-1}$</p>
19	2	83	6	9	0	
20	16	11	11	61	0	<p>In the reaction, the oxidation number of I changes from +5 (in IO₃⁻) to 0 (in I₂) and from -1 (in I⁻) to 0 (in I₂). IO₃⁻(aq) is reduced to I₂(s) and I⁻(aq) is oxidised to I₂(s). The reduction half-equation is $2\text{IO}_3^-(\text{aq}) + 12\text{H}^+(\text{aq}) + 10\text{e}^- \rightarrow \text{I}_2(\text{s}) + 6\text{H}_2\text{O}(\text{l})$.</p> <p>In reduction half-equations the electrons are on the reactant (left-hand) side. However, many students selected option A or C – both of which are oxidation half-equations.</p>



Section B – Short-answer questions

Question 1

Question 1 was generally well done. Part aiii. was notable for the variety of incorrect catalysts associated with the production of ethanol from ethene. As students were required to write a balanced equation, there was no need to include a catalyst; however, if a catalyst was included it needed to be correct. Students should realise that the inclusion of ‘chemically incorrect’ information has an impact on the awarding of marks. Many significant errors occurred in part biii., most of which were associated with the omission of O₂ from the equation or an incorrect coefficient for O₂ due to not taking account of the O atoms in the fatty acid.

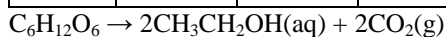
Question 1ai.

Marks	0	1	Average
%	18	82	0.8

glucose

1aii.

Marks	0	1	Average
%	36	64	0.6

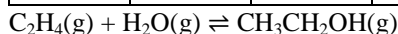


C₂H₆O and C₂H₅OH were also acceptable formulas for ethanol.

In completing the equation for fermentation, students were expected to balance the equation. This was overlooked by some students.

1aiii.

Marks	0	1	Average
%	37	63	0.6



Many responses to this question were marred by the addition of an arbitrary, chemically incorrect catalyst above the arrow. The acid catalyst used is normally phosphoric acid, H₃PO₄.

The frequent use of (aq) as the state of ethene was of concern.

1bi.

Marks	0	1	Average
%	27	73	0.7

Either of:

- 3 CH₃(CH₂)₁₆COOH + 1 C₃H₈O₃
- 3 CH₃(CH₂)₁₆COOH + _ C₃H₈O₃ (that is, no coefficient for glycerol).

The presence of an extra C in the structure of the triglyceride meant that there was a valid argument for only two CH₃(CH₂)₁₆COOH, which was also accepted.

1bii.

Marks	0	1	Average
%	20	80	0.8

Either of:

- stearic acid
- octadecanoic acid.

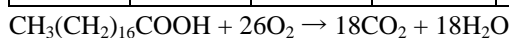
A small number of students did not effectively use the Data Book to identify the fatty acid.

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1biii.

Marks	0	1	2	Average
%	38	28	33	0.9



$\text{C}_{17}\text{H}_{35}\text{COOH}$ and $\text{C}_{18}\text{H}_{36}\text{O}_2$ are also acceptable formulas for stearic acid.

One mark was awarded for correct formulas of all four reactants and products, and one mark was awarded for having all four coefficients correct/consistent with the equation.

Students who did not identify stearic acid in part ii. were awarded marks in part iii. if the equation was consistent with their answer to bii.

The main errors in writing the equation were:

- not including H_2O as a product
- an incorrect coefficient for O_2 .

Question 2

Question 2 required students to explain the difference between two chromatograms of a mixture of four amino acids obtained using different mobile phases in terms of the data provided. Although most students obtained full marks, a number of students could not effectively relate the R_f data provided to the question. Rotating the thin layer plate to obtain the second chromatogram seemed unfamiliar to many students.

