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June 2025

GCE Chemistry 9CH0 03

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Introduction

This synoptic paper provided candidates with the opportunity to demonstrate their knowledge and understanding of the concepts and practical skills in their A Level Chemistry studies. The paper proved accessible to all candidates and there was no evidence that any were hindered by not having sufficient time to complete their answers. A number of the questions were found to be demanding and it was pleasing to note that many candidates rose to the challenge and demonstrated their knowledge and understanding of A Level Chemistry. There were common errors of exam technique such as failing to double check answers, giving answers to the wrong number of significant figures and not reading the question properly before giving an answer. However, it was clear that many candidates were well prepared and were able to demonstrate their comprehension of the subject. Nonetheless, there are some key lessons for centres and candidates to learn from the feedback illustrated in the following examples.

Question 1(a)

This question asked candidates to write the definition of 'first ionisation energy'. This proved to be an accessible first question, with many candidates scoring both marks. Unclear definitions which omitted the mention of 'mole', 'atom(s)' or 'gaseous' state were often able to score one of the available marks.

1 This question is about ionisation energies.

The table shows the first four ionisation energies of three elements in the same group of the Periodic Table.
The letters used are not the symbols of the elements.

Element	First ionisation energy / kJ mol^{-1}	Second ionisation energy / kJ mol^{-1}	Third ionisation energy / kJ mol^{-1}	Fourth ionisation energy / kJ mol^{-1}
X	403	2632	3900	5080
Y	419	3051	4412	5877
Z	496	4563	6913	9544

(a) State what is meant by the term '**first** ionisation energy'.

(2)

The energy required to remove 1 mol of electrons from one mole mol of atoms in their gaseous State, to form 1 mol of gaseous 1+ ions.

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Examiner Comments

This response scored both marks for a good definition.

(2)

the energy required to remove 1 mole of electrons from 1 mole of an element in gaseous phase.

ResultsPlus
Examiner Comments

This response scored just one mark. The candidate has referred to the electrons being lost from an element instead of from atoms (of the element).

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Examiner Tip

Remember to state where the electrons would come from in this definition.

The first ionisation energy is the amount of energy needed to lose an electron from the outer shell of the element to form either a positive or negative ion.

ResultsPlus
Examiner Comments

This response did not score as there was no mention of a mole of electrons, or of atoms or gaseous state.

Question 1(b)

This was generally well-answered with candidates making the connection between the pattern of ionisation energies and the Group that the element is in. There is a clear difference in the table between the first and second ionisation energies indicating that the element is in Group 1.

(b) Explain to which group the elements **X**, **Y** and **Z** belong.

(2)

The elements are in group 1 because there is a large increase in ionisation energy between the first and second ionisation energy values.

ResultsPlus
Examiner Comments

This is a good response, scoring both marks.

group 2

ResultsPlus
Examiner Comments

This response did not score as the group was incorrect and there was no further explanation given.

* Belongs to group 2 as there is the greatest jump / increase between the first and second ionisation energies for all 3 elements X, Y and Z

ResultsPlus
Examiner Comments

This scored one mark for the statement about the jump between the first and second ionisation energies.

The candidate had wrongly identified the element as being in Group 2 and so M2 was not awarded.

Question 1(c)

Many candidates showed a good understanding of the link between ionisation energy and atomic number, correctly identifying that element 'X' would have the lowest first ionisation energy, and many of these went on to score both of the additional marks for a correct explanation. There were a number of candidates who identified the element as element 'Z' instead. They were awarded one mark as long as they had stated that the nuclear charge / number of protons woud be the greatest.

(c) Explain which of the elements **X**, **Y** and **Z** has the highest atomic number.

(3)

• Element X has the greatest atomic number. This is because it has the ~~least~~ lowest first ionisation and other ionisation energies. This is because down the group the number of shells increases which leads to more shielding and a greater atomic radius. Hence, greater distance between valence electron and nucleus. So, electrostatic forces of attraction weaker. This outweighs the increase in nuclear charge. Therefore, less energy required to remove valence electron, so first ionization energy is less

(Total for Question 1 = 7 marks)

• Hence, if X is the furthest down group 1, it must have the greatest atomic number and number of protons.

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Examiner Comments

This response scored three marks. They have identified the correct element and that it has the lowest first ionisation energy with an explanation that the atomic radius would be the largest and that there would be the most shielding.

Element Z has the highest atomic number this is because the first ionisation energy is the highest. This means that element Z has the most protons in the nucleus and so the highest nuclear charge which means the outer electrons are more strongly attracted towards the nucleus, so large amounts of energy is required to break that strong force of attraction and remove an electron.

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Examiner Comments

This is an example of a response scoring one mark for identifying element Z with the accompanying comment about it having the most protons in its nucleus.

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Examiner Tip

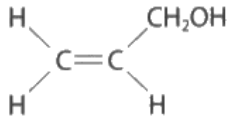
Remember that ionisation energy is linked to the distance between the nucleus and the outer shell electrons, as well as the amount of shielding, and not just to the nuclear charge.

Question 2(a)(i)

This proved to be a straightforward question for many candidates. The most common test described was bromine water turning colourless. There were a few incorrect starting colours given and some candidates described the colourless solution as 'clear' which was not awarded. The test using acidified potassium permanganate was seen less frequently. Candidates who described it were generally correct in the expected result that they gave.

2 This question is about compounds that contain both an alkene and an alcohol functional group.

(a) Prop-2-en-1-ol, present in garlic, has the structure shown.



(i) Describe a test, and the positive result, that confirms the presence of a C=C group.

(2)

Test

add bromine water

Result

if a C-C bond is present the bromine water will go from orange to colourless

ResultsPlus
Examiner Comments

This is an example of a fully correct response, scoring both marks.

Test

Bromine water test

Result

Add bromine water and if there is a colour change from brown to clear, it is positive for C=C

ResultsPlus
Examiner Comments

This scored one mark for the correct test. However, the candidate has described the colour change from a correct 'brown' to an incorrect 'clear' and so the second mark could not be awarded.

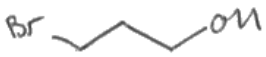
ResultsPlus
Examiner Tip

A solution is never described as 'clear' on its own. The correct term is colourless.

Question 2(a)(ii)

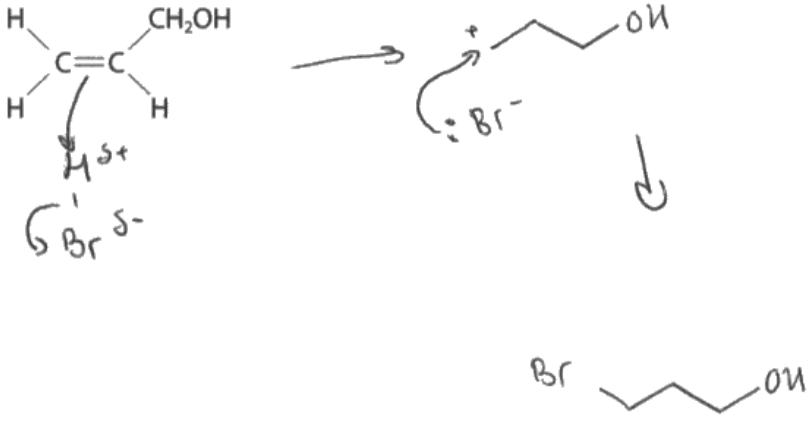
Many candidates demonstrated familiarity with the mechanism for this reaction. However, it was the 'minor' product of the reaction that was asked for, and some candidates lost marks by drawing the incorrect carbocation intermediate.

(ii) Prop-2-en-1-ol reacts with hydrogen bromide to form 3-bromopropan-1-ol as one of the products.



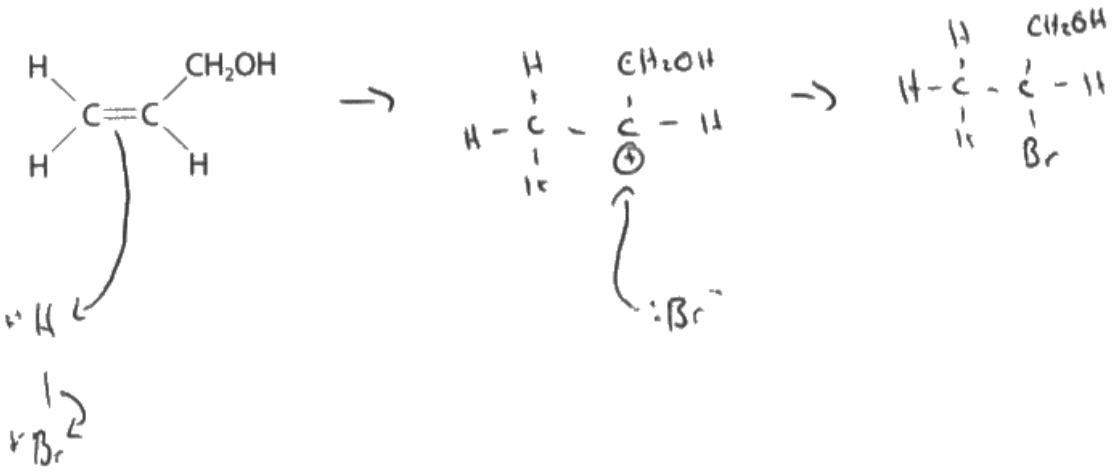
Draw a mechanism for this reaction.
Include curly arrows, and relevant lone pairs and dipoles.

(3)



ResultsPlus
Examiner Comments

This response scored three marks. The candidate has chosen to use skeletal formulae throughout and the mechanism is clearly drawn and fully correct.



ResultsPlus
Examiner Comments

This scored two marks. The candidate had unfortunately drawn the mechanism that would have produced 2-bromopropan-1-ol as the product which was not asked for in the question. The carbocation intermediate is shown on the incorrect carbon atom.

ResultsPlus
Examiner Tip

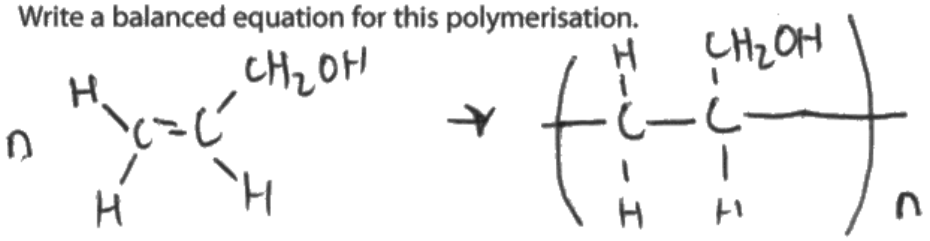
Check the final product to ensure that is is correct.

Question 2(b)

Candidates found it easier to draw the monomer, than the polymer unit correctly. There were a few missing the 'n's, or 'n's in the wrong place, being added after the monomer and /or before the polymer unit. The polymer unit was seen on occasion with double bonds still present.

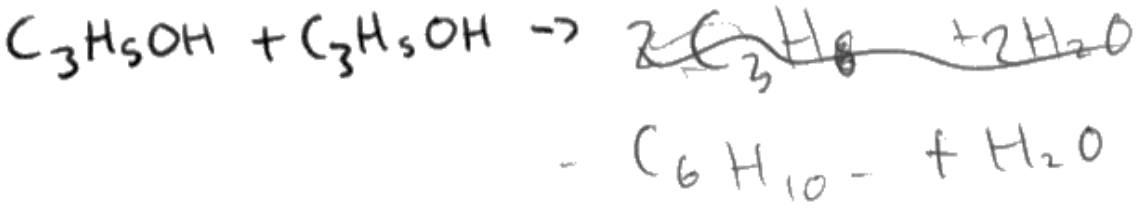
(b) Prop-2-en-1-ol can polymerise to form an addition polymer.

Write a balanced equation for this polymerisation. (2)



ResultsPlus Examiner Comments

This is a fully correct response scoring both marks.



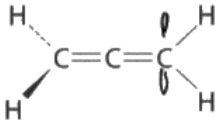
ResultsPlus Examiner Comments

This response did not score because the candidate has not shown the monomer correctly in a polymerisation equation. The molecular formula, although correct for the monomer unit is not awarded for these equations. The product is incorrect, and there is an additional molecule of water which would not occur in addition polymerisation.

Question 2(c)

This question proved challenging for many candidates. Marks were awarded for describing pi bonds as forming from sideways overlap of p orbitals, and that was the most frequent way that candidates gained a mark. Only a few candidates scored both marks as many found it difficult to visualise the reason for the groups being at right angles to each other. Candidates often referenced electron pair repulsion theory in their answers which is not relevant here.

(c) Prop-2-en-1-ol can form the alkene propadiene, which has two adjacent C=C bonds, as shown.



propadiene

Ö rf

Explain why the CH_2 groups at each end of the molecule are at right angles to each other.
Use your knowledge of how orbitals overlap to form π-bonds.

(2)

π bonds are formed from the side-on overlap of p orbitals ✓ across a bond. The central carbon has made 2 ✓ π bonds, and since different p orbitals are at right angles to each other, the bonds are at right angles ✓ and thus the CH_2 groups are at right angles

ResultsPlus
Examiner Comments

This response scored two marks. There was reference to the sideways overlap of p-orbitals in a pi bond and also a description and clear accompanying diagram to show that the pi bonds would be at right angles to each other.

ResultsPlus
Examiner Tip

A good diagram can help with an answer that is difficult to explain in words.

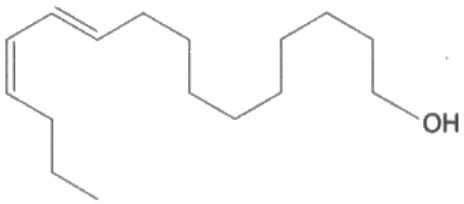
Question 2(d)

The first part of this question, Q02(d)(i), was quite well answered, with a lot of candidates realising that the double C=C bond in the molecule would give rise to 4 geometric isomers of bombykol.

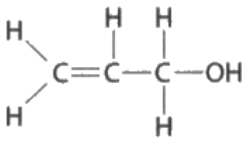
Candidates found part Q02(d)(ii) more difficult, with many failing to give clear answers relating to the fact that there are two hydrogen atoms in the carbon of the double bond. References to the same atoms being on the double bond were too vague to be awarded any marks.

