AS LEVEL

Examiners' report

CHEMISTRY B (SALTERS)

H033
For first teaching in 2015

H033/02 Summer 2018 series
Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates. The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report. A full copy of the question paper can be downloaded from OCR.

Paper H033/02 series overview

H033/02 (Chemistry in Depth) is one of the two examination components for the new revised AS Level examination for GCE Chemistry B (Salters'), comprising 50% of the total AS Level. This component assesses content from across all teaching modules. Question styles include short answer (structured questions, problem solving, calculations, practical) and extended response questions including Level of Response type. To do well on this paper, candidates need to be both familiar with the detail of the AS material and comfortable applying their knowledge and understanding to unfamiliar contexts. They also needed to be familiar with a range of practical techniques.

Candidate performance

Candidates who did well on this paper generally did the following:

- Performed standard calculations following the required rubric (e.g. clear working, units, significant figures) (2(d)); use of $q = mc\Delta T$ to calculate ΔH in kJ mol^{-1} (2(f)); use of bond enthalpies and ΔH of reaction to calculate a missing bond enthalpy (3(f)); use of $E = h\nu$ to calculate a bond enthalpy (4(e)); use of titration results to calculate an amount, hence mass and thereby a % purity (3c(ii)); analysis of titration results (4a(ii)).
- Produced clear and concise responses for Level of Response questions: 1(d) and 2(g).
- Drew clear diagrams for organic structures: 2(a) (skeletal).
- Constructed and balanced both full and ionic equations for both familiar and unfamiliar reactions: 1(b), 1(d), 2(c), 3(a)(ii), 3(g)(ii), 4(d)(iii).
- Applied knowledge and understanding to questions set in both familiar and unfamiliar contexts: 2(b), 2(e), 3(b), 3(d)(i), 3(d)(iii), 4(c)(ii), 4(d)(ii), 4(d)(iv).

Candidates who did less well on this paper generally did the following:

- Found it difficult to apply what they had learnt in familiar but particularly in unfamiliar situations: 2(e), 3(b), 3(d)(iii), 4(c)(ii), 4(d)(ii), 4(d)(iv).
- Produced responses that lacked depth, and were often rambling and peripheral to what had been asked, sometimes simply repeating information provided: 2(b), 3(b), 3(d)(ii), 3(d)(iv).
- Showed poor setting out of unstructured calculations: 2(d), 2(f), 3(f), 4(e).
- Showed poor presentation of observations: 3(d)(i), 4(d)(ii).
- Lacked precision in balancing equations: 1(b), 2(c).

Question 1 (a) (i)

1   Chemists have arranged the elements into a Periodic Table which allows them to make predictions about the behaviour of the elements and their compounds.

   (a)   Many properties, such as first ionisation enthalpy, show a gradual change across a **period**.

   (i)   Write an equation representing the first ionisation enthalpy of sodium.

   Show state symbols.

[2]

Many candidates were familiar with the equation but less so with the gaseous state symbols required for both the sodium atom and cation.

Question 1 (a) (ii)

   (ii)   Explain the **general** increase in first ionisation enthalpy across Period 3 (sodium to argon).

....

....

....

.... [2]

Whilst there were complete answers to this question it was also common for candidates to score only one of the two marks. Some candidates did not recognise the importance of the fact that the electrons being removed are all from the same shell or that they experience the same/similar shielding. Other candidates, whilst recognising that the nuclear charge increases across the Period, did not link that to the fact the electrons are attracted more strongly to the nucleus.

Question 1 (b)

(b) Elements in a **group** often show similar properties.

The Group 2 element calcium reacts with water to produce a solution of calcium hydroxide and bubbles of hydrogen gas.

Predict a chemical equation for the reaction of radium, Ra, with water.
Include state symbols.

[1]

A significant number of candidates struggled with this question because they did not utilise the information in the question. Assuming that candidates recognised that Group 2 elements are solids and water is a liquid, the state symbols of the products are given in the question. The state symbol for calcium hydroxide most frequently caused problems. The formula for calcium hydroxide also caused problems for many with CaOH being a common mistake. This was probably caused by a failure to recognise the reference to Group 2 elements in the question. Further practice at writing and balancing chemical equations would not go amiss.

Question 1 (c)

(c) Mendeleev first proposed his Periodic Table in 1869. He left gaps for elements which he predicted would be discovered later.

One such element was in a gap immediately below silicon and he called it 'eka-silicon'.

Predict the formula of the oxide of eka-silicon, giving a reason.
Use **X** as the symbol for eka-silicon.

Formula ....

Reason ....

.... **[2]**

Most candidates predicted the correct formula. However, the reason proved to be more problematic with a significant number of candidates referring to the loss of the four outer-shell electrons to give a 4+ ion rather than resulting in a +4 oxidation state.

Question 1 (d)

(d)* A student is asked to identify a solid Group 2 compound, **A**.

The student carries out the following tests.

1. A very small amount of the solid is added to 2 cm depth of water in a test tube. Compound **A** partly dissolves. A couple of drops of universal indicator are added which show a pH of 11.

2. The student carries out a titration to calculate the M_r of the compound and hence identify the Group 2 element present.

    0.092 g of compound **A** is dissolved in water and made up to 250 cm³. 25.0 cm³ samples of this solution are titrated with 0.0100 mol dm⁻³ hydrochloric acid giving a mean titre of 24.80 cm³.

Identify compound **A**, giving reasons in full for your choice and including a chemical equation for the reaction in the titration.

....

....

....

....

.... **[6]**

This Level of Response question assessed both AO2 and AO3.