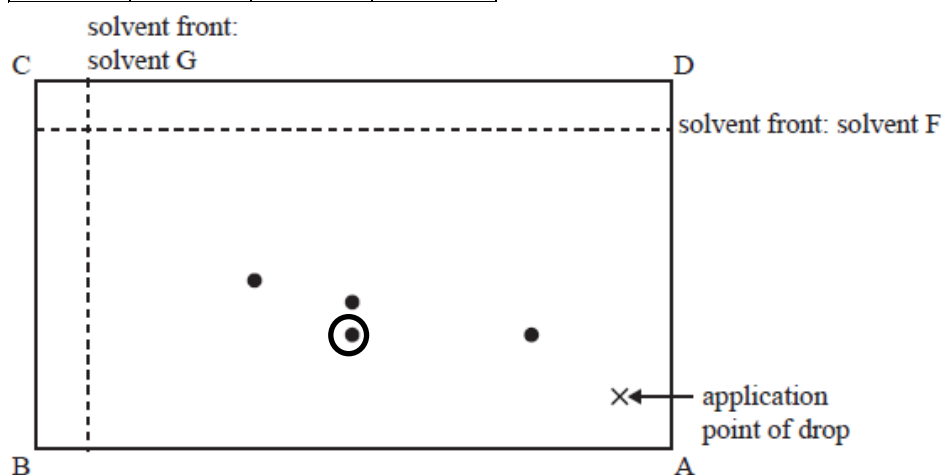
2a.

Marks	0	1	Average
%	9	91	0.9

Tyrosine

2b.

Marks	0	1	Average
%	22	78	0.8



chromatogram II

2c.

Marks	0	1	2	Average
%	24	25	51	1.3

In chromatogram I, which used solvent G, alanine and threonine appeared as the same spot/were not separated since both had the same R_f value (0.51). In chromatogram II, which used solvent F, alanine and threonine had different R_f values and were separate.

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Some good responses referred to the different attractions of alanine and threonine to the stationary/mobile phases with solvent F. Others noted that while alanine and arginine had the same R_f value in solvent F, they had already been separated in solvent G.

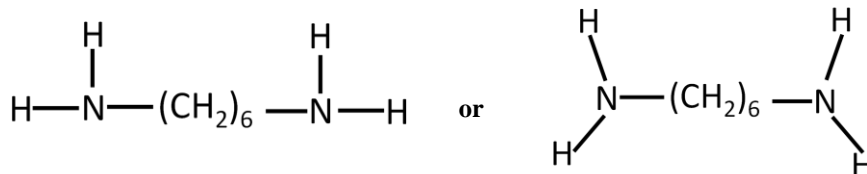
Many students did not effectively interpret the data provided – chromatograms and R_f values in the different solvents. Students need to be able to apply their understanding in both familiar and unfamiliar contexts.

Question 3

Many students struggled with parts b., c. and d. of Question 3. The requirement in part b. to name the functional groups that link the monomers in nylon and protein revealed some confusion about functional groups. Many students focused on the functional groups that react together to produce the linking functional groups rather than the actual linking groups. Many students confused amide and amino groups, and were unable to apply the terms ‘amide’ and ‘peptide’ appropriately. Part c. required students to make appropriate reference to the structures of nylon and protein monomers and explain why that leads to different orientation of the linking functional groups in nylon and protein. Of the students who did gain some marks, the majority simply restated the orientation statements in the stem of the question rather than how that arose from the structures of the monomers. In part d. many students seemed to be confused by the representation of the monomer and did not seem to recognise that the C=C double bond was an indication that the monomers would join via addition polymerisation; so, on adjacent C atoms in the backbone of the polymer, one would have two H atoms attached and the other CH_3 and COOCH_3 groups. This was another example of the need to be able to apply a learned skill (addition polymerisation) in an unfamiliar context.

3a.

Marks	0	1	Average
%	18	82	0.8



The structures represented above were consistent with the style given on the exam for the structure of the other monomer. Other structures correctly showing all bonds were also acceptable.

3b.

Marks	0	1	2	Average
%	26	41	33	1.0

- nylon: amide
- protein: amide or peptide

The functional groups that link the monomers are the functional groups that have formed as a result of the monomers linking together.

A large proportion of students interpreted this question as referring to the functional groups that react together, that is, carboxyl and amino. There was evidence that many students could not distinguish between the amino and amide functional groups. Students should be aware that the ‘peptide’ group is a special case of the broader context ‘amide’ group.

3c.