Many candidates were able to gain at least one mark on part Q02(d)(iii) for either recognising that the prop-2-en-1-ol would be more soluble than the bombykol, or that both would form hydrogen bonds with water. M3 was less frequently awarded due to imprecise use of language - such as 'bombykol has a long chain and so will not dissolve.'

(d) The compound bombykol is a pheromone secreted by female silk moths. Like prop-2-en-1-ol, it can also be classified as both an alkene and an alcohol.



bombykol



prop-2-en-1-ol

Bombykol can exist as a number of geometric isomers.

(i) Give the number of different geometric isomers of bombykol.

(1)

4

(ii) Give the reason why prop-2-en-1-ol does **not** exhibit geometric isomerism.

(1)

As on one side of the double bond two of the same group are ~~attached~~ attached as there are two H-groups.

(iii) Explain the expected solubilities in water of bombykol and prop-2-en-1-ol.

(3)

Both molecules have an O-H group so can undergo hydrogen bonding with water which is a strong intermolecular force so they would both dissolve* Prop-2-en-1-ol would be more soluble than bombykol as bombykol has a long non-polar chain and non-polar compounds do not easily dissolve in polar solvents like water decreasing its solubility.

* The OH group is polar and polar solutes dissolve well in polar solvents like water.

(Total for Question 2 = 14 marks)

ResultsPlus
Examiner Comments

This is a fully correct answer which scores one mark for part Q02(d)(i), one mark for Q02(d)(ii) and three marks for Q02(d)(iii).

ResultsPlus
Examiner Tip

When describing geometric isomers be very clear as to which atom the groups are found on.

Because on one side of the C=C bond there is two of the same group, so geometric isomerism cannot occur.

ResultsPlus
Examiner Comments

This did not score for Q02(d)(ii) as the answer did not explicitly state that the groups woud be on the carbon of the double bond. This response scored four marks.

Question 3

The question tested a candidate's ability to design a series of qualitative tests to identify three unknown solutions. A selection of reagents was given for the candidates to select from. Many candidates made a good attempt at answering this question, even if they did not score all of the marks because some of the details were omitted.

Common errors for each test were:

- Carbonate: to state that a gas was produced, instead of the observation of effervescence.
- Ammonium: to omit the addition of NaOH, or of heating, or to dip the red litmus paper into the solution.
- Sulfate: to omit the addition of acid before the $BaCl_2$.

To test for ammonium carbonate, add NaOH and warm in a water bath, testing the gas produced with damp red litmus. If NH_4 is present, the damp red litmus will turn blue.

To test for K_2CO_3 add HCl and if CO_3 is present then the sample will effervese

To test for K_2SO_4 you add $BaCl_2$ and HCl to a test tube. If SO_4 is present, a white precipitate will form.

Therefore, carry out these 3 tests and if the ammonium test is positive

it must be $(NH_4)_2CO_3$. If the NH_4 test is negative and the CO_3 test is positive, it must be K_2CO_3 and if the SO_4 test is positive it must be K_2SO_4.

ResultsPlus
Examiner Comments

This is a model answer, scoring all of the marks, despite some minor errors.

The correct test for the ammonium ion was described in the first section, followed by a clear test for the carbonate and sulfate ions. Although the candidate has not added any charges to the formulae for the ions, this was not penalised as the marks were being awarded for the correct tests and observations (see additional guidance).

In general however, candidates should take care to ensure that correct formulae are used.

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Examiner Tip

Note that whilst 'effervescence' or 'bubbles produced' is an observation, just 'a gas is produced' is not as there is no accompanying visible sign described.

To identify the sulfate ion, add HCl (to eliminate false positives) then react with $BaCl_2$. If a sulphate ion is present, a white precipitate will form. This will eliminate the sulphate from the list of unknowns.

To identify the ammonium cation, add HCl to the sample in a test tube and ~~a white precipitate will form~~ and damp red litmus will bleach.

to identify the carbonate anion, add $MgCl_2$, and a white precipitate should form.

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Examiner Comments

This scores IP5 and IP6 only, for a correct description of the sulfate ion test. The candidate has not added any information about the carbonate ion test. For the ammonium ion, they have added HCl, and said that the red litmus paper will bleach, neither of which is correct. For the carbonate ion they have said to add $MgCl_2$ and to look for a white precipitate which is also incorrect.

Question 4(a)

This was a straightforward question relating to a practical procedure. Many candidates suggested just rinsing the pipette with distilled water, however it is good practice to rinse out a pipette with the solution to be used, and this was required in the answer. Fewer candidates were able to justify their answers in terms of preventing dilution of the acid.

4 This question is about the kinetics of the reaction between iodine and propanone under acidic conditions.
The equation for the reaction is shown.

$$CH_3COCH_3 + I_2 \xrightarrow{H^+} CH_3COCH_2I + HI$$

An experiment is carried out to determine the order of the reaction with respect to iodine.

Step 1 50.0 cm^3 of 0.0200 mol dm^{-3} iodine solution, $I_2(aq)$, is added from a burette to a conical flask.

Step 2 25.0 cm^3 of 2.00 mol dm^{-3} sulfuric acid, $H_2SO_4(aq)$, is added to the conical flask using a pipette.

Step 3 25.0 cm^3 of 2.00 mol dm^{-3} propanone solution, $CH_3COCH_3(aq)$, is added to the conical flask using a pipette.
The flask is swirled and a timer is started.

Step 4 After 2 minutes, a 10.0 cm^3 sample of the reaction mixture is removed and quenched.

Step 5 The quenched sample is then titrated using 0.0100 mol dm^{-3} sodium thiosulfate solution, $Na_2S_2O_3(aq)$.

Step 6 Steps **4** and **5** are repeated every two minutes, until six titres have been determined.

(a) Before carrying out Step **2**, a student noticed droplets of an unknown colourless aqueous solution in the pipette.

Describe how the pipette should be treated before it is used in Step **2**.
Justify your answer.

(2)

the pipette should be washed out with the sulfuric acid first to ensure there is no contamination or dilution of the H_2SO_4

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Examiner Comments

This is a fully correct answer, scoring both marks. The candidate has indicated the correct procedure (rinsing with H_2SO_4), and justified their answer (no contamination or dilution for the sample).

Wash the pipette with sulfuric acid before using it to remove unwanted ~~set~~ compounds that may contaminate the titrated solutions.

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Examiner Comments

This response scored one mark for washing the pipette with sulfuric acid. The second mark was not awarded as just 'removing contaminants' was not sufficient.

Question 4(b)(i)

Many candidates were familiar with the idea of 'quenching' to stop a reaction. They found it more difficult to express clearly why the reaction would need to be quenched, with many vague answers about allowing time for the actual titration to be carried out. The explanation needed to relate to there being no change in concentration before the titration was completed.

(b) Samples from the reaction mixture are quenched in Step **4**.

(i) Explain why quenching is necessary.

(2)

To slow down the reaction so that the time can be determined for that point in the reaction.

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Examiner Comments

This scored both marks for the correct statement and explanation.

(2)

To stop the reaction ~~so accurate~~ ~~Moles of~~ and remove unreacted ~~oil~~ H_2SO_4

ResultsPlus
Examiner Comments

This scored one mark for the comment about stopping the reaction, but not the second mark because there was no mention of the ensuring that the concentration (of iodine) remained the same.

Question 4(b)(ii)

There were many correct answers to the first part of this question, with many candidates selecting a suitable quenching agent. However, the accompanying equation proved more of a challenge.

The list of incorrect quenching agents included calcium chloride (which is a dehydrating agent), sodium thiosulfate (which would be used in the titration later) and potassium permanganate (oxidising agent).

(ii) State a compound which can be added to the reaction mixture to quench the reaction.
Include an equation for the reaction that takes place during the quenching process. State symbols are not required.

(2)

Compound

$NaOH$ (aq)

Equation

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

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Examiner Comments

This did not score as sodium hydroxide is not a suitable quenching agent. As this was incorrect, the candidate could not access the mark for the equation.

Compound

~~Sodium hydrogen carbonate~~ ~~Sodium hydrogencarbonate~~ Sodium carbonate

Equation

~~$NaHCO_3 + H^+ \rightarrow$~~

$NaCO_3 + 2H^+ \rightarrow Na^+ + CO_2 + H_2O$

ResultsPlus
Examiner Comments

This response scored one mark. There is a correct quenching agent, but the equation is incorrect, as the formula of sodium carbonate is incorrect.

ResultsPlus
Examiner Tip

Check the formulae of all of the species in an equation.

Question 4(c)

This was a question about risk and hazard. The candidates were required to note that a corrosive compound might not need handling in a fume cupboard because it was produced in a small amount and would remain in solution. Most of the candidates that were awarded at least one mark, realised that the iodopropane would not be present as a gas, with fewer commenting that its concentration would be low.

(c) One of the products of the reaction, iodopropanone (CH_3COCH_2I) is corrosive, strongly irritating to the eyes and can cause breathing difficulties.

Explain why a risk assessment for this experiment says it does **not** have to be carried out in a fume cupboard.

(2)

iodopropanone is dissolved in solution / not a gas so does not become airborne so will not damage reach the experimenter. Also only a small amount is produced thereby lowering the extent of hazard.

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This is a fully correct answer, scoring both marks. The candidate notes that the iodopropanone would not be a gas, and also that it would be produced in small amounts.

as it is not a gas and so will not be present in the air so does not have to be removed from the air to prevent harm. As long as the solution is not spilled on skin

ResultsPlus Examiner Comments

This scores one mark. The candidate has noted that the iodopropanone is not a gas, but has not commented on the small amount produced.

Question 4(d)

Many candidates were able to calculate the concentration of the iodine and the propanone correctly. Some went on to describe that the iodine would be a limiting factor and scored three of the marks. For the fourth mark, candidates were required to state that the propanone would be in a **great** excess and hence the change in its concentration would be negligible. This mark was more difficult to score.

(d) Show, by calculating the initial quantities of the reactants involved, that this experiment provides evidence for the order with respect to iodine **only**.

(4)

~~Iodine =~~

~~I~~ Iodine = 1×10^{-3}

propanone = 0.05

Sulfuric = 0.05

There is 50 times more propanone (and sulfuric acid) than iodine, ~~its~~ theyre is in excess so their ~~its~~ change in concentration is negligible. The iodine is the only reactant that will have a significant change in concentration so only it's order can be calculated from the results.

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This was a clear answer scoring four marks.

The quantities are correct for M1 and M2, the candidate has stated that there is a 50 fold excess or propanone compared to iodine and so its change in concentration would be negligible for M3 and that therefore iodine would be the only reagent with a significant change in concentration for M4.

(4)

$I_2 = \frac{50}{1000} \times 0.02 = 1 \times 10^{-3}$

$H_2SO_4 = \frac{25}{1000} \times 2 = 0.05$ $\quad 0.05 > 1 \times 10^{-3}$

$CH_3COCH_3 = \frac{25}{1000} \times 2 = 0.05$

theres larger number of moles for both H_2SO_4 and CH_3COCH_3 ensuring that the concentration of them both stays constant during the reaction so ~~[illegible]~~ is

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Examiner Comments

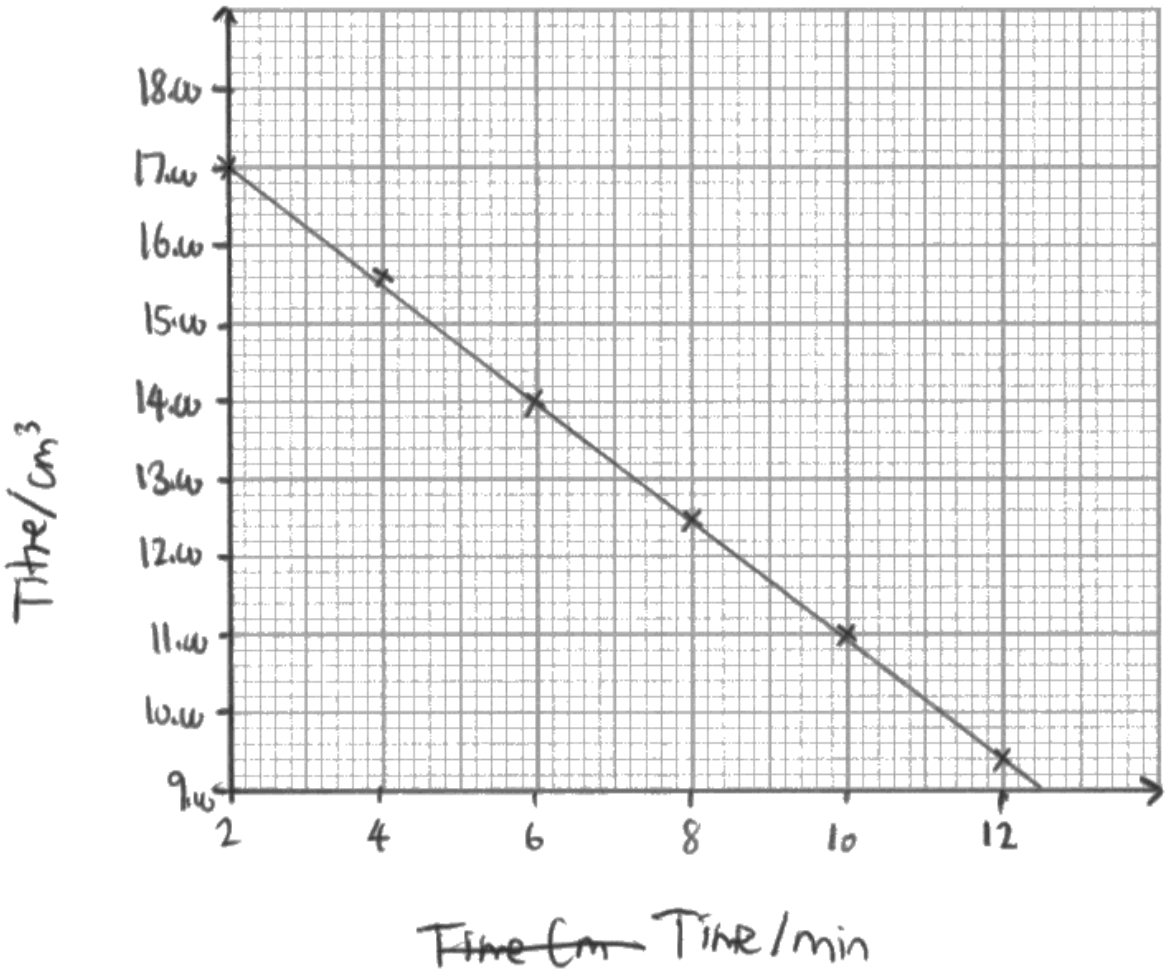
This scored the first and second marks. The comment about the propanone being in excess was not sufficient for the third mark, and there was nothing creditworthy for the fourth mark as the concentration of iodine was not referred to.