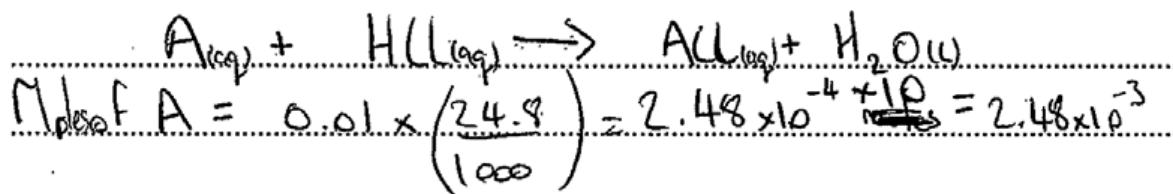This question generated a full range of marks amongst candidates.

At Level 1, whilst many candidates could not handle the quantitative data, they were able to secure at least one mark for recognising that the pH11 meant that A was an oxide or hydroxide.

At Level 2, many candidates were able to make some progress with the calculation of the M_r. However, the main barrier here to successfully completing the calculation was in recognising the importance of the 2 to 1 mole ratio of HCl to X(OH)$_2$. This problem often led to an M_r of the compound of 37.1, which seemed to lead many to conclude that since this was closest to the A_r of calcium, then compound A was indeed the element calcium. Candidates should be encouraged to evaluate their answers more critically because many of those candidates had at least shown A to be a hydroxide in the equation. A few here also confused Atomic Number with Relative Atomic Mass and so concluded that compound A was the element strontium!

Also at Level 2 there were a number of candidates that produced perfectly structured calculations of M_r but did not mention any of the evidence from the qualitative information. This was a real pity as for those candidates some reference to that qualitative data given in the question would probably have moved the answer to Level 3. Pleasingly, there were candidates that did make use of all of the information given in the question.

It may be interesting to note that some of the best answers were given by candidates that 'sketched out' a response amongst the lines of information within the question, almost like a plan for the answer. This tended to result in a response that showed greater clarity.

Exemplar 1

$$A_{(aq)} + HCl_{(aq)} \longrightarrow ACl_{(aq)} + H_2O_{(l)}$$

$$M_{oles} \text{ of } A = 0.01 \times \left(\frac{24.8}{1000}\right) = 2.48 \times 10^{-4} \times 10 = 2.48 \times 10^{-3}$$

$$M_r \text{ of } A = \frac{0.092}{2.48 \times 10^{-3}} = \cancel{} 37.097$$
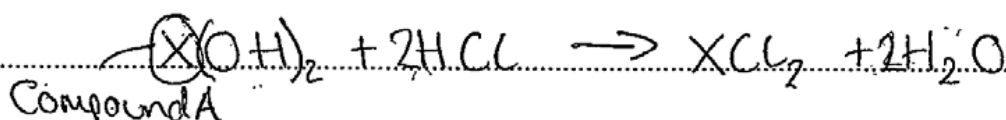
$$2.48 \times 10^{-3}$$

I think that as Compound A is dissolved in water it will have a formula $A_x(OH)_x$ and as the total Mr of the dissolved compound is 37.1, I think that Compound A is Barium and it's dissolved formula is $Ba(OH)_2$. This makes sense with point 1 as $BaOH_2$ can act as a base making it's solution very alkaline. Also, group 2 hydroxides are soluble but do tend to precipitate out a bit, hence the partly dissolves [6]

L1

This response is at L1 (2/6). It makes some use of the qualitative evidence and suggests that the compound is a hydroxide. An equation is given, though this is not correct. Some use has been made of the volumetric data but the response is limited by the incorrect equation. The candidate hasn't seemed to appreciate that it is the hydroxide of A that should appear in the equation.

Exemplar 2

$(X(OH)_2 + 2HCl \longrightarrow XCl_2 + 2H_2O$

Compound A

$0.01 \times \dfrac{24.8}{1000} = 2.48 \times 10^{-4}$ moles of HCl

in reaction

$2.48 \times 10^{-4} \div 2 = 1.24 \times 10^{-4}$ moles of $X(OH_2)_2$

$1.24 \times 10^{-4} \div \dfrac{25}{1000} = 4.96 \times 10^{-3}$ moldm^{-3} of $X(OH)_2$

$4.96 \times 10^{-3} \times 0.25 = 1.24 \times 10^{-3}$ moles of $X(OH)_2$

in the dissolved

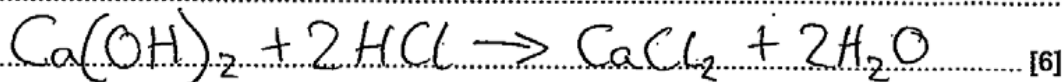$\dfrac{0.092}{1.24 \times 10^{-3}} = 74.19354839$ water

= Mr of $X(OH)_2$

$74.19354839 - (32 + 2) = 40.19354839$

Ca = 40.1   The ∴ Compound A is Calcium

$Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + 2H_2O$ [6]

L2

This response is at L2 (4/6). It begins with a correct reaction equation which enables a correct use of the volumetric data in order to work out the correct value for M_r, and hence the correct identification of compound A. However, there is no support given from the qualitative tests.

Exemplar 3

(d)* A student is asked to identify a solid Group 2 compound, A.

The student carries out the following tests.

$X(OH)_2 + 2HCl \rightarrow XCl_2 + 2H_2O$
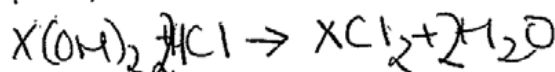
1. A very small amount of the solid is added to 2cm depth of water in a test tube. Compound A partly dissolves. A couple of drops of universal indicator are added which show a pH of 11.