Marks	0	1	2	Average
%	47	32	21	0.7

The monomers from which the protein is produced all contain both the amino (NH_2) and carboxyl (COOH) functional groups, and reaction between different functional groups on adjacent monomers always produces the sequence CONH .

The monomers from which nylon is produced have either two amino (NH_2) or two carboxyl (COOH) functional groups. Reaction between the different functional groups on adjacent monomers alternately produces CONH and NHCO .

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Students were expected to recognise the repeating $-\text{CONH}-$ sequencing in protein and the alternating $-\text{CONH}-$, $-\text{NHCO}-$ sequencing in nylon and relate this to the functional groups present on the reacting monomers.

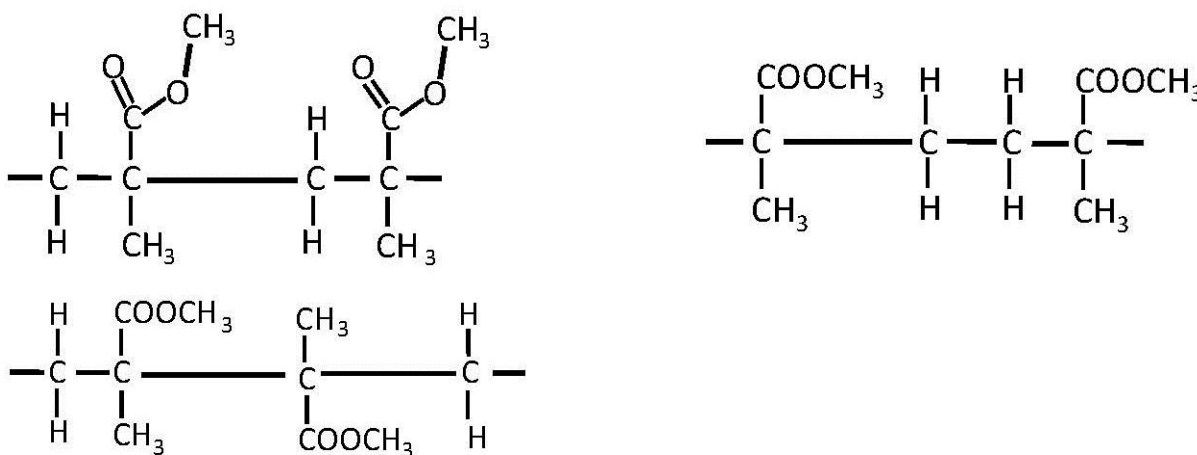
The question proved particularly challenging for the majority of students. The best responses provided a valid argument for the differences in orientation of the amide groups in nylon and protein, but most responses simply restated the information provided in the stem of the question.

There were some unusual interpretations of 'appropriate reference to the structures of nylon and protein monomers', with many students focusing of the nature of the reaction to form the polymers or the structure of the polymers rather than the functional groups present on the monomers.

3d.

Marks	0	1	2	Average
%	71	7	22	0.5

Acceptable representations of the section of the polymer included the three shown below.



One mark was awarded for having the correct connections between all C atoms. One mark was awarded for correctly locating the groups attached to the C–C backbone and for including open bonds at the ends of the C–C backbone.

This question was not well handled. The presence of the C=C double bond in the monomer should have prompted students into realising that the polymerisation process was 'addition' polymerisation and that the monomers linked by the C=C double bonds were being converted to C–C single bonds as the carbon backbone formed. The section of polymer needed to have four C atoms in the backbone: two with two $-\text{H}$ atoms attached and two with $-\text{CH}_3$ and $-\text{COOCH}_3$ attached. There were many responses that included an 'O' atom in the backbone.

A significant number of responses showed all bonds. This was acceptable as long as the correct bonds were shown.

Question 4

Question 4 required students to apply the knowledge and skills acquired in their study of organic chemical pathways. This question made clear the benefits of reading through the whole question before answering. In part a. the systematic name of the alkanol used to produce propyl propanoate may not have initially been evident to some students. However, part c. provided clear evidence that it was propan-1-ol. The equation in part b. was not always handled as well as expected, with common errors including incorrect ester semi-structural formula, lack of H_2O as a product and incorrect states. Part c. was notable for the number of students who ignored the emphasis on 'pure' in the question and did not state a method of purification. Errors in formulas of inorganic reagents were also evident.