Question 4(e)

Q04(e)(i): The graph was generally clearly drawn with the axes labelled and the points plotted correctly, with a straight line of best fit added. The main error was in choosing a correct scale for the graph, as many did not cover half of the graph paper in both directions.

Q04(e)(ii): Many candidates made the correct link that the volume of sodium thiosulfate used would be proportional to the concentration of iodine.

Q04(e)(iii): While many candidates scored the mark for the correct order '0', there were a significant number who stated that the order would be '1', presumably confusing the graph with a 'rate-concentration' graph (although the gradient would be a straight line from the origin for this). Those who stated that the order was '0' usually went on to give a correct explanation.



(ii) Give the reason why it is not necessary to calculate the concentration of iodine so that the order can be deduced.

(1)

The titre tells us how many moles of iodine have been used up in the reaction

(iii) Deduce the order with respect to iodine. Justify your answer.

(2)

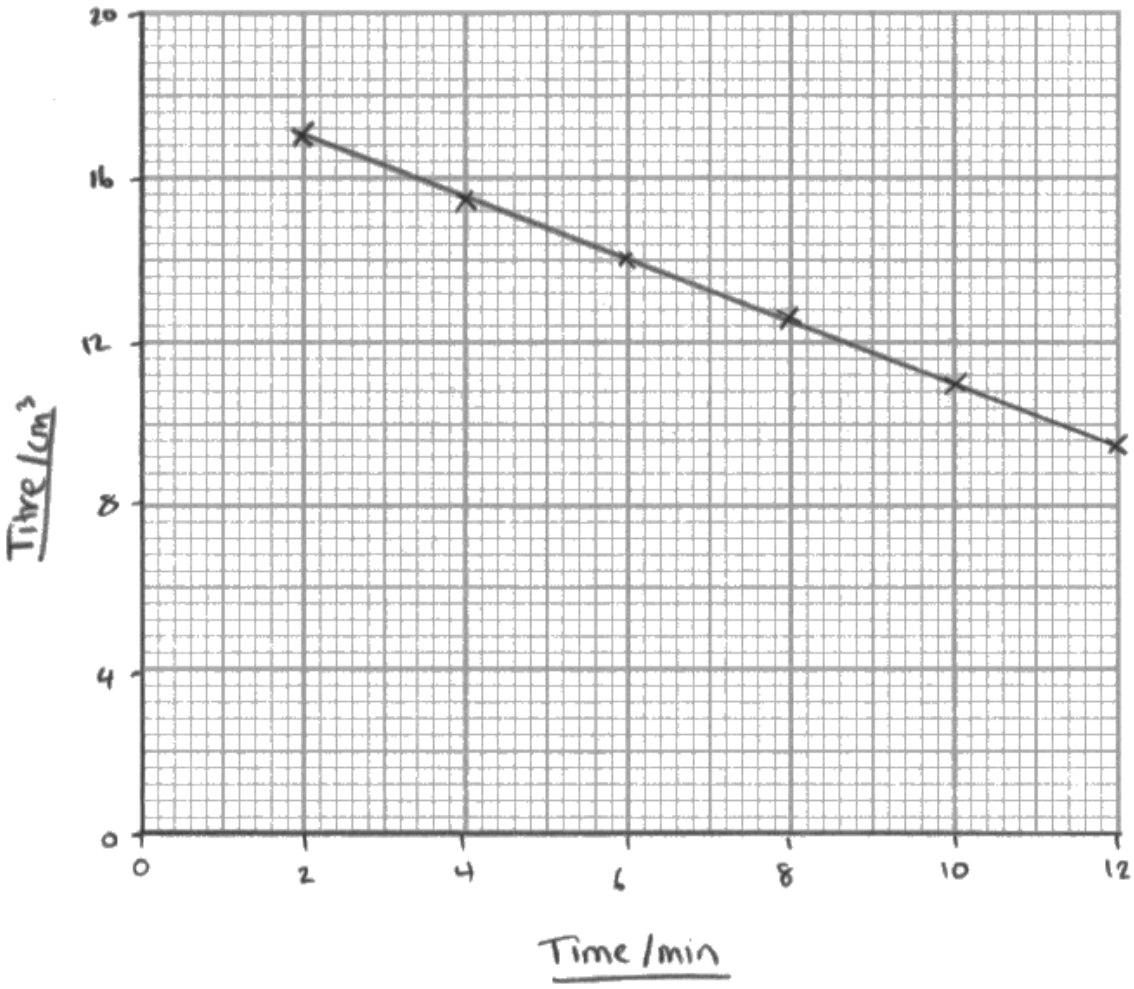
Zero order. This is because the graph shows a straight line with a negative gradient going downwards.

ResultsPlus
Examiner Comments

Q04(e)(i): This was awarded for a fully correct graph covering at least half of the graph paper.

Q04(e)(ii): This was not awarded as their comment did not relate to the link between the titre of thiosulfate and the volume of iodine.

Q04(e)(iii): This scored both marks for a fully correct answer.



(ii) Give the reason why it is not necessary to calculate the concentration of iodine so that the order can be deduced.

(1)

The volume of thiosulfate (titre) is proportional to the concentration of iodine.

(iii) Deduce the order with respect to iodine. Justify your answer.

(2)

Order 0 as the graph is a straight line which means the rate is constant so the concentration of iodine has no impact on the rate

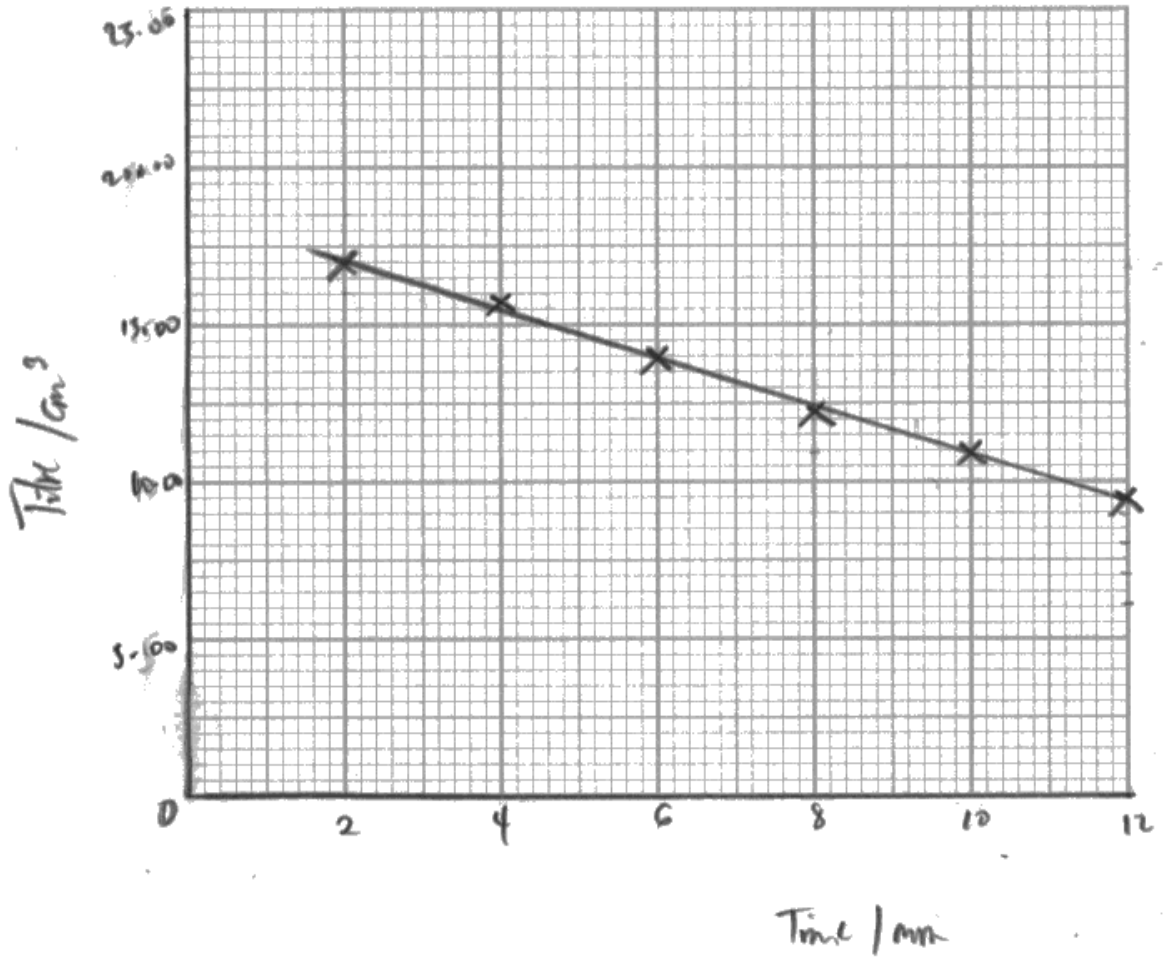
ResultsPlus Examiner Comments

Score for Q04(e)(i): one mark.

This graph did not score M1 as it did not cover half of the graph paper in each direction. The points were correctly plotted, and a straight line of best fit drawn for M2.

ResultsPlus Examiner Tip

Remember to choose a scale that will cover at least half of the graph paper in each direction.



(ii) Give the reason why it is not necessary to calculate the concentration of iodine so that the order can be deduced.

(1)

This is because the titre value is proportional to the concentration of iodine.

(iii) Deduce the order with respect to iodine. Justify your answer.

(2)

It is first order. This is because the gradient which is rate is constant with change in titre.

ResultsPlus
Examiner Comments

This scored the mark in Q04(e)(ii) for the correct statement linking the titre volume to the concentration of iodine.

Question 5(a)(i)

Most candidates were able to work out the number of moles of each element in the sample of the unknown solid. Some of them did not explain the ratio and how to calculate the empirical formula to compare to the molecular mass.

5 This question is about cobalt complexes.

(a) A sample of cobalt(II) chloride was dissolved in aqueous ammonia, $NH_3(aq)$. During the process, a stream of oxygen was gently bubbled through the solution to oxidise the cobalt(II) ion.

A coloured solid, **R**, was extracted from the solution. A pure sample of this solid was found to contain the masses of the elements shown and had a molar mass of 233.4 g mol^{-1}.

Element	Mass / g
Co	1.26
N	1.20
H	0.257
Cl	2.28

(i) Show that the empirical formula **and** the molecular formula of **R** is $CoN_4H_{12}Cl_3$. You must show your working.

(2)

Co: 1.26 / 58.9 = 0.02139...

N: 1.20 / 14 = 0.0857...

H: 0.257 / 1 = 0.257

Cl: 2.28 / 35.5 = 0.06422...

0.02139... / 0.02139... = 1

0.0857... / 0.02139... = 4.006... = 4

0.257 / 0.02139... = 12.013... = 12

0.06422... / 0.02139... = 3.0023... = 3

233.4 = $CoN_4H_{12}Cl_3$

233.4 = (58.9 + (4 × 14) + (12 × 1) + (3 × 35.5))

ResultsPlus
Examiner Comments

This scores both marks. The candidate has clearly shown how to calculate the molar mass and has then gone on to demonstrate how to calculate the molar ratio and the relative formula mass, and hence demonstrate that the empirical and molecular formula of the compound are the same.

ResultsPlus
Examiner Tip

When a question asks you to show working, make sure that you include every step.

moles Co = $\frac{1.26}{58.9}$ = 0.0213..

moles N = $\frac{1.20}{14}$ = 0.0857..

moles H = $\frac{0.257}{1}$ = 0.257

moles Cl = $\frac{2.28}{35.5}$ = 0.0642..

ratio of moles:

Co : N : H : Cl

1 : 4 : 12 : 3

∴ $CoN_4H_{12}Cl_3$ is empirical

molar mass = 58.9 + 14 × 4 + 12 + 35.5 × 3

= 233.4 $gmol^{-1}$ ∴ molecular = $CoN_4H_{12}Cl_3$

ResultsPlus
Examiner Comments

This response just scored one mark. The moles have been calculated, but the molar ratio has just been stated rather than calculated. The working to show how the molecular formula is derived is correct, but insufficient to score the second mark without the calculation showing how the molar ratio is derived.

Question 5(a)(ii-iii)

Q05(a)(ii)

Many candidates scored at least one of the available two marks on this question, with many going on to score the second mark and showing that the ratio would be 1:1.

Q05(a)(iii)

This proved more challenging to candidates. Many were able to deduce that the complex ion would be octahedral in shape, with most drawing a suitable diagram with the correct 'wedge' shapes. Many struggled to identify the correct ligands, with 6 water molecules as a common incorrect answer. There were some correct charges seen, but many candidates thought that the cobalt ion in the centre of the complex had a charge of $^{2+}$, despite it having been oxidised to Co^{3+} in the reaction described in the question.

$$R + H_2O \rightarrow Q + AgCl$$ (2)

$$n(AgCl) = \frac{0.614}{107.9 + 35.5} = 4.28 \times 10^{-3}$$

$$n(R) = \frac{1}{233.5} = 4.284 \times 10^{-3}$$

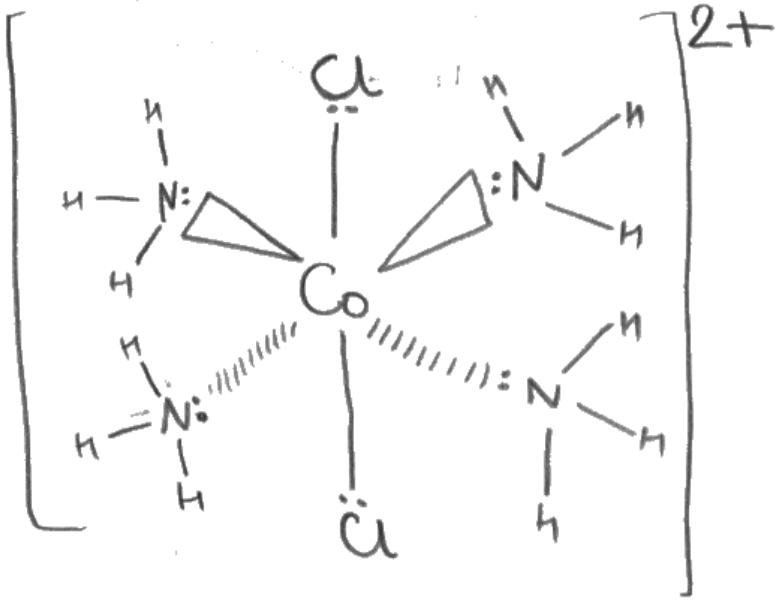
$n(R) : n(AgCl)$

$1 : 1$

1 mol of Cl^- ions produced

(iii) Draw the three-dimensional shape of the complex ion, **Q**, using your answer to (a)(ii) to help deduce the formula and overall charge.