$Mass = Mr \times moles$

2. The student carries out a titration to calculate the M_r of the compound and hence identify the Group 2 element present.

$0.092 \div x$ $\dfrac{1.24 \times 10^{-4}}{}$

0.092g of compound A is dissolved in water and made up to 250 cm³. 25.0 cm³ samples of this solution are titrated with 0.0100 mol dm⁻³ hydrochloric acid giving a mean titre of 24.80 cm³.

$n = 2.48 \times 10^{-4}$ $c = \dfrac{n}{v}$

Identify compound A, giving reasons in full for your choice and including a chemical equation for the reaction in the titration.

The compound has a very high pH, showing it is an alkaline, so it could be a group 2 metal hydroxide. This partly dissolves, suggest the metal in it is higher up in the group a solubility of hydroxides increases down the group 2.

this would mean the reaction with HCl in the titration would be: (with X being the Group 2 metal)

$$X(OH)_2 + 2HCl \rightarrow XCl_2 + 2H_2O$$
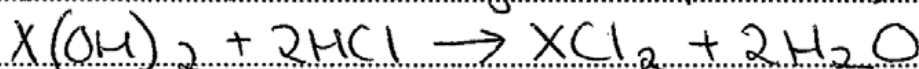
moles of HCl = $0.01 \times 0.0248 = 2.48 \times 10^{-4}$

so moles of X(OH)₂ = 1.24×10^{-4}
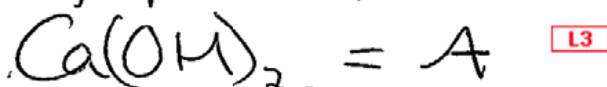
so, the Mr of compound A = $0.092 \div 1.24 \times 10^{-4}$

= 741.935

$9.2 \times 10^{-3} \div 1.24 \times 10^{-4} = 74.2$

= mr of A   [6]

$74.2 - (17 \times 2) = 40.2$

so group 2 metal = calcium

$Ca(OH)_2 = A$ L3

This response is at L3 (6/6). It begins with a helpful use of the qualitative evidence. A correct reaction equation is then provided that enables a clear and logical determination of M_r and hence the correct identification of calcium as the Group 2 metal.

Question 1 (e)

(e) Calculate the volume of gas (in cm^3 at RTP) produced when 0.493 g of barium carbonate, $BaCO_3$, is reacted with an excess of hydrochloric acid. (M_r of $BaCO_3$ = 197.2)

$$BaCO_3 + 2HCl \rightarrow BaCl_2 + CO_2 + H_2O$$

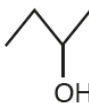volume of gas = ... cm^3 **[1]**

Many candidates were very successful in this question. For those that were not, a common error was failing to use the M_r of $BaCO_3$ given in the question. Some other candidates attempted, inappropriately, to make use of the ideal gas equation.
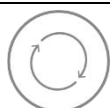
Question 2 (a)

2   Bioethanol is a well-known biofuel. Biobutanol is another biofuel and can be used in some combustion engines. Biobutanol can be produced in the UK from sugar beet.

(a) Butanol has the molecular formula, $C_4H_{10}O$. There are four structural isomers with this formula that contain the –OH functional group.

Complete the table below to show **one** other structural isomer of $C_4H_{10}O$ that contains an –OH group.

skeletal formula	OH	OH	
name	butan-1-ol	butan-2-ol	

[2]

This question identified the need to ensure that candidates are familiar with the principles of drawing skeletal formulae.

In terms of naming, a common mistake was to use 'methylbutan-' as the basis of the name, irrespective of the use of numbers.

Another comment worthy of note here is that if candidates do, quite reasonably, draw in pencil initially and then write over in ink, the pencil must be thoroughly erased as failure to do so can result in answers that lack the clarity required for marking.

AfL   Guidance to offer for future teaching and learning practice.

Question 2 (b)

(b) Explain why the combustion of butan-1-ol is exothermic, using ideas about bond-breaking and bond-making.
You do not need to list the specific bonds broken and made.

....

....

....

....

....

.... **[2]**

Some well-worded answers were seen here which often scored both marks. However, there were also a significant number of candidates that lost marks through careless use of language. It was not uncommon to encounter phrases like, 'more energy is required for bond-making than bond-breaking'. This would not score any marks. However, a slight adjustment such as, 'more energy is released in bond-making than is required for bond-breaking' would have scored both marks. It was also not uncommon to see answers that suggested, incorrectly, that 'more bonds are formed than broken'.

Question 2 (c)

(c) One disadvantage of butan-1-ol as a fuel is that it requires a higher oxygen to fuel ratio for complete combustion when compared to ethanol.

Write equations to show that butan-1-ol requires a higher oxygen to fuel ratio than ethanol for complete combustion.

combustion of butan-1-ol:

combustion of ethanol:

[1]

Although this was a low demand question a significant number of candidates seemed to overlook the oxygen atom in the alcohol and so incorrectly balanced the equations.

Question 2 (d)

(d) In a simple laboratory experiment, the combustion of 1.00 g of a biofuel compound raised the temperature of 500 g of water by 16.0 °C.

Calculate a value for the enthalpy change of combustion of the biofuel compound.
(M_r of the biofuel compound = 214)

$\Delta_c H =$ .... kJ mol^{-1} **[3]**

Given that the use of significant figures was not tested in this question, many full-scoring answers were seen. That said, a common loss of the answer mark was in the omission of the negative sign – the question makes it clear that it is a combustion reaction. Where the correct answer was not achieved, marks could be obtained for correct evaluations of q, n and ΔH using q and n, with ECF being allowed. Perhaps the most common error was calculating q using $mc\Delta T$ where T was, incorrectly, converted to Kelvin.

