

Examiners' Report

June 2019

IAL Chemistry WCH06 01

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Introduction

Candidates on the whole performed well across this paper and very few questions were not attempted. The majority of candidates scored well on questions requiring the straightforward recall or application of knowledge: recognising colours; identifying reagents; deducing functional groups from the results of chemical tests; understanding routine practical procedures. The unstructured calculations were answered particularly well, with the majority of candidates providing clearly presented and well structured responses.

The paper contained some challenging questions, allowing candidates to demonstrate their ability to synthesise information to solve an unfamiliar problem; Q02(c)(iii) and Q02(d)(ii) proved particularly stretching in this regard. Candidates found writing ionic equations and the equation for the organic reaction in Q02(a)(iii) difficult, with many unbalanced responses seen. Marks were commonly lost due to questions not being read carefully, for example, with the majority of candidates identifying the green precipitate instead of compound E in Q01(b)(iii) and giving answers based on the experimental procedure or transfer losses in Q04(f)(ii). The overall standard in the drawing of scientific apparatus in Q04(b) and Q04(c) was fairly poor and candidates demonstrated a limited understanding of distillation in Q04(e).

Question 1 (a) (i)

The majority of candidates were able to link the flame colours to the correct metal ions, however, Li^+ and Sr^{2+} were common incorrect answers for metal ion B, confusing their red colour with the yellow-red of calcium. The question required the identification of the metal **ions**, rather than just the elements, in compounds A and B. Some candidates lost the mark for incorrectly giving the formula of a calcium ion as Ca^+ .

1 This question is about five inorganic compounds (A, B, C, D and E).

(a) Compounds A and B contain s-block elements.

(i) In flame tests, A gave a yellow colour and B gave a yellow-red colour.

Identify the s-block metal ions in A and B.

(1)

The metal ion in A Na^+

The metal ion in B Ca^+



Despite knowing the correct elements, this candidate lost the mark for giving an incorrect charge on the calcium ion.

1 This question is about five inorganic compounds (**A**, **B**, **C**, **D** and **E**).

(a) Compounds **A** and **B** contain s-block elements.

(i) In flame tests, **A** gave a yellow colour and **B** gave a yellow-red colour.

Identify the s-block metal ions in **A** and **B**.

(1)

The metal ion in **A** sodium / Na^+

The metal ion in **B** calcium / Ca^{2+}



This candidate made sure of the mark by giving both the name and formulae of the ions. Note the good exam technique in underlining key information in the question.



When asked to identify an element/compound etc always check if the question specifically requires a name or formula. It is a good idea to highlight such instructions as a prompt.

Question 1 (a) (ii)

The majority of candidates gave the correct colour of the precipitate; s-block elements form white compounds (and colourless solutions).

(ii) Give the colour of the precipitate formed when concentrated sodium hydroxide solution is added to an aqueous solution of B.

(1)



This candidate misunderstood the question, giving the formula rather than the colour of the precipitate.

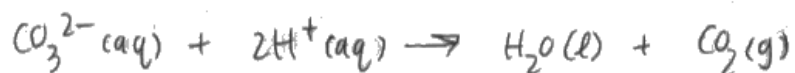
Question 1 (a) (iii)

This question proved challenging, with many candidates failing to read the question carefully, instead giving the overall equation or including solid sodium carbonate. Many equations with incorrectly balanced charge were also seen.

(iii) Compound **A** is a carbonate.

Write an **ionic** equation for the reaction that takes place when dilute hydrochloric acid is added to an aqueous solution of **A**. Include state symbols.

(2)

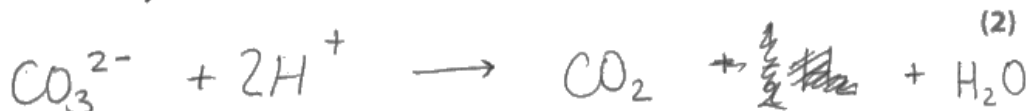


An example of a good response - a correctly balanced equation with clearly presented formulae and state symbols.

(iii) Compound **A** is a carbonate.

Write an **ionic** equation for the reaction that takes place when dilute hydrochloric acid is added to an aqueous solution of **A**. Include state symbols.

(2)



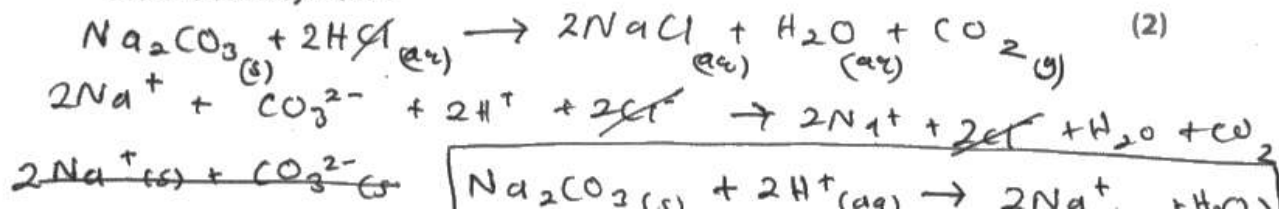
This candidate appears not to have read the instruction to include state symbols.



Read questions carefully, highlighting key commands and instructions as a prompt.

(iii) Compound **A** is a carbonate.

Write an **ionic** equation for the reaction that takes place when dilute hydrochloric acid is added to an aqueous solution of **A**. Include state symbols.



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Examiner Comments

The question concerns adding hydrochloric acid to an aqueous solution of **A**, yet this candidate has given a solid carbonate. The state symbol for water is also incorrect.

The final answer has been put in a box. Make sure to cross out workings so an examiner knows what to mark as your final answer.

Question 1 (a) (iv)

The majority of candidates were able to identify silver nitrate by name or formula. Many included nitric acid, demonstrating good knowledge of the test; the inclusion of ammonia was ignored as this may have been given to distinguish between silver halide precipitates. However, providing additional reagents in this type of question is a risky strategy.

(iv) Compound **B** is a halide.

Identify, by name or formula, a reagent that may be used to test for halide ions in an **aqueous** solution of **B**.

Silver Nitrate with Nitric Acid, or PbCl_2 (1)



This candidate would have scored the mark had they not included an additional incorrect reagent.

Question 1 (b) (i)

The precipitate was generally identified as manganese(II) hydroxide and the darkening was most often attributed to oxidation. Occasionally, the precipitate was stated to be Mn^{2+} or Mn was confused with Mg. Where manganese was not chosen as the d-block element it was clear that candidates did not know whether their choice could be oxidised by oxygen or not. A significant number of candidates lost the second mark for stating that the manganese would be oxidised to a +7 oxidation state, usually in manganate(VII).