(3)

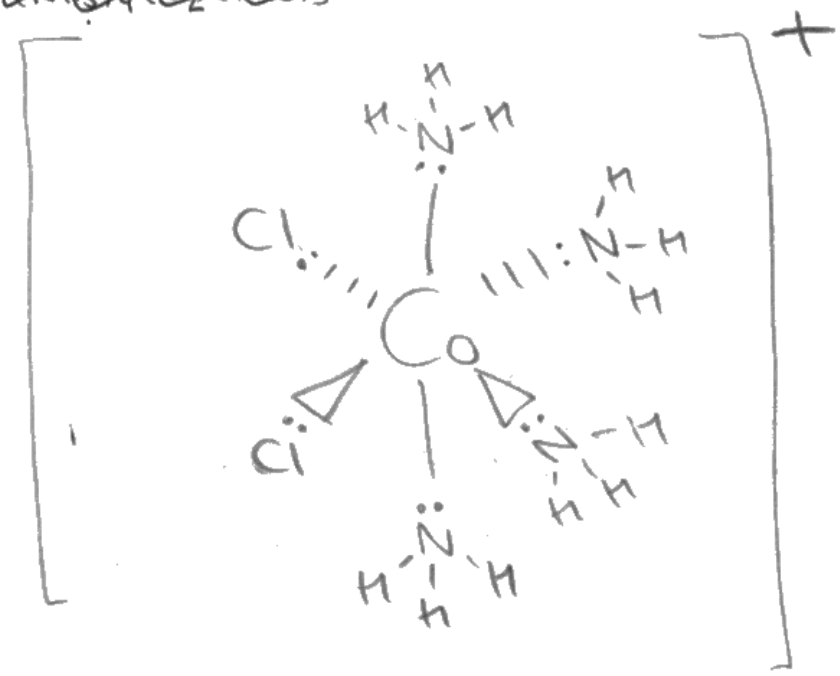


ResultsPlus
Examiner Comments

This scored two marks for Q05(a)(ii) and two marks for Q05(a)(iii). This is an example of a fully correct response for part (ii). The shape and ligands are correct for the first and second marks for part (iii), but the charge is incorrect so just two marks awarded for part (iii).

(iii) Draw the three-dimensional shape of the complex ion, **Q**, using your answer to (a)(ii) to help deduce the formula and overall charge.

(3)



$[Co(NH_3)_4(Cl)_2]^+$

ResultsPlus
Examiner Comments

This is an example of a correct diagram for part (iii), scoring all three marks.

Question 5(b)(i)

This straightforward question involved providing a definition of 'dynamic equilibrium' and many fully correct answers were seen.

Some candidates discussed how changing reaction conditions affected the equilibrium and so did not answer the question.

(b) An aqueous solution of cobalt(II) chloride contains the complex ion $[Co(H_2O)_6]^{2+}$.

The dynamic equilibria shown occur when $NH_3(aq)$ and $EDTA^{4-}(aq)$ are each added to separate solutions of this complex ion.

increase entropy

$[Co(H_2O)_6]^{2+}(aq) + 6NH_3(aq) \rightleftharpoons [Co(NH_3)_6]^{2+}(aq) + 6H_2O(l)$ $\log K_c = 4.39$

$[Co(H_2O)_6]^{2+}(aq) + EDTA^{4-}(aq) \rightleftharpoons [Co(EDTA)]^{2-}(aq) + 6H_2O(l)$ $\log K_c = 16.5$

increase entropy.

(i) State what is meant by the term 'dynamic equilibrium'.

(2)

The rate of the forward and backward reactions are equal and the * concentration remain constant.

* of products and reactants.

ResultsPlus
Examiner Comments

This is a fully correct answer scoring both marks.

Dynamic equilibrium is when the concentration of product & reactants are equal. & Changing the concentration of products or reactants shifts the equilibrium.

ResultsPlus
Examiner Comments

This response did not score any marks. The candidate has wrongly stated that the concentration of products and reactants are equal and has then gone on to make a comment about how the equilibrium would shift which is not asked for in the question.

Question 5(b)(ii)

The question required candidates to deduce which of three complex ions would be more stable based on their equilibria and entropy. Many candidates stated that the [Co(EDTA)] $^{2-}$(aq) complex would be the most stable and related this either to the larger K_c or to an increased entropy in the equation to form it. Candidates who commented on the number of moles on either side of the equation to form [Co(EDTA] $^{2-}$ (aq) often gave the correct number of species, although some lost marks by referring to 'molecules' instead of moles.

In terms of entropy $[Co(EDTA]^{2-}$ is the most stable as there are only 2 moles of reactants which form 7 moles of products. In terms of equilibria it is also $[Co(EDTA)]^{2-}$ as the K_c is highest for this reaction

ResultsPlus
Examiner Comments

This scored two marks.

M1 was awarded as was M2. However, the candidate did not state that there would be an increase in entropy and so M3 was not awarded.

(ii) Explain, in terms of equilibria and entropy, which of the three complex ions is the most stable.

(3)

$[Co(EDTA)]^{2-}$ is the most stable. $\log_{10} K_c = 1.2748439$. The K_c value is larger than 1, indicating equilibrium lies far on the right. Also, the entropy of the reaction is increasing since 2 mols are on the left and 1 mols on the right. This increases the disorder of the system, and indicates $[Co(EDTA)]^{2-}$ is more likely to form due to its stability.

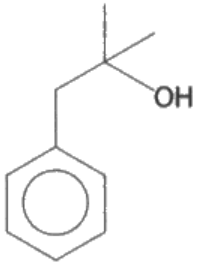
ResultsPlus
Examiner Comments

This is a fully correct answer scoring all three of the marking points.

Question 6(a)

The first part of this question proved accessible to many candidates with the structure of compound A correctly drawn. A few candidates lost marks on their diagrams for compound B, by adding in a covalent bond between the Mg and Br. The structure of compound C proved to be more challenging, with candidates sometimes showing a ketone structure with a pentavalent carbon. The final reagent proved a challenge for many, with LiAlH4 a common wrong answer. There was also often the omission of the '(aq)' with the acid which was required for the mark.

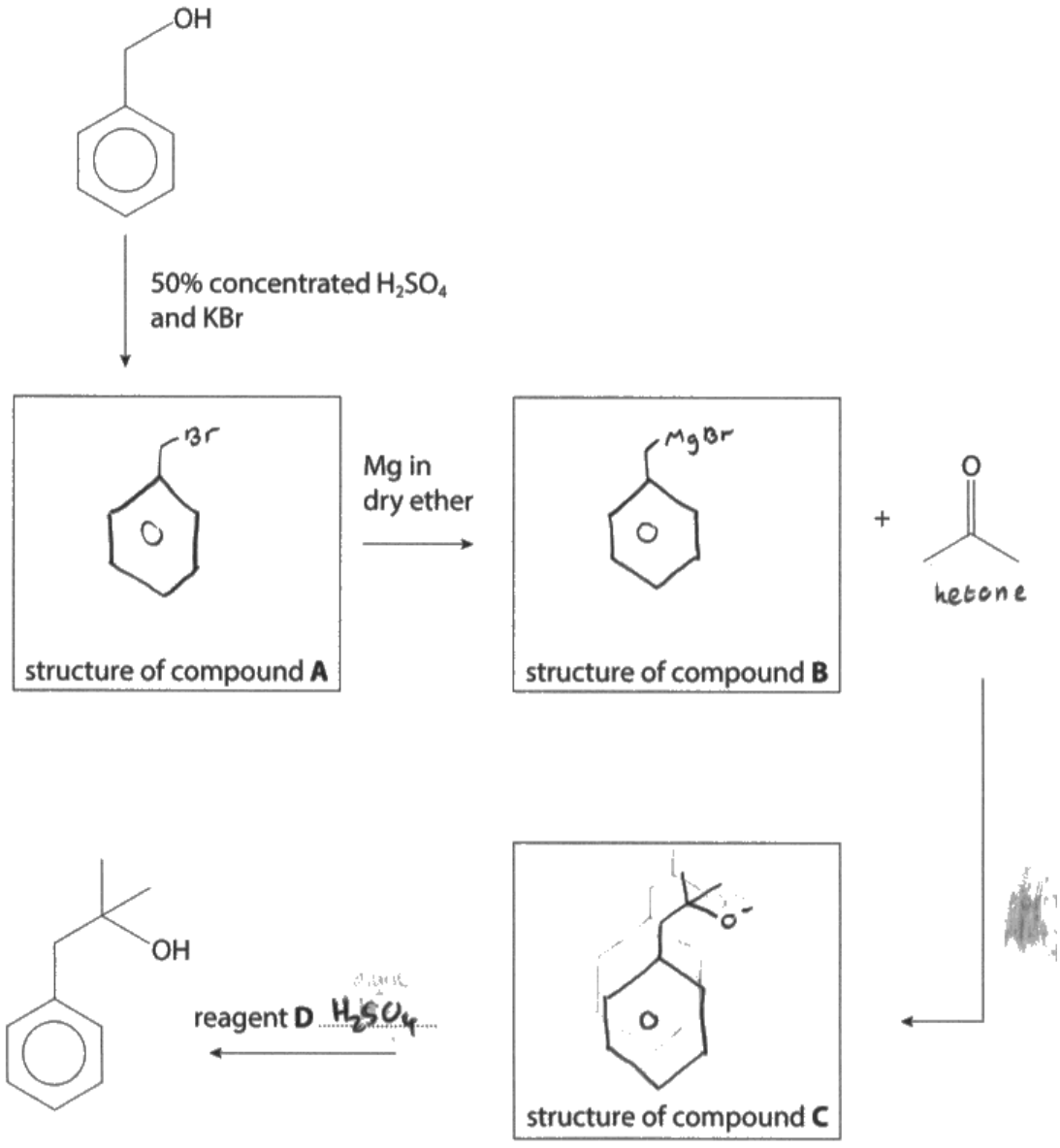
6 The compound 2-methyl-1-phenylpropan-2-ol is found in small amounts in cocoa beans and has the structure shown.



(a) A proposed synthesis of 2-methyl-1-phenylpropan-2-ol from phenylmethanol and propanone is shown.

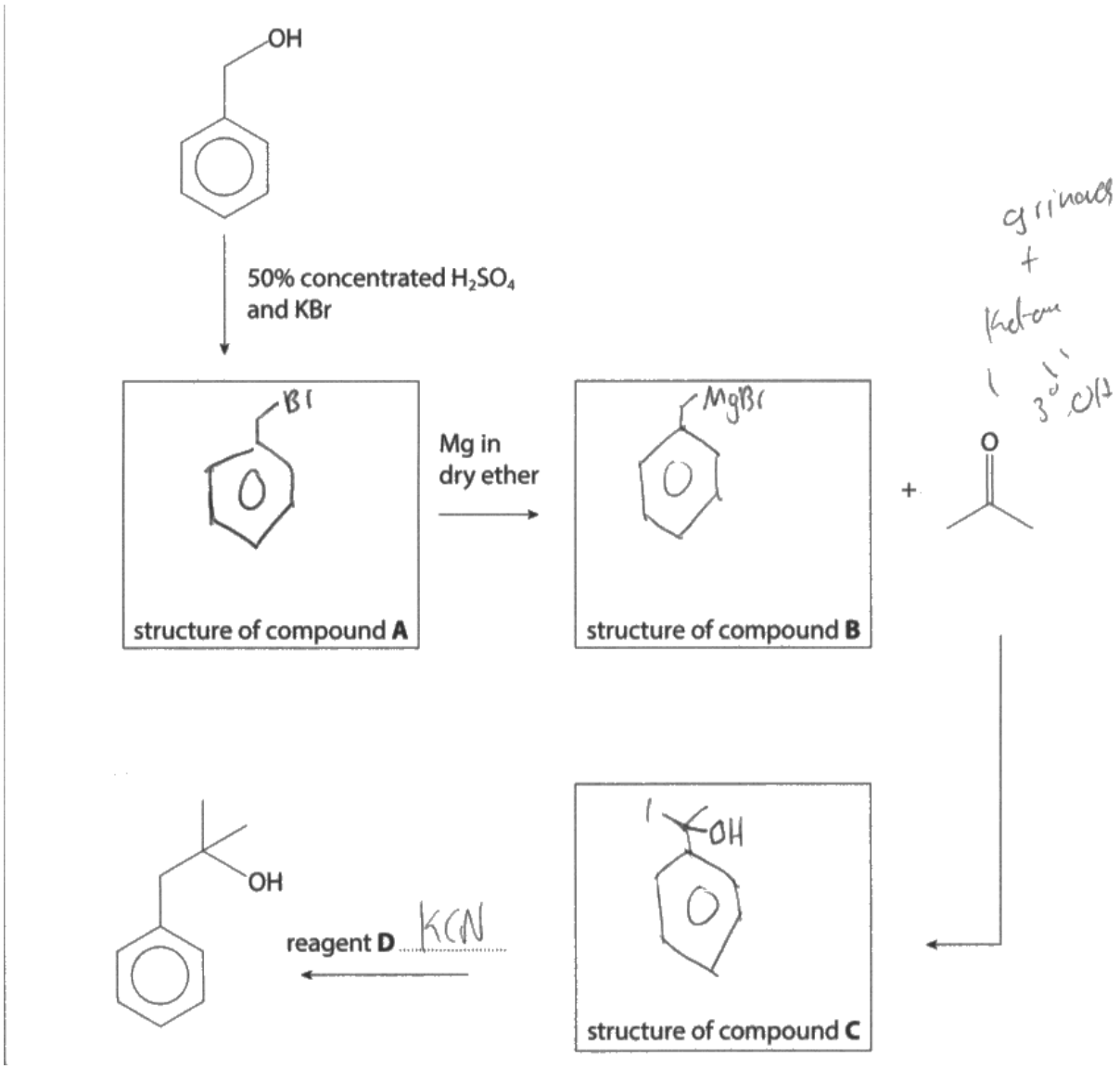
Complete the diagram to show the structures of compounds **A**, **B** and **C** and the formula of reagent **D**.