Question 2 (e)

(e) The laboratory set-up used to obtain the data in part **(d)** is shown below.

- thermometer/stirrer
- 500 g water in glass beaker
- flame from burning biofuel
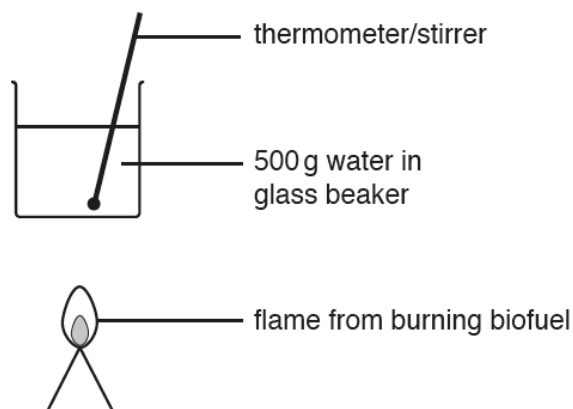
This set-up can be modified to improve the accuracy of the value for the enthalpy change.

Suggest and explain **one** simple modification that could improve the accuracy.

....

....

.... **[1]**

In order to score the mark here both the simple modification and the explanation were required, with the explanation being consistent with the modification. There were many good answers but too many candidates overlooked the word 'simple' and suggested the use of a bomb calorimeter. Others, in suggesting replacing the glass beaker with a polystyrene cup, were not recognising that the calorimeter is being heated with a flame!

Question 2 (f)

(f)   Another alcohol that is used in some fuels is methanol, CH_3OH.

An equation for the complete combustion of methanol is shown below.

$$CH_3OH(g) + 1\tfrac{1}{2}O_2(g) \longrightarrow CO_2(g) + 2H_2O(g) \qquad \Delta_cH = -677 \, kJ\,mol^{-1}$$
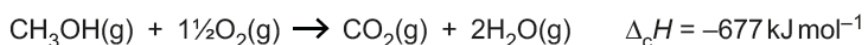
Use this information and the data in the table below to calculate a value for the bond enthalpy of the C–O bond.

Bond	Bond enthalpy / $kJ\,mol^{-1}$
C–H	+413
O=O	+498
O–H	+464
C=O	+805

bond enthalpy of C–O bond = ... $kJ\,mol^{-1}$ **[3]**

Many full-scoring answers were seen. That said, a common loss of the answer mark was in the omission of the positive sign. Many candidates seemed not to be aware that bond enthalpies are positive, even though this was clear from the data provided in the question.

Where the correct answer was not achieved marks could be obtained for correct evaluations of the number of bonds broken and the positive value of that sum (to include the bond to be determined), the number of bonds formed and the negative value of that sum, and the application of Hess's Law.

A common mistake in calculating the enthalpy of the bonds broken was the omission of the O=O, and in calculating the enthalpy of bonds formed was to think that the CO_2 contained two C-O single bonds. Notwithstanding these comments it is certainly also worth noting that many candidates simply did not set out the calculation in a well-structured manner and this did not aid the calculation of the correct answer.

Question 2 (g) part 1

(g)* Apart from being used in fuels, alcohols are also important in the preparation of other organic chemicals.

Alcohol **A**, $C_4H_{10}O$, is an isomer of butanol.
Alcohol **A** can be oxidised to compound **C** using acidified potassium dichromate(VI).

The infrared spectrum of compound **C** is shown below.

Item removed due to third party copyright restrictions

Alcohol **A** reacts with a carboxylic acid **D** to give compound **E**.

The mass spectrum of compound **E** is shown below.

Item removed due to third party copyright restrictions

Question 2 (g) part 2

Using the information on page 8, determine the formulae of the **two** possible compounds that could be alcohol **A**. Determine the corresponding formulae for compounds **C** and **E**, and the formula of **D**.

Give full reasoning for all compounds.

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....

....

....

....

.... **[6]**

This Level of Response question assessed both AO2 and AO3.

As with the other Level of Response question, Q1d, this question generated a full range of marks amongst candidates.

It appeared that there were several problems encountered by the candidates.

In terms of the infrared spectrum, many candidates did not identify the broad absorption at 2980 cm^{-1} as an O-H bond. Most of these candidates did correctly identify the absorption at 1710 cm^{-1} as a C=O, and so incorrectly concluded that compound C was an aldehyde or a ketone. This prevented such candidates from progressing beyond Level 1.
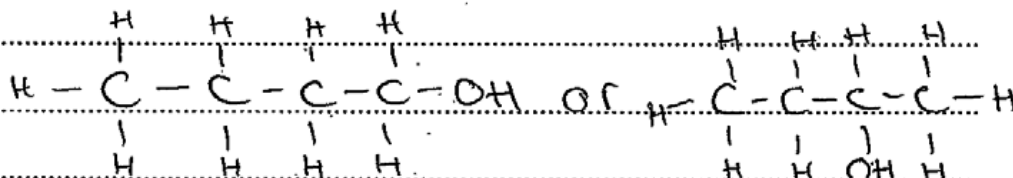
For some of those candidates that did identify C as a carboxylic acid and hence A as a primary alcohol, the reference to compound A being an 'isomer of butanol' seemed to be interpreted, incorrectly, as meaning that butan-1-ol could not be one possibility. This prevented progression beyond Level 2.