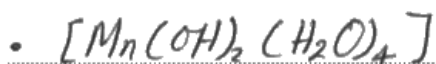
(b) Compounds **C**, **D** and **E** are nitrates of d-block elements.

Aqueous sodium hydroxide is added, drop by drop, until in excess to separate solutions of **C**, **D** and **E**.

(i) Compound **C** forms an off-white precipitate which darkens on standing in air.

Identify the precipitate, by name or formula, and explain why it darkens.

(2)



• It darkens as the oxygen in air oxidises it to MnO_2 which is brown/black.



An example of a good response, including a correct formula for the neutral precipitate, mention of oxygen as the oxidising agent and even the correct formula and colour of a valid oxidation product.

Question 1 (b) (ii)

The question was well understood with almost all candidates giving the formula of a complex ion containing Zn^{2+} . The mark was usually lost, however, for giving the wrong charge or the wrong number of ligands; $[\text{Zn}(\text{OH})_6]^{4-}$ was allowed as it demonstrated a correct understanding of the chemistry although candidates should be aware that the formula of the complex ion formed is best represented as $[\text{Zn}(\text{OH})_4]^{2-}$.

- (ii) Compound **D** forms a white precipitate which dissolves in excess sodium hydroxide to form a colourless solution containing a complex ion.

Write the **formula** of this complex ion.



The mark has been lost for the careless placement of the '6'.

Note that 'zincate' is incomplete but not incorrect. The question asks for the **formula** of the complex ion, however, so this is redundant information that risks losing the mark.

Question 1 (b) (iii)

The identity of the brown solid was well known but, in general, candidates did not consider the question carefully, commonly identifying the green precipitate as opposed to compound E. When names were given, marks were often lost due to omission of oxidation states.

(iii) Compound **E** forms a green precipitate which does **not** dissolve in excess sodium hydroxide.

The precipitate turns brown on standing in air.

Identify, by name or formula, the compound **E** and the brown solid.

(2)

Compound **E** $\text{Fe}(\text{NO}_3)_2$

Brown solid $\text{Fe}(\text{OH})_3$



An example of a perfect response. The question allowed for response by name or formula; providing the latter avoided any ambiguity over the oxidation state of the d-block element.

Question 2 (a) (i)

From the responses seen it was clear that functional group tests were well understood. In general, marks were lost where candidates treated the tests with positive results as isolated experiments, stating what could be deduced from each independently as opposed to reaching an overall conclusion. The instructions were commonly ignored, with many responses including reference to the negative test results, risking contradiction to one or both marking points. Marks were also lost as a result of imprecise answers, such as 'X contains a carbonyl group and a methyl group', which does not show that these groups are adjacent.

Compound	Observations with reagent				
	^{CaO} Sodium metal	$C=C$ Bromine water	^{1°, 2° OH, aldehydes} Acidified sodium dichromate(VI)	$C=O$ Brady's reagent (2,4-DNPH)	Iodine in aqueous sodium hydroxide
X	No change	No change	No change	Orange precipitate	Pale yellow precipitate
Y	Effervescence	Decolourises	Turns green	No change	No change
Z	Effervescence	No change	No change	No change	No change

(a) Use information from the table to answer the following questions.

(i) State what can be deduced about X from the positive test results.

(2)

It consists of $C=O$ and can either be a methyl ketone
or ~~ethanal~~ or secondary methyl alcohol. ~~or ether/alcohol~~.



'(X is a) methyl carbonyl' is all that was required for both marks in this question. This response is an example where the candidate has treated the positive results as isolated tests instead of reaching an overall conclusion from the information provided; both marking points have been contradicted by stating that X could be a secondary methyl alcohol. The molecular formula of X contains only one oxygen atom and an alcohol would not give a positive result with Brady's reagent.

Compound	Observations with reagent				
	Sodium metal	Bromine water	Acidified sodium dichromate(VI)	Brady's reagent (2,4-DNPH)	Iodine in aqueous sodium hydroxide
X	No change	No change	No change	Orange precipitate	Pale yellow precipitate
Y	Effervescence	Decolourises	Turns green	No change	No change
Z	Effervescence	No change	No change	No change	No change

(a) Use information from the table to answer the following questions.

(i) State what can be deduced about X from the positive test results.

(2)

Reaction with Brady's reagent shows that X is a carbonyl compound
 Reaction with Iodine in NaOH further deduces that it is a methyl ketone



A good response where the candidate has considered only the positive test results to reach the correct overall conclusion.

Compound	Observations with reagent				
	Sodium metal	Bromine water	Acidified sodium dichromate(VI)	Brady's reagent (2,4-DNPH)	Iodine in aqueous sodium hydroxide
X	No change	No change	No change	Orange precipitate	Pale yellow precipitate
Y	Effervescence	Decolourises	Turns green	No change	No change
Z	Effervescence	No change	No change	No change	No change

(a) Use information from the table to answer the following questions.

(i) State what can be deduced about X from the positive test results.

(2)

Since it forms an orange precipitate with 2,4-DNPH, and a pale yellow ppt with I_2 and NaOH, it is a carbonyl, ~~either~~ specifically a ketone (since it doesn't produce a change with Na_2CO_3) and it's a methyl ketone (a methyl group is attached to the carbon with the functional group $C=O$).



Despite all the unnecessary text in this response, 'it's a methyl ketone' scores both marks.



This candidate has restated the positive test results and has also referred to one of the negative test results. Do not waste time writing redundant information, which inhibits your ability to check your answers before the end of the exam.

Question 2 (a) (ii)

A significant number of responses scored just 1 mark for only identifying the alkene functional group; candidates should have realised that more than one functional group was present as the word '**groups**' was in bold (and the question was worth 2 marks). It was evident that many candidates had not read the question carefully, referring to the formula as opposed to the **name** of the functional groups.

(ii) Name the functional **groups** present in Y.

(2)

Alcohol and alkene groups. Also, alcohol is
next tertiary.



A good response where the candidate has correctly given the names of both functional groups present in Y. The classification of the alcohol was not required, but demonstrates good knowledge and understanding.

Alkene (Carbon carbon double bond)
~~OH group~~ Hydroxide group



Although appearing to know that Y contains an OH group, this candidate has unfortunately lost the second mark by incorrectly referring to the alcohol group as 'hydroxide'.



This candidate has demonstrated good practice by underlining the command and key information in the question.

Alcohol , Alkene , Aldehyde , benzene.



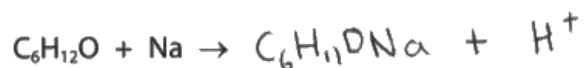
Despite giving both correct answers, the inclusion of an additional two incorrect answers negates both marks in this response.

Question 2 (a) (iii)

This question was poorly answered, with less than half of the candidates scoring the mark. Common errors were to give the formula of the salt as $C_6H_{10}ONa$, where candidates correctly recognised the coproduct as H_2 , or to give an H^+ coproduct alongside the correct salt formula.