(4)



ResultsPlus
Examiner Comments

This scored three marks, as compounds A, B and C were correct. Reagent D was incorrect as the acid needed either the word 'dilute' or (aq) to gain this mark.



ResultsPlus
Examiner Comments

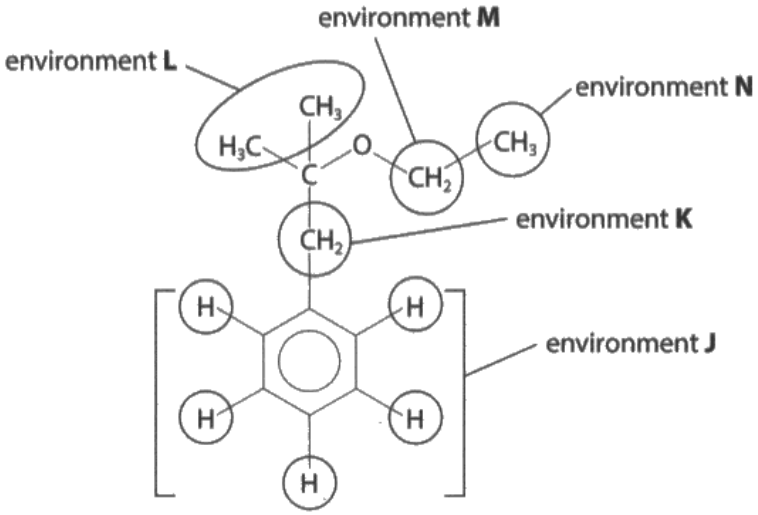
This scored just two marks for compound A and compound B. The structure of compound C is incorrect and the wrong reagent is used for step 4.

Question 6(b)

For this question, the areas were often given correctly, with many candidates also identifying the correct splitting pattern. However, it was common to see that candidates ignored the adjacent aryl group for environment K and so suggested a range of -0.2-2.0.

Please note that to take into account the various data booklets that candidates might have used, the ranges of the acceptable chemical shifts were widened, including to below '0'.

(b) 2-Methyl-1-phenylpropan-2-ol can be converted to compound **S**.
When considering the ^{1}H NMR spectrum of **S**, the hydrogen atoms of the benzene have been assumed to be a single environment, labelled **J**.
The other hydrogen environments have been labelled **K**, **L**, **M** and **N**.



compound **S**

Complete the table for each of the environments **K** to **N** in the high resolution ^{1}H NMR spectrum of **S**.

(5)

	Chemical shift / ppm	Relative peak area	Splitting pattern
Environment **J**	6.8 – 8.2	5	complex
Environment **K**	0.0-1.8	2	doublet
Environment **L**	0.0-1.8	6	sextet
Environment **M**	3.0-4.2	2	doublet
Environment **N**	0.0-1.8	3	triplet

ResultsPlus
Examiner Comments

This response scored three marks. The chemical shifts for environments L, M and N were given correctly. The area under the curve was given correctly for all of the environments. The splitting pattern was correct only for environment N.

This gave a total of 8 points and hence three marks.

ResultsPlus
Examiner Tip

Take care to look at the environment around a group to determine the correct chemical shift range.

	Chemical shift / ppm	Relative peak area	Splitting pattern
Environment J	6.8 – 8.2	5	complex
Environment K	0.0 – 1.8	2	simple
Environment L	0.0 – 1.8	3	complex
Environment M	2.7 – 4.3	2	simple
Environment N	0.0 – 1.8	3	simple

ResultsPlus
Examiner Comments

This scored two marks. The splitting patterns for L, M and N were correct. The area under the curve was correct for K, M and N. The splitting patterns were incorrect. Hence 6 marking points and two marks.

Question 7(a)

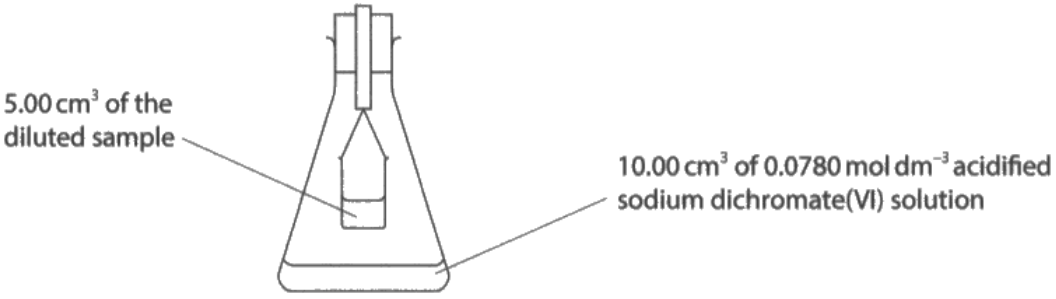
The most common response to this question was to allow time for the ethanol to fully react, with some candidates noting that all of the ethanol would have been converted to ethanoic acid. It was less common to see comments about the ethanol evaporating, and some candidates wrote incorrectly that the sodium dichromate(VII) would be able to evaporate, which is incorrect.

7 A laboratory technician analysed a sample of an alcoholic drink to determine the concentration of ethanol, in g dm^{-3}.

20.00 cm^3 of the alcoholic drink was added to a 250 cm^3 volumetric flask and made up to the mark with deionised water.

The ethanol in 5.00 cm^3 of the diluted sample was oxidised in the equipment shown.

The sample was suspended in an open beaker in a sealed conical flask over 10.00 cm^3 of acidified sodium dichromate(VI), of concentration 0.0780 mol dm^{-3}.



The apparatus was left in a warm place for 24 hours for the acidified sodium dichromate(VI) to oxidise the ethanol.

Excess potassium iodide solution was then added to the **remaining** acidified sodium dichromate(VI) in the conical flask, forming iodine.

All of this iodine was then titrated using 0.0220 mol dm^{-3} sodium thiosulfate solution, $Na_2S_2O_3(aq)$.

The volume of $Na_2S_2O_3(aq)$ required in the titration was 32.70 cm^3.

The equations for the reactions that take place during the experiment are shown.

$$3CH_3CH_2OH(l) + 2Cr_2O_7^{2-}(aq) + 16H^+(aq) \rightarrow 3CH_3COOH(aq) + 4Cr^{3+}(aq) + 11H_2O(l)$$

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6I^-(aq) \rightarrow 2Cr^{3+}(aq) + 3I_2(aq) + 7H_2O(l)$$

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

(a) Explain why the apparatus was left in a **warm** room and for **24 hours**.

(2)

The room was warm as you need heat for oxidation It was left for 24hours to allow the ethanol to fully oxidise into ethanoic acid otherwise it might have just produced ethanal

ResultsPlus
Examiner Comments

This scored two marks for the comment that the ethanol would fully oxidise to ethanoic acid.

ResultsPlus
Examiner Comments

This did not score because just 'leaving the apparatus in a warm room' would not increase the rate of reaction significantly.

ResultsPlus
Examiner Tip

If a question asks you to 'explain', then remember to include a reason for your statement in your answer.

Question 7(b)

Q07(b)(i) and Q07(b)(ii) were linked with many opportunities to score marks for correct logical steps and many fully correct answers were seen.

Q07(b)(i)

M1, M2 and M3 were frequently seen with candidates using the information in the equations in the question to gain these marks. The correct calculation of the moles of acidified dichromate (VI) that reacted proved more challenging, with many candidates just using the moles of dichromate and forgetting to subtract the moles that would have reacted to form the iodine. M5 was often awarded, either as a transferred error (TE) from M3 or correctly from an answer to M4.

Q07(b)(ii)

Candidates had the opportunity to gain marks for this part by using their final answer to part (i). This part was found challenging by some candidates, with some making simple errors such as mis - calculating the M_r of ethanol, or dividing by the M_r of ethanol instead of multiplying.

(b) (i) Calculate the number of moles of ethanol in 5 cm^3 of the **diluted** drink.

(5)

$\frac{32.7}{1000} \times 0.022 = 7.194 \times 10^{-4}$ mol thiosulfate

$\div 2 = 3.597 \times 10^{-4}$ mol I_2

$\div 3 = 1.199 \times 10^{-4}$ mol dichromate remaining

$\frac{10}{1000} \times 0.078 = 7.8 \times 10^{-4}$ mol dichromate originally

$7.8 \times 10^{-4} - 1.199 \times 10^{-4} = 6.601 \times 10^{-4}$ mol reacted

$\times 1.5 = 9.9015 \times 10^{-4}$ moles ethanol

(ii) Calculate the concentration of ethanol in the alcoholic drink in **g dm^{-3}**.

(3)

$9.9015 \times 10^{-4} \times \frac{250}{5} = 0.04945$ moles in 5 flask

$\frac{20}{1000} = 0.02$ dm^3

0.04945 moles = 2.28 g ethanol

ethanol $M_r = 46$

$2.28 \div 0.02 = 113.87$ g dm^{-3}

ResultsPlus
Examiner Comments

This is an example of a fully correct response, scoring five marks for Q07(b)(i) and three marks for QO7(b)(ii).

ResultsPlus
Examiner Tip

If you lay your calculation work out clearly, it is much easier to follow-through with a logical progression.

(b) (i) Calculate the number of moles of ethanol in 5 cm^3 of the **diluted** drink.

(5)

mol of $Na_2S_2O_3$: $0.022 \times \frac{32.70}{1000} = 7.194 \times 10^{-4}$

mol of I_2 = $\frac{7.194 \times 10^{-4}}{2} = 3.597 \times 10^{-4}$

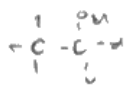
Mol Chromate : $0.0780 \times \frac{10}{1000} = 7.8 \times 10^{-4}$

mol of $Cr_2O_7^{2-}$ = $\frac{3.597 \times 10^{-4}}{3} = 1.199 \times 10^{-4}$

$(3.597 \times 10^{-4}) - (1.199 \times 10^{-4}) = 2.398 \times 10^{-4}$ mol

(ii) Calculate the concentration of ethanol in the alcoholic drink in **g dm^{-3}**.

(3)



mol = C x V

$2.398 \times 10^{-4} = C \times \frac{20}{1000}$

C_2H_5OH

Mr = 46

$C = 0.01199$ mol dm^{-3}

$\times 46$

= 3837 g dm^{-3}

ResultsPlus
Examiner Comments

This scored three marks for Q07(b)(i) and one mark for Q07(b)(ii). M1, M2 and M3 were awarded for part (i). For part (ii) the candidate has correctly multiplied by 46 the M_r of ethanol and so scored one mark as a TE.

Question 7(c)

Many candidates had not quite understood that the question required them to consider how the actual titration method could be improved. The experiment as described only allowed for one titration to be carried out and so candidates needed to indicate that one way to improve would be to repeat the whole experiment, and that another way would be to take smaller samples so that more than one titration could be carried out.

Many candidates were able to score the 'rescue mark' detailed in the additional guidance for repeating the titration and calculating a mean.

(c) It was suggested that the **titration** as described might lead to an unreliable result.

State **two** ways the procedure could be amended to counter this suggestion.

(2)

- Repeat the titration in order to include all concordant results and negate any outliers.

ResultsPlus
Examiner Comments

This scored one mark for repeating the titration until concordant results were obtained.

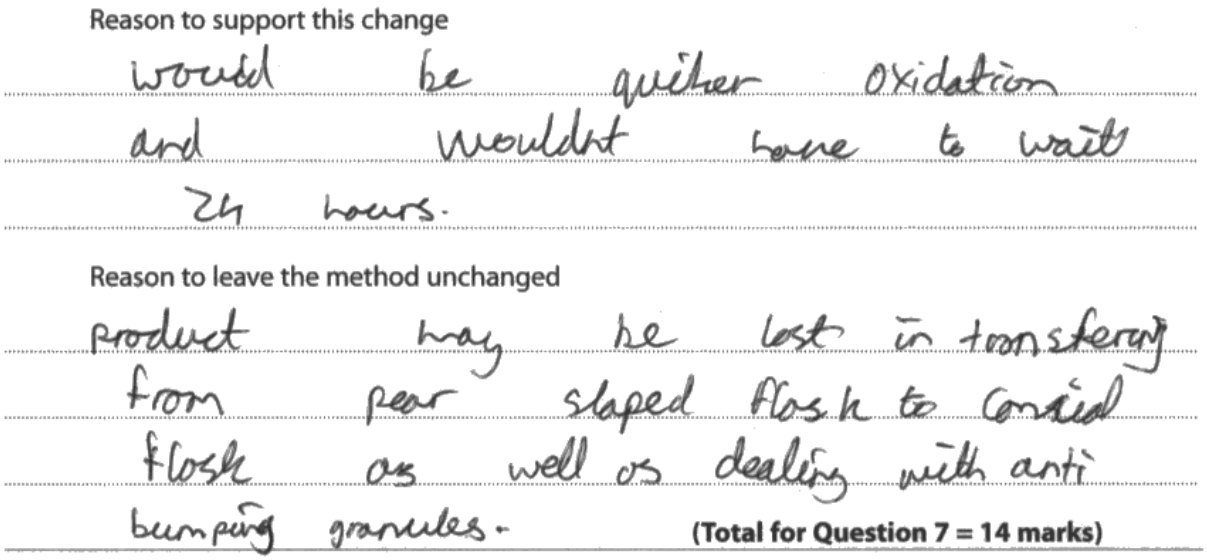
- The volume of $Cr_2O_7^{2-}$ solution is very small, so using a larger volume would reduce % uncertainty. (and diluted sample)
- The experiment could be repeated with 3 more flasks, allowing 1 rough and 3 accurate titrations to be performed, from which concordant values and can be selected and used to calculate an average titre

ResultsPlus
Examiner Comments

This scored one mark for the comment about repeating the whole experiment and setting up multiple flasks.

Question 7(d)

Many candidates scored at least one mark for reasoning that using a reflux set-up would speed up the rate of reaction. The second mark, relating to the reasons not to use reflux, was less well-answered, with many candidates suggesting that it would be difficult to separate the sodium dichromate (VI) or that there would be a greater risk of flammability. The most common correct answer to this part was that some of the ethanol would evaporate with reflux.