Even when some candidates had recognised that there are two primary alcohol possibilities, Level 3 was still not reached by because appropriate formulae were not given in order to distinguish the four compounds in the question. The only formulae that would achieve this end are structural, displayed or skeletal. Molecular formulae were not sufficient.

Having focussed thus far on compounds A and C, it should be noted that candidates' use of the mass spectrum tended to be better than their interpretation of the infrared data. Many correctly identified the M_r value of 116 for compound E and most that did so were able to use other information to identify compound E as an ester. Some were able to make the next steps by using the idea that a four-carbon alcohol would require compound D to be a carboxylic acid containing two carbon atoms.

Exemplar 4

Compound A is either a secondary alcohol or a primary alcohol as the Alcohol A is

$$H-\overset{\overset{\displaystyle H}{|}}{C}-\overset{\overset{\displaystyle H}{|}}{C}-\overset{\overset{\displaystyle H}{|}}{C}-\overset{\overset{\displaystyle H}{|}}{C}-OH \quad or \quad H-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle OH}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-H$$

Compound C is a has a wavenumber peak
at of 2950 which shows it has C-H
bonds and and a peak at 1725 which
shows it is a ketone or Aldehyde.
If Alcohol A is a primary alcohol then
Compound C is an aldehyde. If Alcohol
A is a secondary alcohol then Compound
C is a ketone compound C = $C_4H_9O_2$, C_4H_8O.

[6]

L1   ⋀

$$C-C-C-\overset{\overset{\displaystyle H}{|}}{C}=O$$
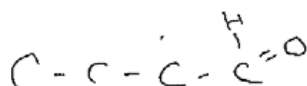
This response is at L1 (1/6). The candidate does not make a commitment to A being a primary alcohol. Instead the candidate correctly states that if C is an aldehyde, A is primary, whereas if C is a ketone, A is secondary. IR absorptions at roughly the correct values are noted but not correctly assigned to appropriate bonds. Nothing is offered for D or E. Whilst this is a weak response it could not be judged as not worthy of any credit, hence the award.

Exemplar 5

The infrared spectrum of compound C shows a broad peak at 3000, suggesting an O-H bond of a carboxylic acid as well as a peak at 1700 suggesting at C=O bond of a carboxylic acid so the compound C is a carboxylic acid, meaning the compound A must be a primary alcohol for it to be able to be oxidised to a carboxylic acid, so A could be

[structure] ∧∧OH   or   [structure] ∧⊥OH   (isomers of butanol)

C would therefore be:
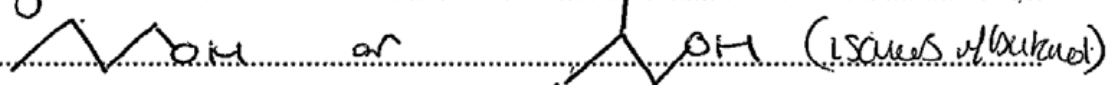
[structure] with C=O and OH   or   [structure]
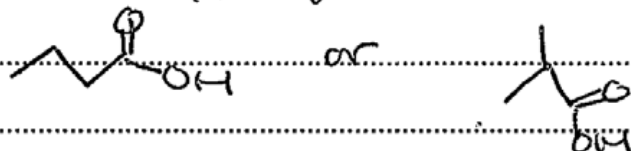
and E would be an ester as an alcohol + an carboxylic acid is an ester. E's Mr is 116 as this 116 − (12×4) = 68 is the heaviest peak except 120, but this is much shorter as it is due to the ^{13}C.

68 − (16×2) = 36
36 ÷ 12 = 3

So, the carboxylic acid A is reacted with is propanoic acid, therefore the compound D is [structure] ∧⊥OH

and E is [structure] ∧∧O⊥∧

[6]

Exemplar 6

Using the information on page 8, determine the formulae of the two possible compounds that could be alcohol A. Determine the corresponding formulae for compounds C and E, and the formula of D.

Give full reasoning for all compounds.

The fact that alcohol A can be oxidised using acidified potassium dichromate means it cannot be a tertiary alcohol for one. It is also oxidised to a carboxylic acid which means as there it there is a broad spectrum at around 2500-3000 cm⁻¹ suggesting the presence of an OH group and a sharp drop at 1700 which shows it must contain a carboxyl group. This means it cannot be a secondary alcohol so it must be a primary alcohol with the formula COHH₂CH₂CH₂CH₃ or COHH₂CH(CH₃)CH₃. For D, the carboxylic acid has the formula CH₃COOH as the Mr of compound E which is an ester is 116. 116 minus the Mr of alcohol A gives you 43 which corresponds to ethanoic acid. The formula for E is CH₃COO.CH₂CH₂CH₂CH₃ which is Butyl ethanoate as it has an Mr of 116 and is made up of butanol and ethanoic acid.

* This would be butanoic acid with the formula C₃H₇COOH

[6]
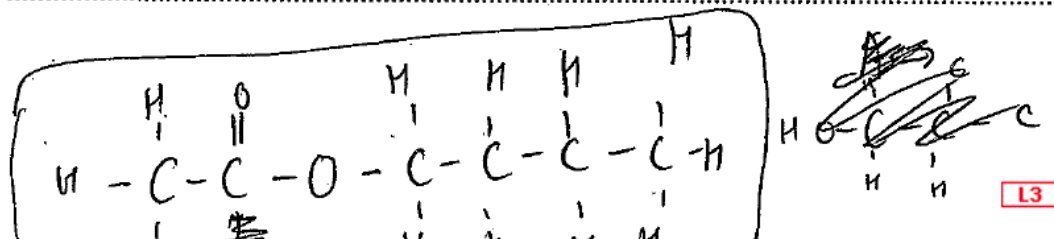
This response is at L3 (6/6). This is a good example of a response that, whilst not perfect, still scores full marks. It is worth remembering that full marks are not reserved for perfection.