(iii) Complete the equation for the reaction between **Z** and sodium metal.
State symbols are not required.

(1)



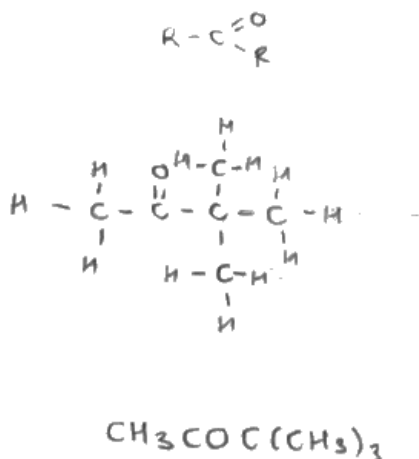
Giving H^+ as the coproduct was a common mistake, which, in addition to being the wrong formula for hydrogen gas, left the charge unbalanced.

Question 2 (b) (iii)

Approximately half of the candidates scored the mark. Common mistakes were to give straight-chained structures, failing to appreciate the significance of the number of peaks and relative peak areas, and to include incorrect functional groups, often in contradiction to the response given in (a)(i). Candidates would benefit from more practice at interpreting nmr spectra.

(iii) Use the nmr information, your answer to (a)(i) and the molecular formula to deduce the structure of X.

(1)

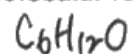


This candidate has given three structures: a generic ketone; a correct displayed formula; a correct structural formula. As there are no contradictions, the mark has been awarded.

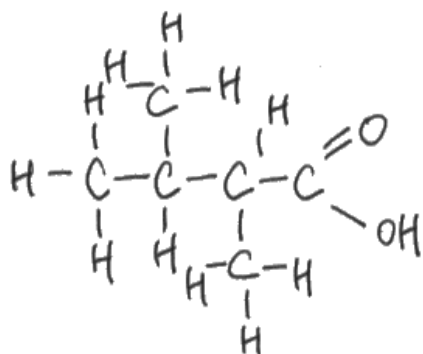


It is risky to give multiple answers to a question as a single trivial mistake could lose the mark.

(iii) Use the nmr information, your answer to (a)(i) and the molecular formula to deduce the structure of X.



(1)



Despite writing the molecular formula of X, this response includes a structure with two oxygen atoms. In addition, the nmr information has been either ignored or misunderstood.

Question 2 (b) (i) - (ii)

In general, a pleasing understanding of the basics of nmr was demonstrated with both the number of environments and the reason for them being singlets being clearly expressed. Some candidates said that the singlet peaks could be due to hydroxyl protons but, by this point, they should have known that X was neither an alcohol nor carboxylic acid.

(b) The **high** resolution proton nmr spectrum of compound **X** has only two peaks which are singlets with relative peak areas of 1:3.

(i) State what can be deduced from the presence of only two peaks in the nmr spectrum.

(1)

there are only two different proton environments present

(ii) State what can be deduced from the fact that these peaks are singlets.

(1)

there are no neighbouring hydrogens on adjacent carbons.



A very good response, with clear and precise terminology, scoring both marks.

(b) The **high** resolution proton nmr spectrum of compound **X** has only two peaks which are singlets with relative peak areas of 1:3.

(i) State what can be deduced from the presence of only two peaks in the nmr spectrum.

(1)

There are only two H^+ environments

(ii) State what can be deduced from the fact that these peaks are singlets.

(1)

that it is a ketone



The response in (b)(i) did not receive credit as 'H⁺ environments' is not acceptable for proton/hydrogen environments in the context of nmr.

The lack of understanding by this candidate is further demonstrated by the incorrect response in (b)(ii).

Question 2 (c) (i)

Candidates found it difficult to express their ideas clearly and it was common to incorrectly attribute the lack of geometric isomers to restricted rotation about the C=C bond or to state that Y did not contain a C=C bond. Where a correct understanding was apparent, the mark was commonly lost for imprecise or careless language, for example, stating that 'one of the carbons has the same group attached' (with no reference to the C=C) or attaching inappropriate species, such as 'molecules'.

(c) Compound **Y** is straight-chained and does **not** have geometric or optical isomers.

(i) State what can be deduced from the fact that **Y** does not exist as geometric isomers.

(1)

First carbon same group in both sides



It appears that this candidate has the right idea but the mark could not be awarded as there is no reference to the **C=C bond** being in the first position or at the end of the chain, or a carbon of the **C=C bond** being attached to the same group.

Question 2 (c) (ii)

Most candidates appreciated the significance of there not being optical isomers although some based their response on an inability to rotate the plane of plane polarised light, failing to appreciate that the question concerned structure determination.

(ii) State what can be deduced from the fact that Y does not have optical isomers.

It cannot rotate the plane of plane polarised light ⁽¹⁾



This response did not score the mark as the candidate has essentially rephrased the question instead of making a deduction about the structure of Y.

Question 2 (c) (iii)

Candidates struggled to piece together the information provided in the question with many getting close to the correct answer but providing a branched-chain structure. Careless mistakes were often seen, such as structures including pentavalent carbons, and many candidates drew enols (with the OH group attached to a C=C carbon).

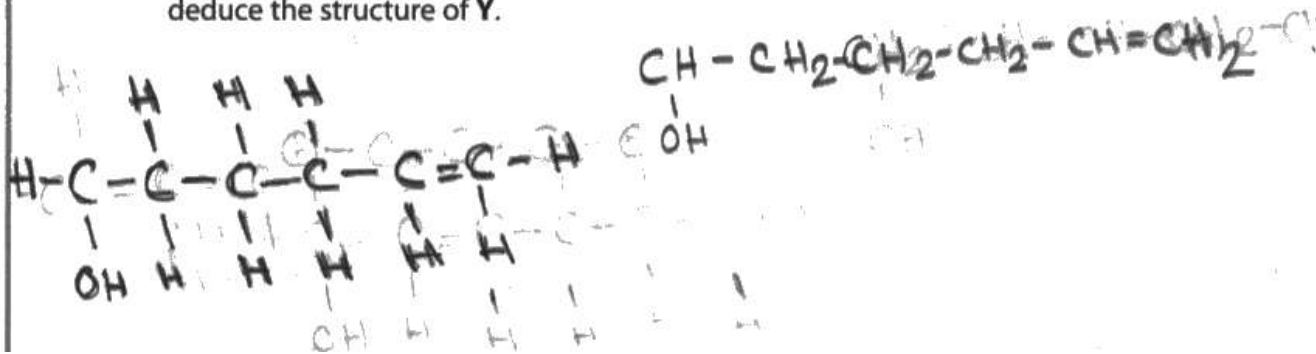
(ii) Name the functional groups present in Y.