4a.

Marks	0	1	2	Average
%	13	45	42	1.3

Both of:

- propan-1-ol or 1-propanol
- propanoic acid.

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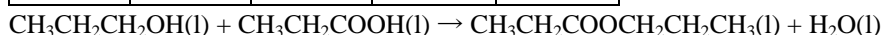
The most common errors in response to this question were either not including the '1-' in 1-propanol or incorrectly including a '1-' in propanoic acid.

Students should be aware that the systematic names for the two isomers with the chemical formula C_3H_7OH are propan-1-ol and propan-2-ol. Hence propanol was not an acceptable response for the 'systematic' name of the alcohol. The ester propyl propanoate is formed by reaction between propan-1-ol and propanoic acid.

In the case of carboxylic acids, the carboxyl carbon is always C-1, so that number is not part of the systematic name.

4b.

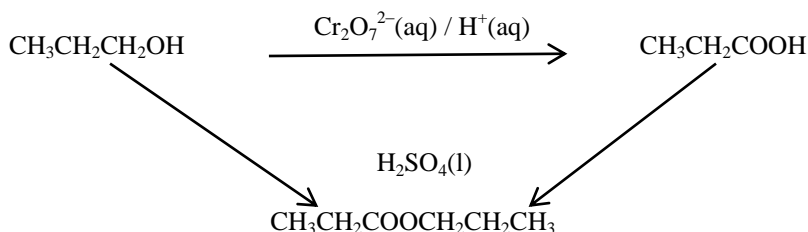
Marks	0	1	2	Average
%	26	41	33	1.2



Two common errors in response to this question were incorrect formulas for the ester (students often included an extra O atom or left off a C atom) and not including H_2O as a product. The proportion of responses that showed all states as (aq) was surprisingly high.

4c.

Marks	0	1	2	3	Average
%	30	20	39	11	1.3



The pure sample is collected by fractional distillation.

One mark was awarded for recognising the need to convert some of the propan-1-ol to propanoic acid. One mark was awarded for identifying the inorganic reagents – acidified dichromate ($Cr_2O_7^{2-}$) for the oxidation of 1-propanol to propanoic acid, and sulfuric acid (H_2SO_4) for the reaction between propan-1-ol and propanoic acid to produce propyl propanoate. The third mark was awarded for identifying the technique used to collect a pure sample of propyl propanoate.

The most common error was not describing how a pure sample of the ester could be obtained, despite the word 'pure' being highlighted in the question.

Errors associated with the inorganic reagents were common. Previous assessment reports have emphasised the importance of providing correct chemical formulas in such questions, but common errors such as incorrect dichromate formulas and $H_2SO_4(aq)$ in ester production persist.

4d.

Marks	0	1	2	Average
%	38	24	38	1.0

Acceptable responses included the following.

IR spectroscopy	Either of: <ul style="list-style-type: none"> run an IR spectrum of the compound and compare it with the IR spectrum of pure propyl propanoate pure propyl propanoate will not produce a broad absorption peak at $2500\text{--}3330\text{ cm}^{-1}$ (O–H acid), or $3200\text{--}3350\text{ cm}^{-1}$ (O–H alcohol).
Boiling temperature	Determine the boiling temperature of the collected ester and compare it with the known boiling temperature of pure propyl propanoate from data sources.

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Chromatography	Either of: <ul style="list-style-type: none"> run a spectrum (HPLC, GC or TLC) of the collected ester and check for the number of peaks or spots. A single peak or spot suggests the sample is pure compare a chromatogram of the collected ester with a chromatogram of a pure sample obtained under the same conditions.
UV-visible spectroscopy	Run an absorption spectrum of the ester and compare it with the UV-visible absorption spectrum of pure propyl propanoate.

One mark was awarded for identifying the method and a further mark was awarded for explaining how the method identified would indicate that the sample was pure propanoate.