A correct analysis of the IR data suggests a carboxylic acid for C, hence a primary alcohol for A. The two possible alcohol isomers are then correctly given as structural formulae (and again at the end of the answer using displayed formulae, along with the correct displayed formulae for both C derived from butan-1-ol and for E). The mass spectrum data is used to give the M_r of E and to deduce the identity of C (although a little mistake is introduced using a fragment at 43).

Overall, the description is well-developed, clear and logically structured, and well worth 6/6.

Question 3 (a) (i)

3   Bromomethane is a gas that is used as a fumigant to protect young plants against insects and rodents.

(a) It is possible to make bromomethane by reacting methane with bromine in the presence of light. This takes place by a radical chain reaction.

   (i) Write an equation to show the effect of light on bromine in the initiation stage of this reaction.

[1]

Very few candidates had a problem with this low demand question.

However, a word of caution is appropriate. Not all candidates made a clear enough distinction between a dot (for the unpaired electron) and a negative sign (incorrect).

Question 3 (a) (ii)

   (ii) The initiation stage is followed by the propagation stage which involves two steps.

   The equation for the **first** propagation step is shown below.

$$CH_4 + Br^\bullet \longrightarrow {}^\bullet CH_3 + HBr$$
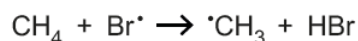
   Write the mechanism for the **second** propagation step using 'half curly arrows'. Indicate radicals with dots as above.

[2]

This was a high-demand question and it proved to be quite problematic for most candidates. Many candidates reacted (incorrectly) the products of the first propagation step given in the question. Where candidates did correctly react the methyl radical with a bromine molecule, very few were able to correctly show the three half curly arrows required to illustrate the mechanism.

Further work would appear to be required in the teaching and learning of the use of mechanistic half curly arrows.

Question 3 (a) (iii)

(iii) Bromomethane can also be made by treating methanol with hydrogen bromide.

Is this method or the reaction of methane and bromine preferable?

Give a reason for your answer.

....

.... **[1]**

This was a high-demand question and very few candidates realised that the methanol/hydrogen bromide method is better because it only makes the desired organic product (and water). Alternatively, the methane/bromine method leads to a mixture of organic products owing to further substitution. This fact seemed to be largely unknown.

Question 3 (b)

(b) A student predicts incorrectly that chloromethane will have a higher boiling point than bromomethane. The student's reason is that chlorine is more electronegative than bromine and thus the carbon to chlorine bond is more polar than the carbon to bromine bond. This will cause stronger permanent dipole-permanent dipole bonds.

Discuss the student's reasoning and give the correct chemistry where necessary.

....

....

.... **[4]**

This question offered something at low-, medium- and high-demand levels.

Many candidates were able to recognise that the first part of the students' prediction was correct, whether in terms of the bond polarity referred to in the question or expressed in terms of the greater electronegativity of chlorine than bromine. Unfortunately, a minority of candidates then proceeded to refer to bond enthalpy as the reason for the different boiling points and therefore did not usually score further.

Others then focussed primarily on the permanent dipole-permanent dipole (pd-pd) intermolecular bonds and so were also usually unable to access further marks. Some did recognise that bromine, hence bromomethane, is bigger, or has more electrons than chlorine (chloromethane). Many candidates that did make this statement did go on to link that to the greater instantaneous dipole-induced dipole (id-id) intermolecular bonds. However, some candidates referred rather more vaguely to 'intermolecular forces' which was not specific enough for credit in this answer.

Some candidates did seem confused about the different types of intermolecular bonds and gave a rather 'mixed up' response. Some candidates that did score well also included, unnecessarily, an explanation of how id-id intermolecular bonds arise. Very few candidates were able to state that the increase in id-id intermolecular bonds has a greater effect on boiling point than the decrease in pd-pd intermolecular bonds when explaining the greater boiling point of bromomethane than chloromethane. It is also worth noting that a few candidates refer to melting point instead of boiling point.
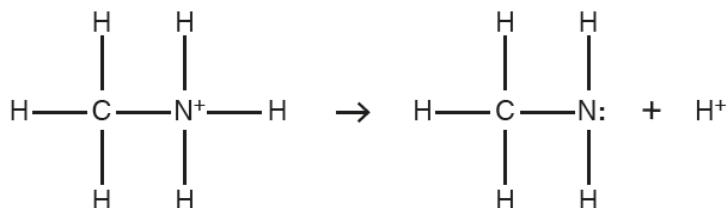
Question 3 (c) (i)

(c) Haloalkanes react with ammonia under suitable conditions.

(i) The first step in the mechanism of the reaction of bromomethane with ammonia involves the following reaction.

$$CH_3Br + NH_3 \rightarrow CH_3NH_3^+ + Br^-$$
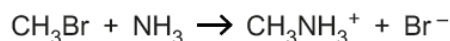
Draw a 'curly arrow' to show the electron movement in the second step in the mechanism below.

[1]

> Unlike Q3(a)(ii) this required the use of a full curly arrow.
>
> Although this question was generally better answered than the previous mechanistic question, it is clear that the concept of the 'curly arrow' is not well understood.

Question 3 (c) (ii)

(ii) Name the mechanism for the reaction of bromomethane with ammonia.