(methyl ketone)

It contains C-C double bond i.e. C=C, alkene

It contains hydroxyl group OH group

asymmetric carbon
(iii) Use information about Y, your answer to (a)(ii) and the molecular formula to deduce the structure of Y.



This candidate has done all the hard work but lost the mark for omitting a hydrogen atom from the carbon attached to the OH group.



When drawing organic structures, make sure that each type of atom has the correct number of bonds.

Question 2 (d) (i)

The question asked for the **type and classification** of the functional group and most candidates failed to address the latter.

- (d) (i) Deduce the type and classification of the functional group present in Z, using observations from the table.

OH group, hydroxide group. Tertiary alcohol⁽¹⁾
~~Carbonyl group. It is a, Carboxylic acid.~~



It is unfortunate that this candidate has lost the mark by incorrectly referring to the alcohol as a 'hydroxide' group. 'Tertiary alcohol' alone would have scored.

Question 2 (d) (ii)

This question did not appear to have been well read with many candidates giving straight-chained structures or six-membered rings. Even where (d)(i) had been answered correctly, many candidates gave primary or secondary alcohols in (d)(ii), or even cyclic ethers.

- (d) (i) Deduce the type and classification of the functional group present in **Z**, using observations from the table.

(1)

Primary alcohol

- (ii) Compound **Z** contains a five-membered carbon ring.

Deduce the structure of **Z** using this information, your deduction in (d)(i) and the molecular formula.

(1)



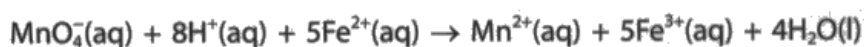
Even though this candidate has given an incorrect response in (d)(i), the mark could have been awarded for transferred error in (d)(ii) had a primary alcohol with a five-membered ring and molecular formula $C_6H_{12}O$ been given. The phenol structure provided meets none of these requirements and so cannot receive credit.

Question 3 (a)

The concept of a redox titration was well understood and most candidates were able to successfully express the self-indicating nature of the titration. A few incorrectly stated that it was the colour of the manganate(VII) ions that changed during the titration, failing to appreciate that the colour changes because they are no longer reduced to manganese(II) ions, which have a different colour, at the end-point.

In (a)(ii) many candidates lost the mark for giving the inverse colour change or using 'purple' to describe the permanent pale pink observed at the end-point upon addition of one drop of excess manganate(VII). Those who attempted to involve the colours of Fe^{2+} and Fe^{3+} ions generally ran into confusion and did not score the mark. A significant number of candidates referred to a single colour only, not appreciating that the question required the colour change.

The overall equation for the reaction occurring in the titration is



(a) (i) Give the reason why the titration in Step 4 does **not** require the addition of an indicator.

(1)

Reaction is self-indicating

(ii) Give the colour **change** at the end-point.

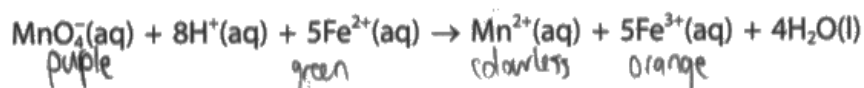
(1)

Colourless to first permanent pale pink.



A good example of a clear and concise response, which scores the mark in both (a)(i) and (a)(ii).

The overall equation for the reaction occurring in the titration is



(a) (i) Give the reason why the titration in Step 4 does **not** require the addition of an indicator.

(1)

$\text{MnO}_4^- (\text{aq})$ is purple coloured and $\text{Mn}^{2+} (\text{aq})$ is colourless. also $\text{Fe}^{2+} (\text{aq})$ is green coloured while $\text{Fe}^{3+} (\text{aq})$ is orange coloured. thus there is already a colour change at the end point.

(ii) Give the colour **change** at the end-point.

(1)

green to orange



The response given in (a)(i) demonstrates an understanding of the self-indicating nature of the titration and scores the mark. Note that the candidate has annotated the reaction equation with the colours of the aqueous species involved. As the colours due to Fe^{2+} and Fe^{3+} are ignored, this alone would have been sufficient to score the mark in (a)(i).

In (a)(ii), the candidate has incorrectly assigned the self-indicating nature of the titration to the different colour of the iron ions so does not score the mark. Note, also, that the colour of $\text{Fe}^{3+} (\text{aq})$ should be referred to as yellow or brown and not orange.



Annotating equations (and diagrams) can be a good way of demonstrating knowledge and understanding to examiners.

Question 3 (b)

The response to this question was polarised with candidates either thinking that the titre value would change or understanding that it would not change as it is the difference between the two burette readings. The second mark was occasionally not scored through a lack of clarity, with candidates simply stating that the error in the two readings would cancel. Although not penalised in this exam, a significant number of candidates incorrectly thought that reading from the top of the meniscus increases each individual burette reading.

(b) The student decided to take the burette readings from the top of the liquid level rather than from the bottom of the meniscus.

Suggest the effect of this, if any, on the titre values. Justify your answer.

(2)

The titre value's will be greater. ~~the~~ buret
is meant to be read below the meniscus.



This response did not score either mark. The candidate is perhaps referring to the individual burette readings (which would be smaller rather than greater) as opposed to the titre value.

(b) The student decided to take the burette readings from the top of the liquid level rather than from the bottom of the meniscus.

Suggest the effect of this, if any, on the titre values. Justify your answer.

She will ~~read~~ ^{have} smaller values of titres, ⁽²⁾ ~~however~~ ^{since} she will be reading a smaller number.

However, ~~the~~ this error is cancelled since the titre volume is the difference between final and initial reading.



It appears that this candidate understands the effect on the measurements being made but the first mark is not scored as they have confused the individual burette readings with the titre. The second mark scores, however, for the correct statement that the titre is the difference between the two readings.

Question 3 (c) (d)

Most candidates were able to correctly calculate the mean titre, using only the concordant results, though titre values were occasionally given to one decimal place. The titration calculation was well answered with many clearly presented responses seen. Typical errors included: failing to scale from 10cm^3 to 100cm^3 ; multiplying the amount of Fe^{2+} by the wrong M_r ; forgetting to divide the mass of hydrated iron(II) sulfate by two; failing to give the final answer to an appropriate number of significant figures as specified in the question. Even where errors were made, transferred error could usually be applied. The percentage uncertainty calculations were also done well, although some candidates incorrectly switched the measurement uncertainties or volumes.

(c) Results of the titrations are given in the table.

Titration number	1	2	3	4
Burette reading (final) / cm^3	10.85	21.40	31.60	42.40
Burette reading (initial) / cm^3	0.00	10.85	21.40	32.10
Titre / cm^3	10.85	10.55	10.2	10.3

(i) Complete the table and use the concordant values to calculate the mean titre.