Chromatography and IR spectroscopy were the most commonly identified methods for students who were awarded both marks for the question. A significant number of responses identified fractional distillation as the method; however, reference to the appropriate boiling temperature and a discussion were needed for such responses to be awarded full marks. Techniques such as mass spectrometry and NMR spectroscopy, while relatively rare in responses, were also acceptable provided they included an appropriate explanation.

Reference to inappropriate techniques such as AAS, gravimetric analysis, use of indicators and many others suggested that the issue of product purity is not always part of organic chemical pathways discussions.

Question 5

Question 5 was well done. However, responses to part c. suggested that many students, after having identified the compound as an alcohol, did not check back to the NMR spectra before drawing its structure.

5ai.

Marks	0	1	Average
%	7	93	

Two

5aii.

Marks	0	1	Average
%	7	93	

Three

5aiii.

Marks	0	1	Average
%	18	82	

Six

Interpretation of simple NMR spectra was once again handled well by the majority of students. While most responses to part iii. correctly deduced that the septet at 3.6 ppm on the ^1H NMR spectrum implied the presence of six equivalent H atoms on neighbouring C atoms, a number also made it clear that this must mean three H atoms on each of two neighbouring C atoms.

5b.

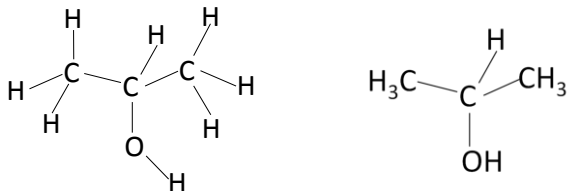
Marks	0	1	Average
%	13	87	

O and H



5c.

Marks	0	1	Average
%	42	58	0.6



While most students deduced that C_3H_8O was an alcohol, a significant proportion of responses showed the structure of propan-1-ol rather than the required propan-2-ol. It would seem that many of these students did not check back to the NMR spectra or their answers to part a. before drawing the structure. Students must be careful when showing bonds in structures. When showing the bond between carbon and the hydroxyl group in an alcohol, it must be clear that the bond is between C and O.

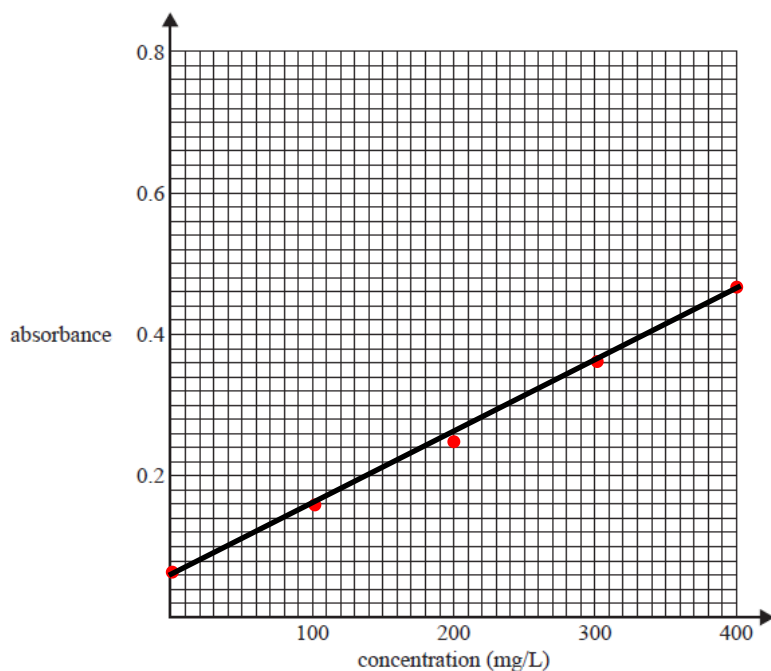
Question 6

Students generally constructed the graph for Question 6ai. accurately; however, errors arose in 6aii. because of inaccurate reading of the graph. Also in 6aii., many responses did not include the average iron content.