ResultsPlus
Examiner Comments

This scored the first mark for the oxidation proceeding more quickly, but there is nothing creditworthy for the second mark.

(d) Another technician suggested that it was unnecessary to suspend the drink sample above the acidified sodium dichromate(VI) solution and proposed a change to the procedure.

The proposal was that the drink sample should be mixed with the acidified sodium dichromate(VI) solution and then heated under reflux to allow the ethanol to be oxidised.

Give **one** reason to support this change and **one** reason to leave the method unchanged. In each case justify your answer.

(2)

Reason to support this change

Ensures that the ethanol is fully oxidised to ethanoic acid, and is faster.

Reason to leave the method unchanged

The heat and reflux may cause other vapours in the alcohol mixture to oxidise and mix in with the ethanoic acid.

ResultsPlus
Examiner Comments

This scored two marks. The first for the full oxidation of ethanol if using reflux, and the second for other vapours that could be oxidised by the sodium dichromate (VI).

Question 8(a)

Most candidates scored at least one mark on this question for correctly calculating the $[H^+]$. Many then went on to score the second mark for the correct K_a value.

8 This question is about weak acids.

(a) An aqueous solution of a weak acid, HA(aq), with a concentration of $0.0712\,mol\,dm^{-3}$, has a pH = 3.25 at room temperature.

Calculate the value of K_a for the weak acid HA(aq).

(2)

$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{[H^+]^2}{[HA]}$ $(H^+) = 5.6234 \times 10^{-4}$

$K_a = 4.44 \times 10^{-6}$

ResultsPlus
Examiner Comments

This scored two marks for a fully correct answer.

$10^{-3.25} = 0.0005623413 2 . (H)$

$Ka = [HA][A]$

$0.0005623413 2 \times 0.0712 = 0.0000400387$

ResultsPlus
Examiner Comments

This candidate scored the first mark for the correct calculation of the [H+]. However they did not carry out the correct calculation for the second part (they multiplied the [H+] by 0.0712 instead of performing the correct calculation ([H +] ^{2} / 0.072) and so did not score the mark.

Question 8(b)

Q08(b)(i): This proved difficult for candidates to score all three marks available, with many candidates losing marks through not starting and ending at the correct pH, making the vertical section too long or too short, and not showing the steep rise at the start. Most candidates did however realise that the vertical section would be at 20cm^3 as the acid and base were in equimolar concentrations.

Q08(b)(ii): This was quite well-answered with candidates knowing to use half the volume taken from the vertical section of their graph and read off the pH.

Q08(b)(iii): Many candidates scored the final mark for calculating the K_a from the value read from their graph. The question had asked candidates to show their working and those who did this were able to access the other two marks.

(b) The value of K_a may be determined from experimental data, using a titration curve.

Ethanoic acid, $CH_3COOH(aq)$, with a concentration of 0.0500 mol dm^{-3}, has a pH of 3.03 at room temperature.

A 20.0 cm^3 sample of the acid was titrated with sodium hydroxide solution, NaOH(aq), with a concentration of 0.0500 mol dm^{-3}.
During the experiment, 40.0 cm^3 of sodium hydroxide solution was slowly added to the ethanoic acid.

A pH probe connected to a data logger was used to monitor the pH throughout the experiment.

(i) Calculate the pH of the sodium hydroxide solution.
Give your answer to one decimal place.

[$K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}]

(1)

$K_w = [OH^-][H^+]$

$[H^+] = \frac{1 \times 10^{-14}}{0.05}$

$= 2 \times 10^{-13}$

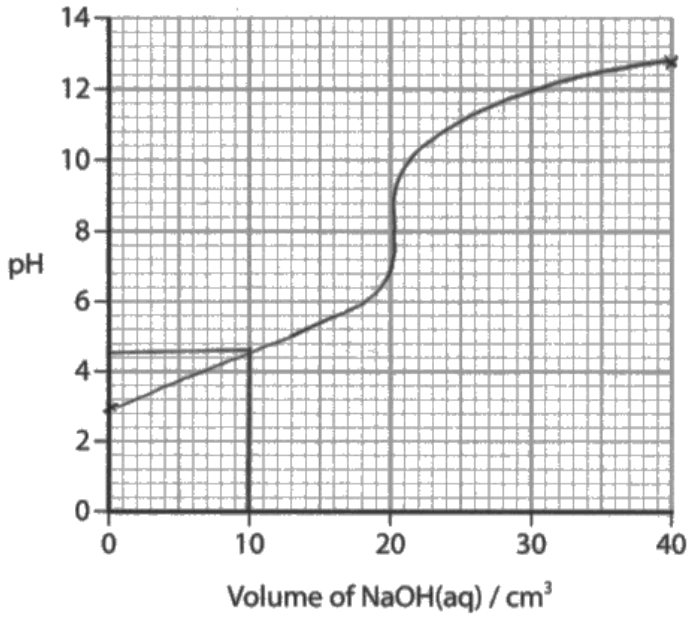
$pH = -\log_{10}[H^+]$

$= 12.698...$

$= 12.7$ (1 d.p)

(ii) Draw a titration curve, on the axes shown, to show the change in pH throughout the experiment.

(3)



(iii) Give an estimate of the pH value at the half-equivalence point. Show your working on the titration curve.

(1)

4.6

(iv) Calculate a value for K_a of ethanoic acid using your answer to (b)(iii). You **must** show your working.

(3)

@ Half equivalence, $[A^-] = [HA]$

$K_a = \frac{[A^-][H^+]}{[HA]}$, $[HA] = [A^-]$

$\therefore K_a = [H^+]$ $\quad [H^+] = 10^{-pH}$

$\therefore K_a = 10^{-pH}$

$K_a = 10^{-4.6}$

$K_a = 2.51 \times 10^{-5}$ moldm^{-3} (3 s.f.)

ResultsPlus
Examiner Comments

Q08(b)(i): This mark was awarded for the correct pH to 1dp.

Q08(b)(ii): This was awarded M1 for the correct starting and end-points of the curve. The vertical section, although at 20cm^3, was not within the limit to score M2 and the shape at the start did not show a steep rise at the start and so no M3.

Q08(b)(iii): This mark was awarded for showing the working on the graph at 10cm^3 and for reading off the correct pH.

Q08(b)(iv) was correct with all of the working shown and awarded three marks.

(b) The value of K_a may be determined from experimental data, using a titration curve.

Ethanoic acid, $CH_3COOH(aq)$, with a concentration of 0.0500 mol dm^{-3}, has a pH of 3.03 at room temperature.

A 20.0 cm^3 sample of the acid was titrated with sodium hydroxide solution, NaOH(aq), with a concentration of 0.0500 mol dm^{-3}.
During the experiment, 40.0 cm^3 of sodium hydroxide solution was slowly added to the ethanoic acid.

A pH probe connected to a data logger was used to monitor the pH throughout the experiment.

(i) Calculate the pH of the sodium hydroxide solution.
Give your answer to one decimal place.

[$K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}]

(1)

$1\times10^{-14} = [H^+][OH^-]$

$1\times10^{-14} = [H^+] \times 0.05$

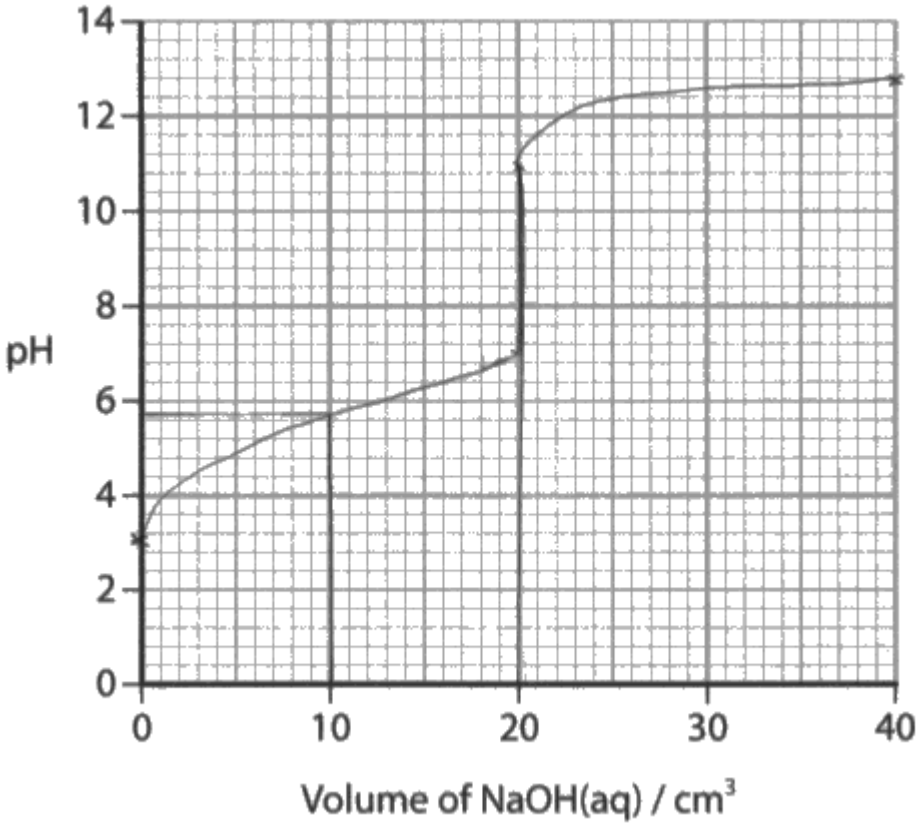
$[H^+] = \frac{1\times10^{-14}}{0.05}$

$= 2\times10^{-13}$

$pH = -\log_{10}(2\times10^{-13})$

$= 12.69897$

≈ 12.7



ResultsPlus
Examiner Comments

Q08(b)(ii) This candidate scored three marks for a completely correct titration curve.

Question 8(c)

Many candidates were able to score at least one mark on this question with the most common responses being that the data logger would speed up the procedure and reduce human error. It should be noted that just a comment about being more accurate without any more detail was not sufficient to score any marks. There were many other opportunities to score on this question, including that processed data could be seen in real time, that there would be greater resolution of the data and that the data could be stored.

(c) Another method used to monitor the titration is to use a pH meter without a data logger. The pH is measured and recorded after the addition of each 1.00 cm^3 portion of NaOH(aq).

A student assessed the two methods and concluded that using the data logger was a more effective way to carry out the experiment.

Give **three** reasons that support this conclusion.

(3)

(1) Data logger monitors pH all throughout, not just between 1 cm^3 intervals, so intermediate values are entirely accurate, a more accurate graph and results are drawn and obtained

(2) Data logger reduces risk of human error as is computerised and automated

(3) Data logger is faster as you don't need to draw your own results table as it can record for you.

ResultsPlus
Examiner Comments

This was a good answer, scoring three marks for continuous data being produced, a graph being drawn, and reduction in human error.

(c) Another method used to monitor the titration is to use a pH meter without a data logger. The pH is measured and recorded after the addition of each 1.00 cm^3 portion of NaOH(aq).

A student assessed the two methods and concluded that using the data logger was a more effective way to carry out the experiment.

Give **three** reasons that support this conclusion.

(3)

- pH is measured continuously throughout the experiment
- lower chance of impurities from outside the reaction coming in contact with the pH probe

ResultsPlus
Examiner Comments

This scored one mark for the comment about pH being measured continuously.

Question 8(d)(i)

This calculation to find the concentration of propanoic acid in a buffer solution proved challenging. However, many candidates were able to follow through their calculations in a logical progression in order to obtain the correct answer. A common error was to calculate the moles of salt (0.023958) instead of the concentration (0.23958). Candidates who used the Henderson-Hasselbalch equation did less well, as they often mis-remembered the equation.

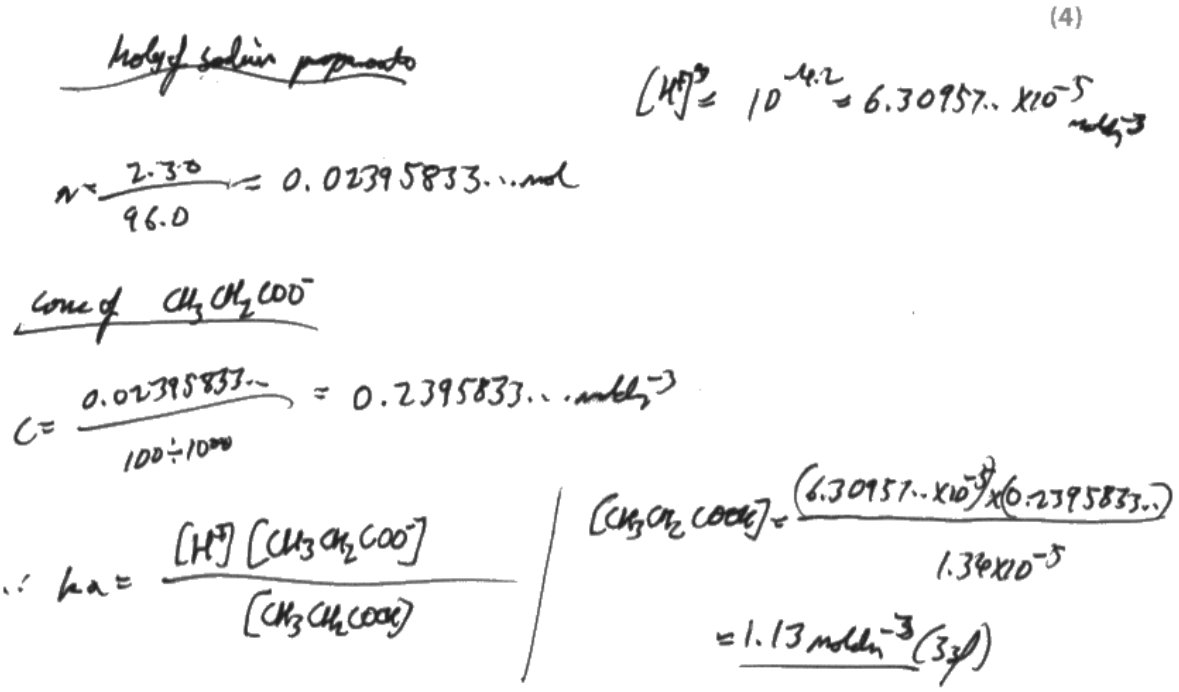
(d) A solution containing propanoic acid and sodium propanoate forms a buffer.