(2)

$$\frac{10.2 + 10.3}{2} = 10.25\text{cm}^3$$

- (ii) Use your mean titre and information from the procedure to calculate the mass of hydrated iron(II) sulfate, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, present in **one** iron tablet.

Give your answer to an appropriate number of significant figures.

(5)

$$10.25 \times 0.005 = 0.051 \text{ mol}$$

$$0.051 \times 5 = 0.255 \text{ mol in } 10 \text{ cm}^3$$

$$10 \times 0.255 = 2.55 \text{ mol in } 100 \text{ cm}^3$$

$$2.55 \times 55.8 = 142.29 \text{ g}$$

$0.005 \text{ mol/cm}^3 \text{ MnO}_4^-$

$$\frac{10.25}{1000} \times 0.005 = 0.01 \text{ mol}$$

$$0.01 \times 5 = 0.05 \text{ mol of Fe}^{2+} \text{ in } 10 \text{ cm}^3$$

$$0.05 \times 10 = 0.51 \text{ mol in } 100 \text{ cm}^3$$

$$0.51 \times 55.8 = 28.597 \text{ g}$$

28.6 g in one Tablet.

- (d) The uncertainties in the burette and pipette measurements are $\pm 0.05 \text{ cm}^3$ and $\pm 0.06 \text{ cm}^3$ respectively.

Calculate which of these pieces of apparatus gives the greater percentage uncertainty in this experiment.

Burette	$\frac{2 \times 0.05}{10.25} \times 100$,	Pipette	$\frac{2 \times 0.06}{10} \times 100$	(2)
	0.97%			1.2%	

Pipette gives a higher % percentage uncertainty.

In (c)(i), the mean titre has been correctly calculated from the concordant results but the first mark has not been scored as the titre values for titrations 3 and 4 have been recorded to only one decimal place in the table.

The calculation in (c)(ii) is poorly presented with limited labelling of the individual steps. The amount of manganate(VII) ions has been incorrectly evaluated so the first mark is not scored. Transferred error has been applied in the awarding of the second and third marks, however, this is only possible due to the labelling. Note also that benefit of doubt has been given in relation to significant figures (i.e. that the value of 0.01 represents the more precise value of 0.01025). No further marks are scored as the A_r value of iron has been used instead of the M_r value of hydrated iron(II) sulfate and, although the final answer is given to three significant figures, there is no division by two.

The candidate has carelessly lost both marks in (d): the operation for the percentage uncertainty in the burette is correct but their answer is incorrectly rounded; the uncertainty in the pipette measurement has been incorrectly doubled.

(c) Results of the titrations are given in the table.

Titration number	1	2	3	4
Burette reading (final) / cm ³	10.85	21.40	31.60	42.40
Burette reading (initial) / cm ³	0.00	10.85	21.40	32.10
Titre / cm ³	10.85	10.55	10.20	10.30

(i) Complete the table and use the concordant values to calculate the mean titre. (2)

$$\text{Mean titre} = \frac{10.2 + 10.3}{2} = 10.25 \text{ cm}^3$$

(ii) Use your mean titre and information from the procedure to calculate the mass of hydrated iron(II) sulfate, FeSO₄·7H₂O, present in **one** iron tablet.

Give your answer to an appropriate number of significant figures. (5)

$$\begin{aligned} n \text{ of potassium manganate(VII)} &= 0.01025 \times 0.005 \\ &= 5.125 \times 10^{-5} \text{ mol} \end{aligned}$$

$$\begin{aligned} \therefore n \text{ of Fe}^{2+} \text{ in } 100 \text{ cm}^3 &= 5.125 \times 10^{-5} \times 5 \times 10 \\ &= 2.5625 \times 10^{-3} \text{ mol} \end{aligned}$$

$$\begin{aligned} \therefore \text{mass of Iron(II) sulfate} &= 2.5625 \times 10^{-3} \times (55.8 + 32.1 + 64 + 7(2 + 16)) \\ &= 0.712 \text{ g} \end{aligned}$$

$$\begin{aligned} \therefore \text{mass of Iron(II) sulfate in one iron tablet} &= \frac{0.712}{2} \\ &= 0.356 \text{ g} \end{aligned}$$

(d) The uncertainties in the burette and pipette measurements are $\pm 0.05 \text{ cm}^3$ and $\pm 0.06 \text{ cm}^3$ respectively.

Calculate which of these pieces of apparatus gives the greater percentage uncertainty in this experiment.

$$\% \text{U of burette} = \frac{0.05 \times 2}{10.25} \times 100 = 0.98\%$$

(2)

$$\% \text{U of pipette} = \frac{0.06}{10} \times 100 = 0.6\%$$

\therefore The burette gives a greater percentage of uncertainty.



A very well structured and clearly presented response that scores full marks for all parts.

In (c)(i), all titres are given to two decimal places in the table and the mean titre is correctly calculated.

The second and third steps have been combined in the calculation in (c)(ii) but all operations are easy to follow in this clearly presented response.

Question 4 (a)

This question was generally well answered with most candidates recognising the role of the sulfuric acid as a catalyst; incorrect answers generally stated its purpose as a solvent, an oxidising agent or a reducing agent. The purpose of the anti-bumping granules was also well understood, although some candidates lost the mark for being too vague or imprecise with responses such as 'to prevent bumping' or 'to prevent splashing'.

(a) State the purpose of the concentrated sulfuric acid and of the anti-bumping granules added to the round-bottom flask.

(2)

Concentrated sulfuric acid in Step 1 ... *It is a catalyst*

Anti-bumping granules in Step 2 ... *To allow for smooth boiling and to prevent the formation of large bubbles.*



An example of a concise response scoring both marks. Either of the reasons given for the purpose of the anti-bumping is sufficient although 'to promote smooth boiling' is the preferred answer.

(a) State the purpose of the concentrated sulfuric acid and of the anti-bumping granules added to the round-bottom flask.

(2)

Concentrated sulfuric acid in Step 1 To initiate the reaction as a catalyst.

Anti-bumping granules in Step 2 Increases surface area to ensure efficient reaction and also so that reactants do not escape the apparatus.



'To initiate the reaction' alone would not have scored the first mark, which is awarded for 'as a catalyst'.