Question 6b. revealed some significant misunderstandings of the effects of the interaction of electromagnetic radiation with matter, most notably the absorption of IR radiation. Students should be aware that the absorption causes a change in some characteristic of atoms or molecules, be that electron transition to a higher energy level (AAS), change in nucleus spin state (NMR) or a change in bond vibrations (IR). Although IR spectroscopy was the most commonly selected method, most students showed a misunderstanding that the absorption of IR radiation initiates bond vibration. Changes in atoms or molecules during the absorption of electromagnetic radiation in the different types of spectroscopy should be addressed.

6ai.

Marks	0	1	2	Average
%	9	15	76	1.7



One mark was awarded for correctly locating all points on the graph, and the second mark was awarded for an accurate line of best fit.

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Most errors on this question occurred in locating the points on the axes and/or drawing the line back through zero.

6a.iii.

Marks	0	1	2	Average
%	26	41	33	1.1

Average absorbance of the iron tablets = 0.42

$$c(\text{Fe}) = 360 \text{ mg L}^{-1}$$

Average $m(\text{Fe})$ in each tablet (in 100 mL solution) = 36 mg

$$\text{Average iron content} = 36 \text{ (mg)}$$

Some students omitted the second step – converting the average concentration in mg L^{-1} to the mass of Fe present in the 100 mL of solution analysed. A number of responses did this correctly for all three tablets but did not then determine the average Fe content. Inaccurate reading of the graph drawn in part i. was also common.

Students whose graph in part i. was inaccurate could still access the marks for part ii. if their calculations were consistent with their graphs.

6b.i.

Marks	0	1	Average
%	31	69	0.7

One mark was awarded for correctly identifying the part of the electromagnetic spectrum used by the technique nominated.

Many students named a technique but did not actually identify the associated part of the electromagnetic spectrum.

6b.ii.

Marks	0	1	2	Average
%	35	45	19	0.8

Spectroscopic technique	Part of spectrum	How it interacts	Information provided
AAS (Atomic Absorption)	visible radiation	Electrons (in atoms) move to higher energy levels	Concentration of the absorbing species
UV-visible	ultraviolet and/or visible radiation	Electrons (in molecules or ions) move to higher energy levels	Concentration of the absorbing species
IR (infrared)	infrared radiation	'Change' in bond vibration/stretching/polarity in molecules	Types of bonds/functional groups in a molecule
¹ H NMR (Nuclear magnetic resonance)	radiowave radiation	¹ H nuclei, in molecules, change to nucleus energy levels/spin states	Bonding environments of H atoms in a molecule
¹³ C NMR (Nuclear magnetic resonance)	radiowave radiation	¹³ C nuclei, in molecules, change to nucleus energy levels/spin states	Bonding environments of C atoms in a molecule

In part b.ii., one mark was awarded for correctly describing the effect of electromagnetic radiation on the substance being analysed, and a second mark was awarded for correctly describing the information obtained through the electromagnetic radiation.

Infrared spectroscopy was a very popular choice. However, explanations of how IR radiation interacts with matter indicated that students had an incorrect perception that it is the absorption of IR radiation that initiates vibrational modes such as stretching rather than causes a change in such vibrational modes. Students should be aware of this important distinction. Another aspect of IR-based responses was use of the general term 'structure' when describing the information supplied by the absorption of IR radiation rather than the more accurate 'bonds' or 'functional groups'.

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The most common correct spectroscopic technique was atomic absorption spectroscopy. However, students should be reminded that the absorption of radiation causes electrons to move to 'higher' energy levels.

Question 7

Question 7 required students to provide a balanced equation (which was not well done), calculate amounts of substance (which was generally well done except for some issues with sample size) and provide two explanations of information provided. When asked to explain why no lead(II) nitrate formed, the majority of students simply stated that 'all nitrates are soluble' rather than responding in the context of the question. The supplied data showed that lead(II) nitrate had a much greater solubility than the alternative option lead(II) ethanoate. Students should always answer with reference to the question, rather than simply providing previously learned facts.

7ai.

Marks	0	1	Average
%	55	45	0.5

Acceptable equations included:

- $\text{Pb}(\text{CH}_3\text{COO})_2(\text{aq}) + 2\text{KI}(\text{aq}) \rightleftharpoons \text{PbI}_2(\text{s}) + 2\text{KCH}_3\text{COO}(\text{aq})$
- $\text{Pb}^{2+}(\text{aq}) + 2\text{I}^{-}(\text{aq}) \rightleftharpoons \text{PbI}_2(\text{s})$.