(i) 2.30 g of sodium propanoate is dissolved in propanoic acid solution.
This forms a buffer with pH = 4.2 and a volume of exactly 100 cm^3.

Calculate the concentration of the propanoic acid, in mol dm^{-3}, in this buffer.

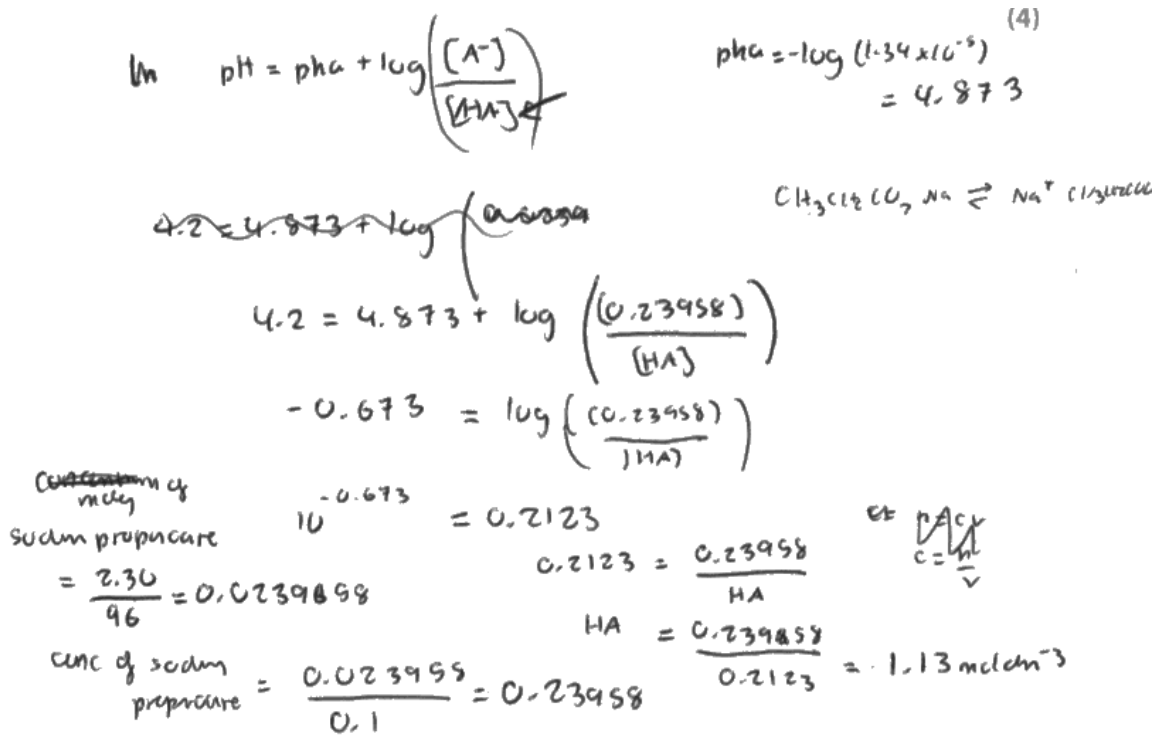
[K_a (propanoic acid) = 1.34×10^{-5} mol dm^{-3} $M_r(CH_3CH_2CO_2Na) = 96.0$]

(4)



ResultsPlus
Examiner Comments

This is an example of a fully correct response scoring all four marks.



ResultsPlus
Examiner Comments

This is an example of a completely correct calculation using the Henderson-Hasselbalch equation which scored four marks.

ResultsPlus
Examiner Tip

If you are going to use the Henderson-Hasselbalch calculation for buffers, make sure that you are using the correct equation as it is easy to make a slip.

(d) A solution containing propanoic acid and sodium propanoate forms a buffer.

(i) 2.30 g of sodium propanoate is dissolved in propanoic acid solution.
This forms a buffer with pH = 4.2 and a volume of exactly 100 cm^3.

Calculate the concentration of the propanoic acid, in mol dm^{-3}, in this buffer.

[K_a (propanoic acid) = 1.34×10^{-5} mol dm^{-3} $M_r(CH_3CH_2CO_2Na)$ = 96.0] (4)

$\frac{2.30}{96} = 0.02395...$ mol propanoate ions

$1.34 \times 10^{-5} = \frac{[10^{-4.2}][0.02395...]}{[CH_3CH_2COOH]}$

$[CH_3CH_2COOH] = \frac{10^{-4.2} \times 0.02395...}{1.34 \times 10^{-5}}$

$= 0.113$ mol dm^{-3} (3 s.f.)

ResultsPlus
Examiner Comments

This answer scored three marks. The candidate has used the moles of salt rather than the concentration and so their final answer is out by a factor of 10. Everything else is correct as a transferred error (TE).

ResultsPlus
Examiner Tip

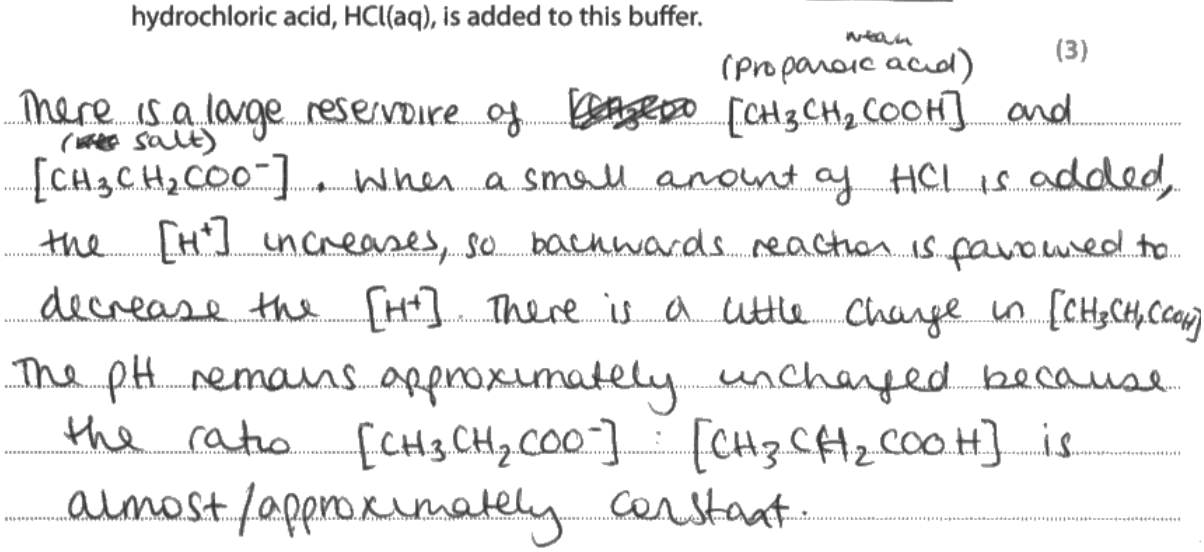
Set out calculations carefully and check at each stage.

Question 8(d)(ii)

This question required candidates to be able to articulate how a buffer works in general terms and to apply it to the buffer solution in the question. The most commonly awarded mark was M2 via the additional guidance route of the equilibrium moving to the left accompanied by a correct equation or explanation. Many candidates omitted to mention the large reservoir of the sodium propanoate (and propanoic acid) that would be fundamental to the action of this buffer. Even fewer scored M3 to note the ratio of the acid: salt would remain nearly constant.

(ii) Explain why there is no significant change in pH when a small amount of hydrochloric acid, HCl(aq), is added to this buffer.

(3)



ResultsPlus
Examiner Comments

This is an excellent answer with all three marks awarded.

ResultsPlus
Examiner Tip

Ensure that you understand how a buffer works as then it is easy to apply your knowledge to any buffer action.

(ii) Explain why there is no significant change in pH when a small amount of hydrochloric acid, HCl(aq), is added to this buffer.

$CH_3CH_2COOH \rightarrow CH_3COO^- + H^+$ (3)

H^+ of HCl reacts with large reservoir of $CH_3CH_2COO^-$ to form CH_3CH_2COOH so ~~reaction shift~~ equilibrium shifts to the left to increase reactants of CH_3CH_2COOH to overcome ~~acidic~~ H^+ ions increasing acidity. So there is a large reservoir of CH_3COO^- and CH_3COOH ions to resist changes in pH when H^+ added

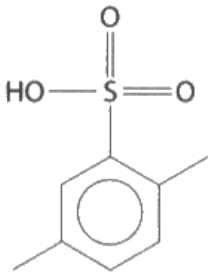
ResultsPlus
Examiner Comments

This scored two marks, M1 and M2. The candidate did not mention anything about the ratio of acid: salt and so M3 was not awarded.

Question 9(a)

This question required candidates to draw the reaction mechanism for the electrophilic substitution of 1,4-dimethylbenzene to form 2,5-dimethylbenzenesulfonic acid. Many candidates scored at least two points for the correct first steps (the arrow from inside the hexagon to the sulfur atom, and the partial charges on the S and O). Some candidates omitted the methyl groups on the intermediate which cost them a point, but many added the correct lone pair and negative charge to the oxygen. Occasionally the arrow to form the lone pair of the oxytem to the hydrogen was missing, but the final arrow showing the return of the C - H bond pair towards the ring was often shown.

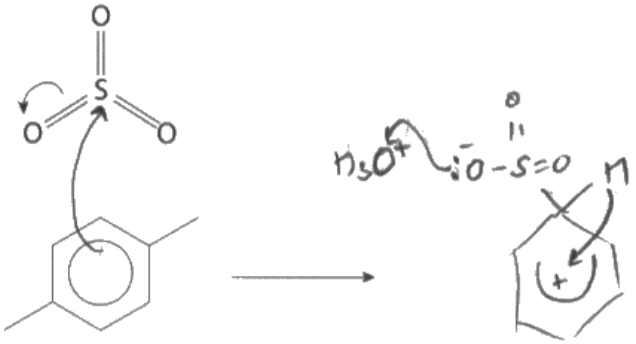
9 This question is about the compound 2,5-dimethylbenzenesulfonic acid, which has the structure shown.



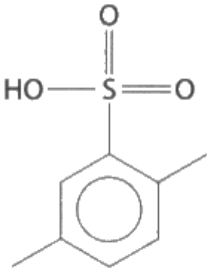
It is used to analyse levels of cholesterol in blood plasma. It can be synthesised by the reaction of 1,4-dimethylbenzene with concentrated sulfuric acid. The electrophile in this reaction is sulfur trioxide.

(a) Complete a possible mechanism for this reaction by adding curly arrows, and any relevant dipoles, charges and lone pairs.

(3)



structure of intermediate



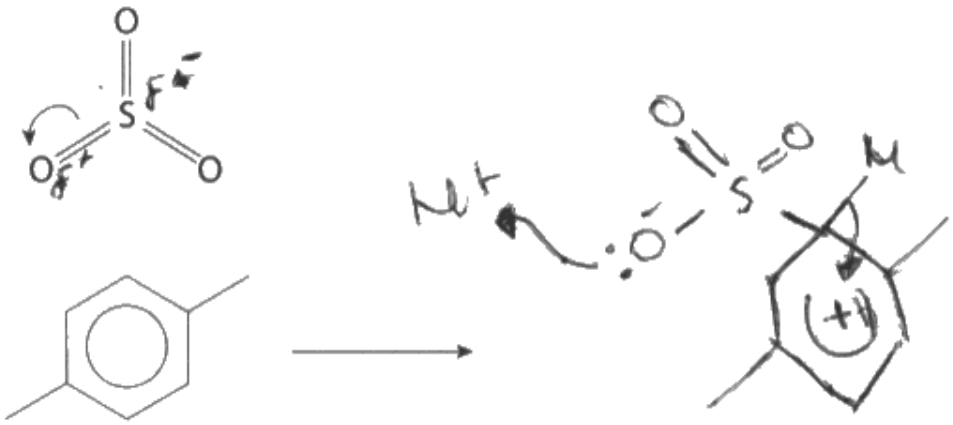
ResultsPlus
Examiner Comments

This scored one mark, for 3 correct points.

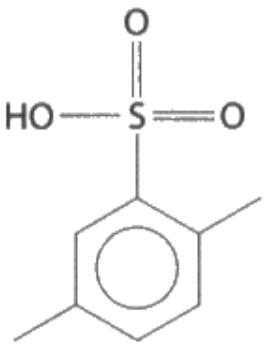
The arrow from inside the hexagon to the sulfur atom was correct, scoring P1. There was no dipole on the S and O and so no P2. The intermediate, whilst showing the correct broken hexagon and charge, was missing the methyl groups and so no P3. The lone pair and charge on the oxygen were shown so P4 was awarded. There was a arrow from the lone pair oxygen but it went to the 'O' on water and so no P5. There was an arrow showing the return of the C-H bond pair towards the ring so P6 was awarded.

ResultsPlus
Examiner Tip

Check all molecules for additional groups when you are copying them across.



structure of intermediate



ResultsPlus
Examiner Comments

This scored two marks for 4 correct points.

The first points were not awarded, as there was no arrow from inside the hexagon to the sulfur atom and the dipole on the S and O is the wrong way round. Everything else is correct.

Question 9(b)(i)

This question should have been straightforward for candidates that have a good understanding of how recrystallisation works and so could explain each step in the process. However, many gave answers that showed a level of confusion. This technique could have been broken down into:

- M1: both the acid and the impurities dissolving in the hot solvent.
- M2: the acid being insolube on cooling, with the impurities staying in solution.
- M3: the impurities being filtered off and the acid recrystallising.

It would be of benefit for candidates preparing for examinations to review the practical procedure (which is part of Core Practical 16, the preparation of aspirin) and ensure that they can describe and explain each step clearly.

(b) The 2,5-dimethylbenzenesulfonic acid formed can be purified by recrystallisation using hot water as a solvent.

Procedure

Step **1** Dissolve impure 2,5-dimethylbenzenesulfonic acid in the minimum volume of hot water.

Step **2** Allow the solution to cool until 2,5-dimethylbenzenesulfonic acid has crystallised.

Step **3** Separate the 2,5-dimethylbenzenesulfonic acid by filtering under reduced pressure.

Step **4** Rinse the 2,5-dimethylbenzenesulfonic acid using a small amount of ice-cold water.

Step **5** Dry the 2,5-dimethylbenzenesulfonic acid between two pieces of filter paper.

(i) Explain how recrystallisation reduces the amount of **soluble** impurities.