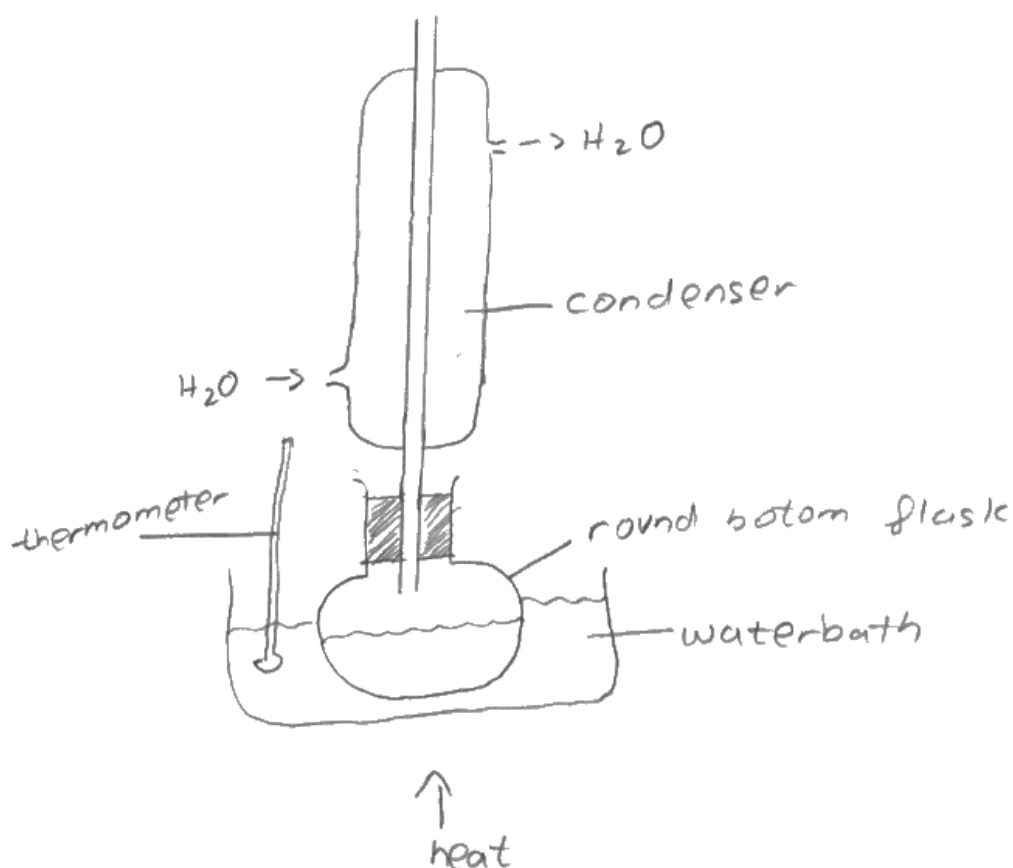
The reasons given for the purpose of the anti-bumping granules do not score the second mark as they are too vague. The candidate may be thinking of small bubbles forming on the surface of the granules or violent boiling resulting in some of the reaction mixture ejecting from the apparatus, but neither of these acceptable responses is clearly implied.

Question 4 (b)

Many diagrams were poorly drawn with a lack of attention to detail. The first mark was commonly lost for any one of several reasons: the lack of a joint between the flask and condenser; the inclusion of a thermometer in the condenser; the deliberate or unintentional sealing of the apparatus; the use of a water bath for heating, which was inappropriate given the boiling temperatures of the reactants. The second mark was more frequently scored, although some candidates drew inappropriate water jackets that would have resulted in water flowing directly into the round-bottom flask.

(b) Draw a labelled diagram of the apparatus used to heat the reaction mixture under reflux in Step 2.

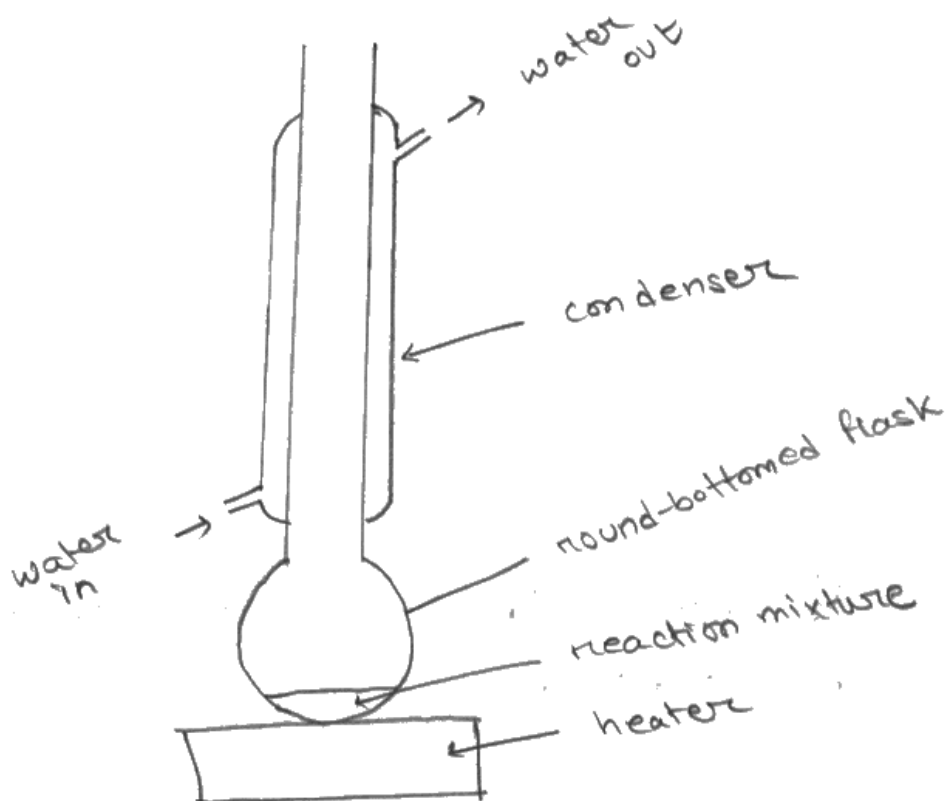
(2)



A carefully drawn and suitably **labelled** diagram that would have scored both marks had a more appropriate heat source been given. The boiling temperature of the reactants are all above 100°C, information that was provided in the question.

(b) Draw a labelled diagram of the apparatus used to heat the reaction mixture under reflux in Step 2.