Errors included incorrect balancing, incorrect or missing states, and incorrect formulas (most notably incorrect variations on the correct formula for potassium acetate).

Students should be encouraged to write either a full equation or an ionic equation for precipitation reactions. Consistent errors on states suggested that students may benefit from including them in all balanced equations.

7aii.

Marks	0	1	Average
%	38	62	0.6

Either of:

- to ensure that the precipitate was dry
- to remove any water present.

Many responses referred, incorrectly, to the removal of impurities as the purpose for heating and weighing. Others indicated the purpose was 'heating to constant mass'. This was not acceptable because it is the outcome of heating and taken as indication that the 'purpose' – drying the precipitate – has been achieved.

7aiii.

Marks	0	1	Average
%	31	69	0.7

$$\begin{aligned} m(\text{PbI}_2) &= m(\text{filter paper} + \text{precipitate}) - m(\text{precipitate}) \\ &= 0.4059 - 0.3120 \\ &= 0.0939 \text{ g} \end{aligned}$$

A large number of students did not use the precipitation data to calculate the $m(\text{PbI}_2)$ formed.

7aiv.

Marks	0	1	2	3	Average
%	26	12	23	39	1.7

$$\begin{aligned} n(\text{PbI}_2) \text{ collected} &= 0.0939 \div 461.0 \\ &= 2.04 \times 10^{-4} \text{ mol} \end{aligned}$$

$$n[\text{Pb}(\text{CH}_3\text{COO})_2] \text{ in } 20.0 \text{ mL dye} = 2.04 \times 10^{-4} \text{ mol}$$

$$n[\text{Pb}(\text{CH}_3\text{COO})_2] \text{ in } 100 \text{ mL dye} = 5 \times 2.04 \times 10^{-4}$$

$$= 1.02 \times 10^{-3} \text{ mol}$$

$$\begin{aligned} m[\text{Pb}(\text{CH}_3\text{COO})_2] \text{ in } 100 \text{ mL dye} &= 1.02 \times 10^{-3} \times 325.3 \\ &= 0.331 \text{ (g)} \end{aligned}$$

The most common error was not adjusting the amount of $\text{Pb}(\text{CH}_3\text{COO})_2$ from that present in the 20.0 mL analysed to the 100 mL sample.

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7b.

Marks	0	1	Average
%	78	22	0.2

Either of:

- lead(II) nitrate is highly soluble
- lead(II) nitrate has a much higher solubility than lead(II) iodide.

The majority of responses simply stated that 'all nitrates are soluble'. However, to obtain the mark in the context of this question, some indication of the relative solubility of lead(II) nitrate compared to lead(II) iodide was required. The data given in the question provided the relative solubilities of lead(II) nitrate and lead(II) iodide at 25 °C and showed that lead(II) nitrate is much more soluble than lead(II) iodide.

Question 8

Question 8a. required students to apply learned techniques associated with back titration and dilution. It was clear that some students were comfortable with these techniques and others were not. There were significant misinterpretations evident in many responses. In many back-titration questions equations are provided. This was not the case on this question so careful reading was required. Part av. proved to be the most challenging for students, with calculations suggesting that many students struggled to convert between units, in this case from an amount in 5.0 mL to a mass in 1 L. Students should be aware that on questions such as this, where all data involved in the calculations is given to three significant figures, it is expected that the answer will also be expressed to three significant figures. Question 8b. assessed students' ability to explain predicted outcomes. Of those students who identified that rinsing the burette with water would increase the titre volume, about half were able to explain how that would lead to a lower calculated solubility.

8ai.

Marks	0	1	Average
%	31	69	0.7

Either of:

- $\text{NaOH(aq)} + \text{HCl(aq)} \rightleftharpoons \text{NaCl(aq)} + \text{H}_2\text{O(l)}$
- $\text{OH}^{\text{-}}(\text{aq}) + \text{H}^{\text{+}}(\text{aq}) \rightleftharpoons \text{H}_2\text{O(l)}$.