(3)

– Adding hot water dissolves impure ~~2,5-dimethyl~~ 2,5-dimethylbenzenesulfonic acid and other soluble impurities
– The acid is insoluble in cold water therefore crystallises, but soluble impurities remain dissolved
– The acid is filtered, the acid crystals remain on filter paper while soluble impurities ~~of~~ do not, the crystals are then rinsed in cold water to remove excess soluble impurities

ResultsPlus
Examiner Comments

This response scored all three of the marks for a clear explanation of each step.

Dissolving the impure 2,5-dimethylbenzenesulfonic acid in minimum volume of hot water dissolves the soluble impurities but ensures the crystals don't fully dissolve. Filtering under reduced pressure means soluble impurities accumulate in the flask and can be discarded.

ResultsPlus
Examiner Comments

This did not score any marks.

For M1 the candidate needed to state that both the acid and the impurities dissolve in the hot water. They did not mention anything about the cooling step and so no M2. They mentioned that the soluble impurities would pass through the filter, but did not state that the acid would remain on the filter paper so no M3.

ResultsPlus
Examiner Tip

Recrystallisation is a commonly used procedure and it is important that you can explain the steps clearly.

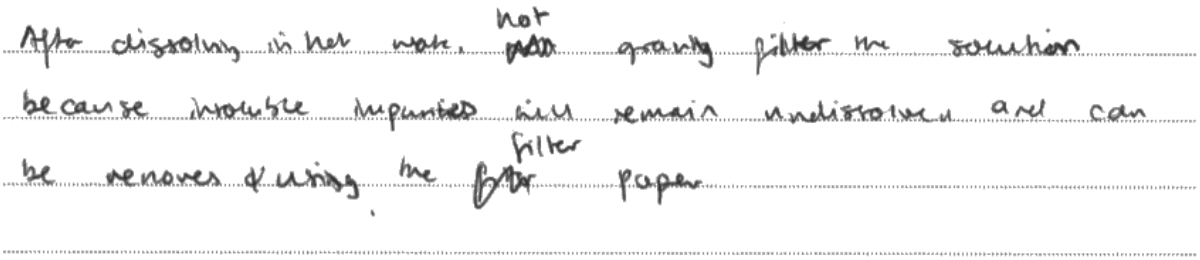
Question 9(b)(ii)

Candidates found this question about modifying the procedure quite challenging. However, some completely correct answers were seen, showing that some candidates were able to apply their knowledge in an unfamiliar situation. They needed to state that to remove these soluble impurities they needed to carry out a filtration step when the solution was still hot, before cooling in step 2.

(ii) A student carrying out this procedure noticed some **insoluble** impurities in their sample.

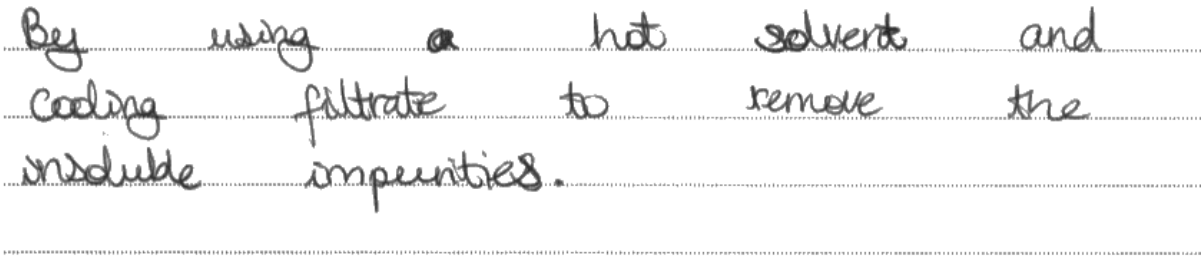
Describe how the procedure should be amended to remove these insoluble impurities.

(2)



ResultsPlus
Examiner Comments

This is a fully correct answer scoring both marking points.

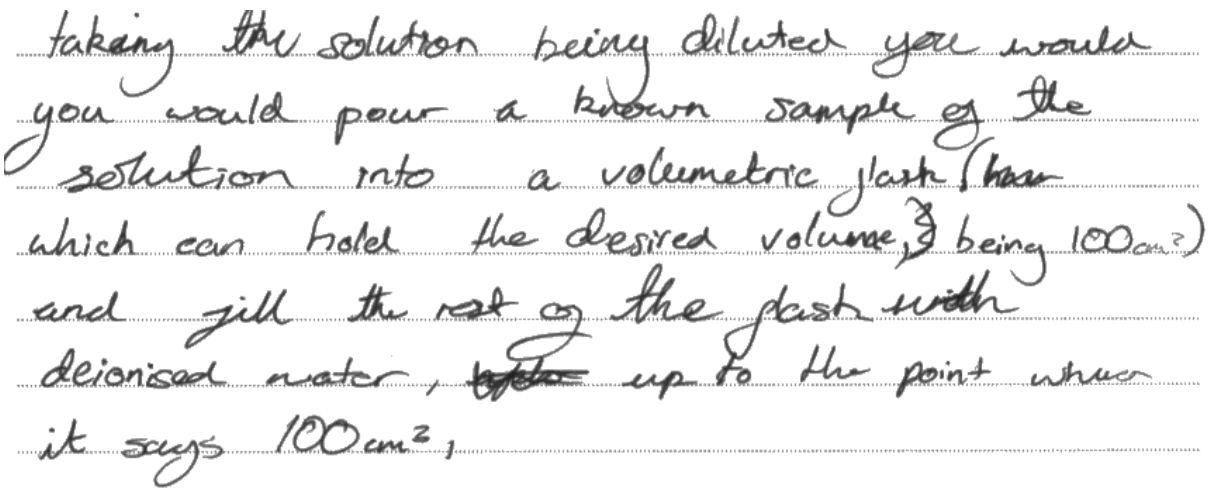


ResultsPlus
Examiner Comments

This was too vague to score and so no marks were awarded.

Question 9(c)(i)

This was an accessible question where candidates had to describe how to make up a standard solution, including a dilution. Many good answers were seen. The most common mark which was missed was to invert the volumetric flask at the end to mix the solution. It should be noted that in the correct practical procedure, the flask is not actually shaken, and so this was not allowed for M4.



ResultsPlus
Examiner Comments

This candidate has included the essential points to be awarded two marks. They have used the correct volume of volumetric flask and described adding 100cm^3 of deionised water to the flask up to the mark. They have omitted the step of adding the washings and also have not mentioned inverting the flask.

(c) The hydrated form of the acid has the formula $C_6H_3(CH_3)_2SO_3H \cdot nH_2O$.
An experiment was carried out to determine the number of moles of water of crystallisation, n, in this formula.

The method involves adding excess sodium hydroxide to a known mass of the hydrated 2,5-dimethylbenzenesulfonic acid.
The amount of unreacted sodium hydroxide is then determined by titration.

Procedure

Step **1** 10.0 cm^3 of 1.00 mol dm^{-3} NaOH(aq) was added to 1.60 g of hydrated 2,5-dimethylbenzenesulfonic acid in a small conical flask.

Step **2** The solution formed was diluted to give a volume of exactly 100 cm^3.

Step **3** 20.0 cm^3 samples of the diluted solution required a mean titre of 22.40 cm^3 of 0.02500 mol dm^{-3} HCl(aq) to neutralise the unreacted sodium hydroxide present in the sample.

(i) Describe how to make the diluted solution, in Step **2**.

(4)

ensure that all the known amount of acid and NaOH are fully mixed by using a glass rod then transfer it into a volumetric flask ensuring that you add washings into the beaker and transfer them into the flask, then while using deionised water fill the flask to 100cm^3 ensuring that the bottom of the miniscus is directly on the line, then invert the flask with a lid to mix the contents fully.

ResultsPlus
Examiner Comments

This is a fully correct answer scoring all four marks.

ResultsPlus
Examiner Tip

Make sure that you are familiar with all of the methods in the Core Practicals. This is included in Core Practical 2.

Question 9(c)(ii)

This was a calculation question worth five marks. Many candidates successfully scored M1, M2 and M3. However, after that some lost their way and were unable to calculate the moles of the acid. This then led them to an incorrect M_r and hence an incorrect value of 'n'. It was possible to be awarded marks as a transferred error at each stage, which allowed candidates to gain additional marks for their method. There were some slips in the calculation of the M_r of the formula of the acid, with some missing off the final 'H' and arriving at 185.1 instead of 186.1. It should also be noted that water of crystallisation should be an integer, and so the final answer needed to be rounded to the nearest whole number.

(ii) Calculate the relative formula mass of hydrated 2,5-dimethylbenzenesulfonic acid and hence deduce the value of n.

(5)

n of (HCl) 20cm³ = CV = $0.025 \times 22.4 \times 10^{-3} = 5.6 \times 10^{-4}$ mol

n of (HCl) 100 cm³ = $5.6 \times 10^{-4} \times 5 = 2.8 \times 10^{-3}$ mol

n of (NaOH) unreacted = 2.8×10^{-3} mol

n of (NaOH) total = $CV = 1 \times 10 \times 10^{-3} = 0.01$ mol

n of (NaOH) reacted = $0.01 - 2.8 \times 10^{-3} = 7.2 \times 10^{-3}$ mol

$Mr = \frac{m}{n} = \frac{1.60}{7.2 \times 10^{-3}} = 222.2$

As $C_6H_3(CH_3)_2SO_3H \cdot n H_2O$

Mr of $C_6H_3(CH_3)_2SO_3H = 6 \times 12 + 3 + 2 \times 12 + 6 + 32.1 + 3 \times 16 + 1 = 180.1$

Mr of $n H_2O = 222.2 - 180.1 = 36.1$

$\Rightarrow$ Mr of $H_2O = 2 + 16 = 18$ $\Rightarrow$ $2H_2O = 2 \times 18 = 36$.

$\Rightarrow n = 2$

ResultsPlus
Examiner Comments

This is an example of a well-laid out and fully correct answer.

ResultsPlus
Examiner Tip

Lay calculations out clearly so that if you make a slip you can track it.

$n(NaOH) = 0.01 \longrightarrow$ in $10cm^3$

$0.1 \longrightarrow$ in $100cm^3$

$n(HCl) = 5.6 \times 10^{-4} \rightarrow 20$

$2.8 \times 10^{-3} \rightarrow 100 cm^3$

~~$C_6H_3(CH_3)_2SO_3H \cdot nH_2O \rightarrow C_6H_3(CH_3)_2SO$~~

$C_6H_3(CH_3)_2SO_3H \cdot nH_2O \rightarrow C_6H_3(CH_3)_2SO_3H + nH_2O$

1.60

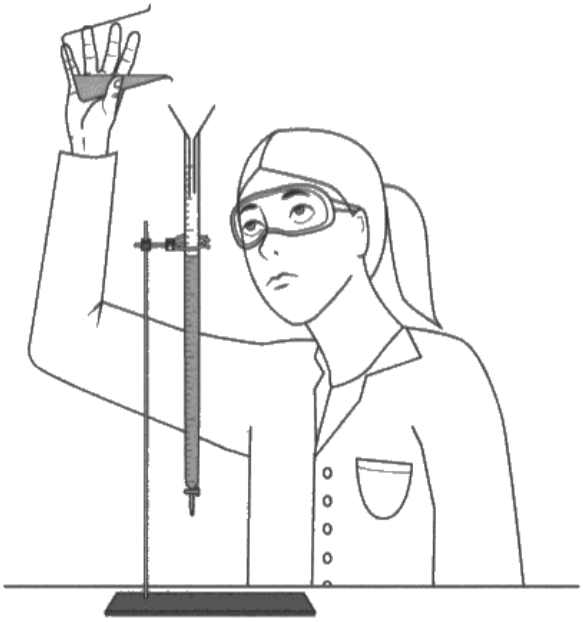
ResultsPlus
Examiner Comments

This response scored M1 and M2 but there was nothing else creditworthy.

Question 9(d)(i)

This should have been a straightforward question about safety in filling a burette. Most candidates gave an answer showing that they knew that the burette should be filled below eye level to avoid the acid splashing into their eyes as the safety glasses would not offer complete protection.

(d) A student carrying out this experiment used a funnel as shown to try to ensure the acid was added safely to the burette during the titration.



(i) Give **one** change to this technique that would reduce the risk to this student.

(1)

place burette lower or on floor when filling it up

ResultsPlus
Examiner Comments

This was an acceptable answer and scored the mark.

Put a beaker at the bottom to prevent spilling. Check if the valve is closed and the student should make sure they are going to pour directly into the funnel, stand on a chair.

ResultsPlus
Examiner Comments

There were many suggestions here, but none were creditworthy and so no mark was awarded.

Question 9(d)(ii)

This final question proved to be challenging. Nevertheless some candidates were able to follow through the logic of what would happen if some extra drops of acid dripped into the burette. For all marks to be awarded the candidate needed to state that the titre would be lower, that this would result in it appearing that there were more moles of the 2,5-dimethylsulfonic acid reacting, and so the M_r would appear smaller which would reduce the value of 'n'.

(ii) The student forgot to remove the funnel from the burette and during the titration five drops of acid from the funnel dripped into the burette.

Explain what effect, if any, this error will have on the final value for n.

(3)

cm^3 of Acid ↓ mean titre of HCl would be lower, so unreacted NaOH would be calculated to be lower. More NaOH would have reacted with acid so more moles of acid. M_r of acid would be smaller so n would be smaller as well.

ResultsPlus Examiner Comments

This is a fully correct answer scoring all three marks.

A few drops of acid increases the volume of acid in the burrette The initial reading will stay the same but the final value will be higher causing a lower titre A lower titre would decrease the calculated r.f.m and the calculated value of n

ResultsPlus Examiner Comments

This scored the first mark for the effect to reduce the titre. There was nothing else creditworthy.

Paper Summary

Based on their performance on this paper, candidates should:

- Be able to interpret data of first ionisation energy.
- Be able to explain how a buffer solution works.
- Draw accurate mechanisms for organic reactions, including features such as dipoles and curly arrows.
- Be able to explain how recrystallisation works.
- Learn the tests for inorganic ions and organic functional groups in the specification.
- Select appropriate scales for graphs so that they cover half of the graph paper in each direction.
- Practise drawing titration curves.
- Check all calculations and do not leave expressions unevaluated.
- Use correct vocabulary when describing species (atom, ion, molecule, etc).

Grade boundaries

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