.... [1]

> The correct answer of 'nucleophilic substitution' was generally well known.

Question 3 (c) (iii)

(iii) Name the functional group in the organic product of the reaction.

.... [1]

> The correct answer of 'amine' was well known but the incorrect 'amide' was not infrequent.

Question 3 (d) (i)

(d) A student investigates the rate of hydrolysis of haloalkanes.

Two test tubes, each containing aqueous silver nitrate and ethanol, are placed in a water bath at 60 °C. Five drops of each of chlorobutane and iodobutane are added separately to each of the two test tubes.

(i) Describe what the student would see as the reactions progress that would show that iodobutane reacts faster.

....

.... [1]

This question required the candidate to note that iodobutane reacts faster (quicker) than chlorobutane. Candidates also had to recognise that with silver nitrate present both would produce a precipitate or cloudiness, owing to the formation of insoluble silver iodide and silver chloride respectively. The colour of the precipitate is not important here.)

This ought to be a familiar experiment (usually the bromoalkane would be present as well). Describing what the student would see cannot then be answered in terms of faster (quicker) since that is stated in the question. The candidate needed to ask 'what would I see for the faster reaction?' The answer is that the cloudiness in the iodobutane tube would form before that in the chlorobutane tube.

Question 3 (d) (ii)

(ii) Suggest why ethanol is used in the mixture.

....

.... **[1]**

The answer of 'as a solvent' was not frequently seen. A significant number of candidates thought it was a catalyst.

Question 3 (d) (iii)

(iii) Use the following data to explain whether bond enthalpy or bond polarity is the more important in determining the order of the rate of hydrolysis of haloalkanes.

Electronegativity $Cl = 3.2$ $I = 2.7$ $C = 2.6$

Bond enthalpy/kJ mol^{-1} $C-Cl = +346$ $C-I = +228$

....

....

....

.... **[3]**

Most candidates deduced that bond enthalpy is more important than bond polarity. Many of these candidates seemed to understand the significance of the data in supporting that deduction and were usually clear in their recognition of the weaker bond enthalpy for C-I (or reverse argument). However, some candidates often ended up referring to comparisons between the differences in electronegativities of Cl and I, thereby implying but not stating that the C-I bond is the least polar (or reverse argument).

Question 3 (e)

(e) When bromomethane, CH_3Br, gets into the Earth's atmosphere, a C–Br bond may be broken by ultraviolet radiation from the Sun. However, the ultraviolet radiation may not have high enough energy to break the bond.

Suggest what other effect it may have on the molecule.

.... **[1]**

The idea of increasing electronic energy was not well known.

Question 3 (f)

(f) The minimum frequency of radiation needed to break one C–Br bond is 7.14×10^{14} Hz.

Calculate the bond enthalpy of the C–Br bond, in $kJ\,mol^{-1}$.

Give your answer to an **appropriate** number of significant figures.

bond enthalpy = ... $kJ\,mol^{-1}$ **[3]**

Obtaining full marks for this question proved to be quite challenging, even to those whose working out showed that they knew what they were doing. The calculation requires an application of $E=h\nu$, together with a recognition that by using the data in the question the value of E will be for one C-Br bond. Thus the value of E must then be converted to a value for one mole of bonds, and finally this value converted from J into kJ:

$E = (6.63 \times 10^{-34} \times 7.14 \times 10^{14}) = 4.73 \times 10^{-19}$ J per C-Br bond

$E = (4.73 \times 10^{-19} \times 6.02 \times 10^{23}) = 284746$ J mol^{-1}

$E = 284.7$ kJ mol^{-1}

This is a bond enthalpy and so it must have a positive sign, and the question asks for an appropriate number of significant figures. To score all marks, the answer must be given as +285.

Question 3 (g) (i)

(g) Ozone is present in both the troposphere (lower atmosphere) and the stratosphere (upper atmosphere).

(i) The ozone percentage concentration in the stratosphere is 0.000021% by volume.

Calculate the concentration of ozone in ppm (parts per million).

ozone concentration = ... ppm **[1]**

The conversion to ppm caused some problems for some candidates.

Question 3 (g) (ii)

(ii) The process by which Br reacts with ozone in the stratosphere is represented in the following equations.

$$Br + O_3 \rightarrow BrO + O_2 \qquad \textbf{Equation 3.1}$$

$$BrO + O \rightarrow Br + O_2 \qquad \textbf{Equation 3.2}$$
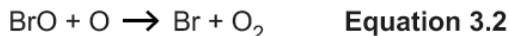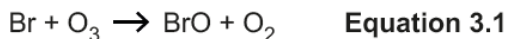
Combine **equations 3.1** and **3.2** to produce the overall equation for the process.

[1]

This was generally well answered. A common error involved leaving the bromine species in when adding the two equations together.

Question 3 (g) (iii)

(iii) Explain how **equations 3.1** and **3.2** show that Br could be a catalyst for the breakdown of ozone.

....

.... [1]

The idea of a catalyst (the bromine here) not being used up in the reaction was well known. However, the rather careless statement 'the bromine is not used in the reaction' will not score, nor would 'the bromine speeds up the reaction'.

Question 3 (g) (iv)

(iv) Give **one** disadvantage of a build-up of **tropospheric** ozone.

.... [1]

This was generally well known although incorrect references to global warming were also seen.