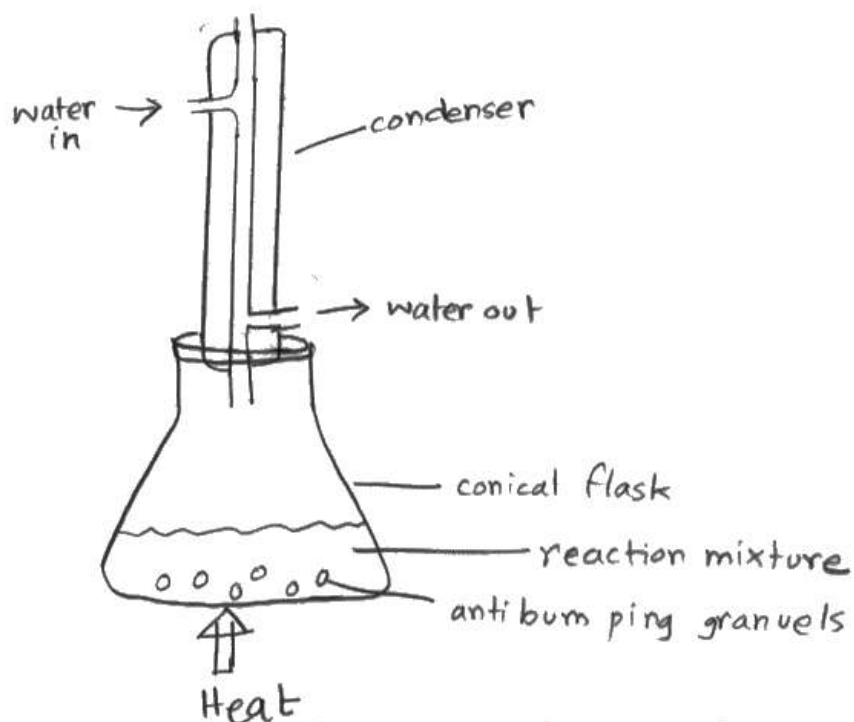
(2)



Another carefully drawn and labelled diagram that would have scored both marks had there been a joint between the round-bottom flask and condenser. Note that the 'heater' would have been better labelled as a 'heating mantle' or 'electric heater'. The internal diameter of the condenser is large, but acceptable given the overall quality of the response.

(b) Draw a labelled diagram of the apparatus used to heat the reaction mixture under reflux in Step 2.

(2)



There are several issues with this poor response:

- a conical flask is not a suitable reaction vessel;
- there is a gap between the flask and the bottom of the condenser, which would allow vapours to escape;
- a horizontal line has been drawn through the inner tube of the condenser, inadvertently sealing it;
- the water flows into the inner tube of the condenser rather than into the condenser jacket.

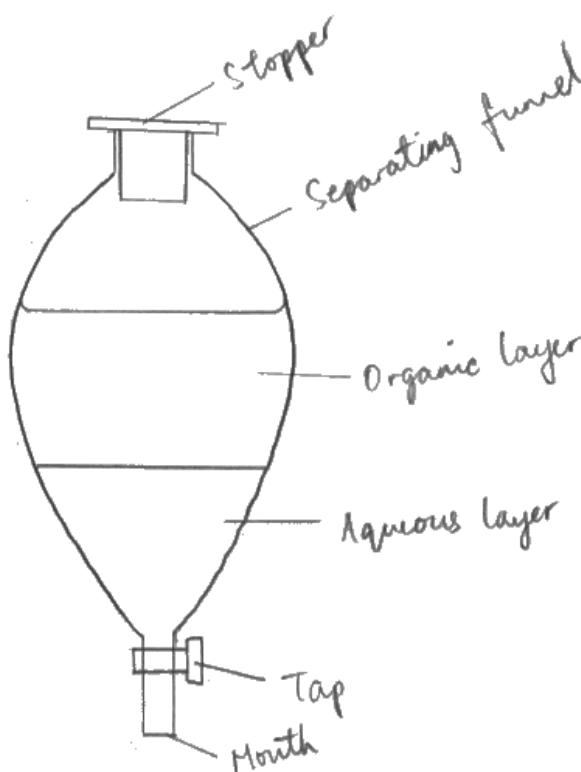
No marks awarded.

Question 4 (c)

The overall quality of response was superior to that in the previous question, however, many poorly drawn diagrams were seen including funnels with parallel or diverging sides and funnels that were completely sealed (i.e. essentially a glass bulb). The majority of candidates appreciated, hopefully through consideration of the data provided, that the aqueous layer was the more dense in this experiment. Some candidates gave three or more layers, giving separate layers for the alcohol, ethanoic acid, ester and water for example, failing to understand that just two immiscible layers would form.

(c) Draw a diagram of the separating funnel in Step 3, clearly labelling the aqueous and organic layers.

(2)



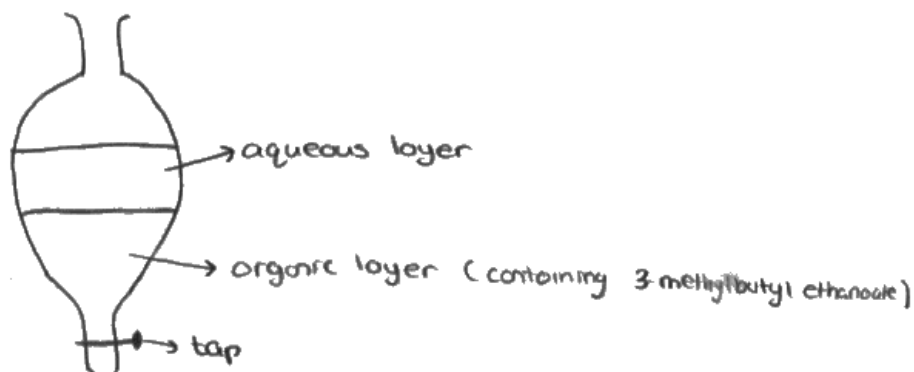
An excellent example of a correct response scoring both marks.

The aqueous and organic layers are clearly **labelled** and in the correct order.

Note that it would be better if the end of the funnel did not have a horizontal line across it. However, this was accepted as the word 'mouth' demonstrates that there is an opening.

(c) Draw a diagram of the separating funnel in Step 3, clearly labelling the aqueous and organic layers.

(2)



This is a perfectly acceptable diagram of a separating funnel, with a top that is capable of being sealed with a stopper or bung.

The candidate has sensibly underlined the instruction to label the aqueous and organic layers but has lost the mark as they do not appear to have considered the density data provided in the question.



Highlight any key information provided as you read through a question.

Question 4 (d)

The majority of candidates understood that the sodium hydrogencarbonate was used to remove excess acidity. The second mark was most simply scored for suggestion of testing the alkalinity of the aqueous layer with either a specified indicator **paper** or a pH meter. To score the mark from use of a specified indicator, candidates needed to state that a sample of the aqueous layer should be removed from the funnel before testing (in order to prevent contamination); very few were able to make this connection.

(d) Give the reason why the organic layer is washed with sodium hydrogencarbonate solution in Step 4 and suggest how the alkalinity of the aqueous layer should be confirmed.

(2)

To remove excess ~~H₂SO₄~~ sulfuric acid and the alkalinity is confirmed by a moist red litmus paper which turns blue



An example of a concise response scoring both marks.

Note that it would have been more precise to say 'to react with' or 'to neutralise' the excess acid.