Students should be reminded that states are not an optional extra in equations.

8aii.

Marks	0	1	Average
%	18	82	0.8

$$\begin{aligned} n(\text{NaOH}) &= 0.400 \times 10.0 \times 10^{-3} \\ &= 4.00 \times 10^{-3} \text{ (mol)} \end{aligned}$$

8aiii.

Marks	0	1	2	Average
%	44	7	49	1.0

$$\begin{aligned} n(\text{NH}_4\text{Cl}) \text{ in } 20.0 \text{ mL aliquot} &= n(\text{NaOH}) \text{ reacting with } \text{NH}_4\text{Cl} \text{ in the } 20.0 \text{ mL aliquot} \\ &= n(\text{NaOH}) \text{ initially} - n(\text{NaOH}) \text{ in excess} \end{aligned}$$

$$\begin{aligned} n(\text{NaOH}) \text{ in excess} &= n(\text{HCl}) \\ &= 0.125 \times 14.7 \times 10^{-3} \text{ mol} \\ &= 1.84 \times 10^{-3} \text{ mol} \end{aligned}$$

$$\begin{aligned} n(\text{NH}_4\text{Cl}) \text{ in } 20.0 \text{ mL aliquot} &= 4.00 \times 10^{-3} - 1.84 \times 10^{-3} \\ &= 2.16 \times 10^{-3} \text{ mol} \end{aligned}$$

It was clear that some students realised they were dealing with a back titration and others did not, despite the indication in the first sentence. Those in the latter category generally assumed, incorrectly, that the amount of NH_4Cl in the 20.0 mL aliquot was the same as the amount of NaOH to which the aliquot was added; that is, the answer to part aii. There was also some unnecessary application of dilution factors.

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8aiv.

Marks	0	1	Average
%	55	45	0.5

$$\begin{aligned}n(\text{NH}_4\text{Cl}) \text{ in } 5.00 \text{ mL saturated solution} &= n(\text{NH}_4\text{Cl}) \text{ in } 250 \text{ mL diluted solution} \\ &= (n(\text{NH}_4\text{Cl}) \text{ in } 20 \text{ mL diluted solution}/20) \times 250 \\ &= (2.16 \times 10^{-3} \div 20) \times 250 \\ &= 0.0270 \text{ mol}\end{aligned}$$

Identifying the correct dilution factor (250/20) proved problematic for many students. Factors of (20/5) and (250/5) were common, presumably because students thought that because 5.00 mL of saturated solution was mentioned in the question, then 5 had to be part of the dilution factor.

8av.

Marks	0	1	2	Average
%	52	24	24	0.7

$$\begin{aligned}n(\text{NH}_4\text{Cl}) \text{ in one litre} &= (0.0270/5) \times 1000 \\ &= 5.41 \text{ mol}\end{aligned}$$

$$\begin{aligned}m(\text{NH}_4\text{Cl}) \text{ in one litre} &= 5.41 \times 53.5 \\ &= 289 \text{ g}\end{aligned}$$

Solubility 289 g L⁻¹ (288–290)

In this part of the question, students were awarded marks for accurately multiplying their answer to part iv. by 200 (that is, 1000 ÷ 5) and by 53.5, with the answer expressed to three significant figures. Many students seemed unsure how to adjust from the amount present in 5.00 mL to the amount present in one litre (1000 mL) and divided by 200, rather than multiplying by 200. Given that all data was expressed to three significant figures, the number of answers that were not also expressed to three significant figures was surprising.

8b.

Marks	0	1	2	Average
%	54	22	24	0.7

Since the HCl(aq) in the burette was diluted, a larger V(HCl) (titre) was required to react with the excess NaOH. Hence the $n(\text{NaOH})$ in excess was calculated as higher than true, leading to a smaller calculated $n(\text{NaOH})$ reacted with NH_4Cl and a lower calculated amount (solubility) of NH_4Cl .

One mark was awarded for indication of the larger titre (V(HCl)) or larger calculated $n(\text{HCl})$. The second mark was awarded for an appropriate explanation of how this leads to a lower calculated solubility.

Many students who recognised the large titre volume struggled to explain why the calculated solubility would be lower.