Question 4 (a)

4 Iodine can be extracted from the ash of burnt seaweed. The ash is washed with water. The washed ash is heated with manganese(IV) oxide, MnO_2, and concentrated sulfuric acid, forming iodine.

$$2I^- + MnO_2 + 4H^+ \rightarrow Mn^{2+} + 2H_2O + I_2 \qquad \textbf{Equation 4.1}$$
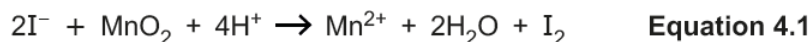
(a) Complete the table below to show the oxidation states for manganese and iodine in the reaction shown in **equation 4.1**.

Element	Initial oxidation state	Final oxidation state
Mn		
I		

[1]

This was generally well answered with the most common loss of mark caused by putting the positive and/or negative sign after the number, thereby confusing charge and oxidation state. Others lost the mark by omitting the sign altogether for the positive oxidation states.

Question 4 (b)

(b) The half-equation for the conversion of MnO_2 to Mn^{2+} ions is shown below.

$$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O \qquad \textbf{Equation 4.2}$$
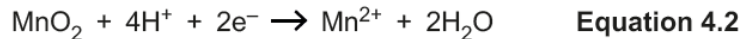
Explain, in terms of electrons, why the manganese is said to be reduced.

.... [1]

Generally well answered although care is required as a few candidates followed a correct answer to Q4(a) with an incorrect 'loss of electrons' in this part.

Question 4 (c) (i)

(c) A student extracts iodine from seaweed ash in the laboratory. The student suspects that the water used to wash the ash contains a mixture of salts, including sodium chloride.

The student tests this water to see if it contains chloride ions by adding silver nitrate solution.

(i) Give the result of the test for chloride ions.

.... [1]

This was generally very well known.

Question 4 (c) (ii)

(ii) Suggest why the student might not get this result.

....

.... [2]

This was a high-demand question and proved particularly challenging. Very few candidates scored both marks and some came tantalisingly close to one of the marks but still missed out. In order to achieve both marks a candidate had various options available. One option was suggesting an ion other than chloride could be present and stating the associated colour of precipitate. However, with the second mark dependent upon the first, an answer of 'contains iodine giving a yellow precipitate' would not score.

If the alternative of 'the chloride concentration is too low' was stated, a recognition that 'no precipitate would form' was needed for the second mark. Even a more general response of 'other ions may be present' could score a mark provided that it was accompanied by 'giving a precipitate of different colour' and not just 'giving a different precipitate'. Some marks were lost here owing to either imprecise wording or missing detail, or both.

Question 4 (d) (i)

(d) Iodine and chlorine are both members of the halogen group.

(i) Write the electron configuration for the highest energy sub-shell for an **iodide ion**.

.... [1]

Incorrect answers here showed two main errors. Some candidates gave the configuration for the atom and not the ion (in spite of the emphasis in the question). Others seemed to not understand the difference between a shell and a sub-shell.

Question 4 (d) (ii)

(ii) A student carries out a displacement reaction to show that chlorine is more reactive than iodine.

Describe the experiment the student would do and the expected result.

....

.... [2]

This question proved to be difficult for many, especially the second marking point, perhaps suggesting a lack of familiarity with this displacement reaction in a practical context. The idea that a more reactive halogen will displace a less reactive halogen from the halide of the less reactive halogen seemed not as well known as might be expected.

The candidate only needed to refer to 'chlorine being added to an iodide' to score the first mark. Those candidates that did score this mark often failed to score the second mark because the expected result was given in terms of what had happened ('iodine is formed') rather than the expected result ('(the mixture) turns brown'). There were also a number of (incorrect) references to the use of silver nitrate.

Finally, although not required, if addition of cyclohexane was included the correct pink/purple colour in the organic layer was required if the reference to the mixture turning brown had not been included.

Question 4 (d) (iii)

(iii)   Write an ionic equation for the reaction in **(ii)**.

[1]

The writing of an ionic equation proved difficult for many. However, it was pleasing to see that even when Q4(d)(ii) had not been answered correctly from the practical perspective, some candidates did understand the underlying chemistry and so wrote a correct ionic equation.

Question 4 (d) (iv)

(iv)   Describe and explain, in terms of electrons, why chlorine is more reactive than iodine.

....

....

....

.... [2]

This question resulted in confused answers. Many candidates recognised that a chlorine atom is smaller than an iodine atom. However, for some the confusion that followed was caused by believing that a halogen atom loses an electron when it reacts. Where this error was not made, some candidates, having realised that the halogen atom gains an electron when reacting, simply said of the smaller size of chlorine that 'the electron is gained more easily' without referring to the fact that this is because of the greater attraction (and retention) of the electron that is gained.

Question 4 (e)

(e) The student collected 0.92 g of impure iodine, I_2, and decided to determine its purity.

The student dissolved the impure iodine in potassium iodide solution.
This iodine solution was then titrated with sodium thiosulfate solution.
The equation for the reaction is shown below.

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-} \qquad \textbf{Equation 4.3}$$
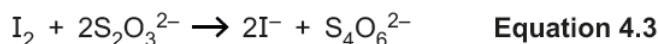
The titration required 28.40 cm^3 of 0.200 mol dm^{-3} sodium thiosulfate solution.

Calculate the percentage purity of the iodine.

purity of iodine = ... % **[3]**

This calculation met with varying degrees of success but the use of error carried forward meant that many scored on this question.

A common error was to assume that the amount (in moles) of iodine that could be calculated from the titration data referred to iodine atoms and not molecules. This error resulted in the A_r of I (126.9) being used instead of the M_r of I_2 (253.8) to calculate the mass of iodine present in the solution. This gave a percentage purity that was half of the correct answer.

It was also possible to answer this question in terms of moles rather than mass.

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Q2g, Graph 1

Q2g, Graph 2

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