(d) Give the reason why the organic layer is washed with sodium hydrogencarbonate solution in Step 4 and suggest how the alkalinity of the aqueous layer should be confirmed.

(2)

• to quench the reaction

• Add ~~also~~ phenolphthalein indicator; should change

from colorless to pink



This response did not score either mark.

The candidate has perhaps confused the use of sodium hydrogencarbonate in this experiment with its use in the kinetics study of the iodination of propanone.

Use of phenolphthalein indicator could have scored the second mark, had they said that a sample of the aqueous layer should be removed from the separating funnel before testing.

Question 4 (e)

The reason behind collecting the distillate above 140°C was not well understood and poorly articulated. A significant number of responses referred to the effect of impurities on the magnitude or range of the boiling temperature and many candidates incorrectly stated that the ester would not evaporate below its boiling temperature. Relatively few answers quoted the boiling temperature of the alcohol and/or ester and candidates should be encouraged to make better use of the data provided in questions when constructing their responses. Where no other mark was awarded, the 'rescue mark' was frequently scored for the idea of an impure distillate being collected below 140°C.

(e) Explain why the distillate is **not** collected below 140°C in Step 6.

(2)

pure methyl 3-ethylbutanoate 3-methylbutyl ethanoate boils at 142°C. Pure substances boiling points are between ± 2 (in her 140-144) of the range. If it is collected below 140°C, it means the distillate has not reached its boiling point yet/ has not boiled over and there is no ~~eff~~ evidence of the ester component to pure or not.



This response did not score either mark.

Although the candidate has used the data provided in referring to the boiling temperature of the ester, they have misunderstood the process of distillation in stating that no ester would be obtained below its boiling temperature.

(e) Explain why the distillate is **not** collected below 140°C in Step 6.

(2)

This is because 3-methylbutan-1-ol has its boiling point (131°C) below 140°C, so it would also get collected along with the ester as the distillate. The 3-methylbutyl ethanoate collected would be impure.



An example of an excellent response, which scored both marks.

The candidate has clearly explained that the distillate would be contaminated with (unreacted) alcohol due to its lower boiling temperature.

(e) Explain why the distillate is **not** collected below 140°C in Step 6.

(2)

- If it is collected below 140°C ~~there~~ the product collected will be much impure than the product collected within range 140°C - 144°C which is $\pm 2^\circ\text{C}$ of the actual boiling temperature of pure product.



An example of a vague response, with no specific reference to either the alcohol or ester, which scores the 'rescue mark' for the idea of an impure distillate being collected below 140°C.

Question 4 (f) (i)

The overall quality of response to this question was very good with many clearly presented calculations seen. While the majority of candidates scored highly, marks were occasionally lost for incorrect use of the data, for example, switching the densities or molar masses. A few candidates scored the first mark only, calculating the mass of alcohol correctly but using this as the mass of ester in the percentage yield calculation.

(f) A student prepared 4.75 g of 3-methylbutyl ethanoate starting with 7.5 cm³ of 3-methylbutan-1-ol and excess ethanoic acid.

(i) Calculate the percentage yield of 3-methylbutyl ethanoate.

(3)

$$7.5 \times 0.81 = 6.075 \text{ g}$$

$$\frac{6.075}{88} = 0.069 \text{ mol}$$

$$0.069 \times 130 = 8.97 \text{ g theoretical yield}$$

$$\frac{4.75}{8.97} \times 100 = \underline{\underline{52.93\%}}$$



This response received full credit despite the careless portrayal of significant figures and rounding. The amount of alcohol and theoretical yield of ester have both been recorded to two significant figures. The final operation, as written, evaluates to 52.95% but benefit of doubt has been given that the full calculator values for the amount of alcohol and mass of ester have been used, which would give a result that is consistent with the stated answer.

It would have been better to give the amount of alcohol and mass of ester to a greater number of significant figures, or write them as '0.069...mol' and '8.97...g' respectively.



Avoid premature rounding in unstructured calculations. Take the full calculator values through to the final operation before giving the final answer to an appropriate number of significant figures.

(f) A student prepared 4.75 g of 3-methylbutyl ethanoate starting with $\frac{7.5 \text{ cm}^3}{\text{Vol.}}$ of 3-methylbutan-1-ol and excess ethanoic acid.

(i) Calculate the percentage yield of 3-methylbutyl ethanoate.

$$\text{density} = \frac{\text{mass}}{\text{Vol.}} \quad \text{mass of 3-methylbutan-1-ol} = \frac{7.5}{1000} \times 0.81(3)$$

$$= 0.006075$$

$$\text{moles of 3-methylbutan-1-ol} = \frac{0.006075}{88} = 0.0000690$$

$$\text{moles of 3-methylbutyl ethanoate} = 0.0000690$$

$$\text{mass of it} = 0.0000690 \times 130 = 0.00897$$

$$\frac{0.00897}{4.75} \times 100 = 0.189\%$$



The first mark does not score in this response as the candidate has converted the mass of alcohol to kg unnecessarily; the density was given in units of g cm^{-3} .

The second mark is awarded as a transferred error.

The final mark does not score as the candidate has inverted the operation, dividing the theoretical yield by the actual yield. Even had they performed the correct operation, the final mark would still not score as the percentage yield would be (very much) greater than 100%.



Always check that the magnitude of your answer to a calculation seems sensible.

Question 4 (f) (ii)

The majority of candidates missed the point of the question and ignored the instructions, in general choosing to give answers relating to the experimental procedure or transfer losses. Some candidates confused percentage yield with atom economy, attributing the lost yield to the water coproduct. Of those who scored the mark, a wide range in quality of response was seen with the best answers making specific reference to the equilibrium nature of the esterification reaction.

(ii) Give the main reason why the yield is significantly less than 100%.

Do not consider errors in the experimental procedure or transfer losses.

(1)

The esterification reaction is reversible and did not go to completion.

(Total for Question 4 = 14 marks)



An excellent example of a specific and concise response, demonstrating a good comprehension of the question.

(ii) Give the main reason why the yield is significantly less than 100%.

Do not consider errors in the experimental procedure or transfer losses.

(1)

The main reason why the yield is significantly less than 100% is because some of the organic layer washed with NaHCO_3 could have been dissolved and washed away and not properly dried.

(Total for Question 4 = 14 marks)



This response does not receive credit as the candidate has failed to follow the instructions, giving an answer based on the experimental procedure.

Paper Summary

Based on their performance on this paper, candidates should:

- read the question carefully and answer the question that has been asked;
- highlight key information and instructions in questions, as a prompt;
- check their equations are balanced, including charge;
- practise writing balanced equations for organic reactions;
- check their organic structures agree with valency rules;
- practise drawing accurate and labelled diagrams of scientific apparatus;
- make use of data provided in questions when constructing their answers;
- **not** round prematurely in unstructured calculations.

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