Examiners' Report
June 2015

IAL Chemistry WCH03 01

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Introduction

The paper contained many straightforward questions but also some challenging ones. Candidates were often well prepared for the types of questions which look familiar, but when a question is asked in a new way they need to read it carefully and not assume that it is exactly the same as an example they have seen previously.

Most candidates were familiar with the results of tests on ionic compounds and simple reactions of organic compounds. However understanding of organic chemistry was not as good; one weakness was in understanding how spectroscopy is used. The information that could be obtained from mass spectra and infrared spectra was not known. Also many candidates were not familiar with the processes used to prepare an organic compound. There were many correct answers to numerical questions, though examiners often found it difficult to follow the working, and it is evident that few candidates are clear in their mind about what is an appropriate number of significant figures to use.

Question 1 (a) (i)

The question asked for the name **or** formula of the cation causing a persistent yellow flame. If candidates give both a name and a formula, then both must be correct ie the sodium ion and Na^+. In some answers the name did not match the formula, but the more common error was to show an incorrect charge on Na.

Answer ALL the questions. Write your answers in the spaces provided.

1 (a) A series of tests is carried out on a white solid, **X**, which contains one cation and one anion.

Complete the table below.

	Test	Observation	Inference (Name or formula)	
(i)	Carry out a flame test on **X**	A persistent yellow colour	The cation in **X** is Sodium ion (Na^+)	(1)

ResultsPlus
Examiner Comments

This answer is correct but either name or formula would have been enough.

ResultsPlus
Examiner Tip

It is best to avoid giving alternative answers as if one is incorrect you will lose the mark.

Question 1 (a) (ii)

As in the previous question, if both a name and a fomula are given then both must be correct. The best advice for candidates is to give the answer about which they are most confident, and not give two possibilities.

The most common mistakes here were to give the formula CO_3 without a charge, or to give the name of the gas causing the effervescence (carbon dioxide).

(ii)	Add dilute hydrochloric acid to the solid **X**	Effervescence		
	Bubble the gas given off into limewater	The limewater turns cloudy	The anion in **X** is CO_3	(1)

ResultsPlus
Examiner Comments

The formula of an ion must include the charge.

Question 1 (a) (iii)

Most answers attempted the equation for the reaction between carbon dioxide and lime water.

Many candidates failed to follow the instruction to include state symbols and, when they were included, common mistakes were to use the symbol (l) for lime water and (aq) for water. Lime water turns cloudy when calcium carbonate forms, so the equation showing the formation of soluble calcium hydrogencarbonate was not allowed.

(iii) Write a balanced equation, including state symbols, for the reaction between the gas formed in the reaction in (a)(ii) and limewater (calcium hydroxide solution).

(2)

$Ca(OH)_{2(aq)} + CO_{2(g)} \longrightarrow CaCO_{3(aq)} + H_2O_{(l)}$

ResultsPlus
Examiner Comments

This candidate has made another common error which is to give the state symbol for calcium carbonate as (aq).

Question 1 (b) (i)

A number of different colours to describe the strontium flame were allowed and most candidates scored this mark.

(b) Another white solid, **Y**, also contains one cation and one anion.

Complete the table below.

	Test	Observation	Inference	
	Test	Observation	Inference	
(i)	Carry out a flame test on **Y**	Crimson ppt ~~the~~ forms	Strontium ions are present	(1)

ResultsPlus

Examiner Comments

The flame test does not involve mixing solutions so the formation of a precipitate was not allowed.

Question 1 (b) (ii)

The correct answer was a white precipitate or white solid. Again, candidates often lose the mark by adding extra information which is incorrect. The mark was given for the correct observation, and if only the name of the precipitate was given, it did not score.

(ii)	Add dilute nitric acid and dilute aqueous silver nitrate to a solution of **Y**	white percipitate dissolves	The anion in **Y** is probably a chloride	(1)

ResultsPlus
Examiner Comments

This implies that a precipitate forms and then dissolves without anything else being added, so it was not allowed.

(ii)	Add dilute nitric acid and dilute aqueous silver nitrate to a solution of **Y**	A silver chloride is seen.	The anion in **Y** is probably a chloride	(1)

ResultsPlus
Examiner Comments

This does not describe what is observed, so did not get the mark.

Question 1 (b) (iii)

The only silver halide precipitate which is soluble in **dilute** ammonia is silver chloride, so if the answer was for a further test using ammonia it had to be dilute.

Concentrated sulfuric acid could be used to confirm that the precipitate was a chloride, but if the acid is added to the mixture it will be diluted and steamy fumes will not be seen.

(iii) A further test is carried out on the mixture formed in (b)(ii). This confirms that **Y** contains chloride ions, and **not** bromide or iodide ions.

Describe this test and give the result.

(2)

Test The test is that in the white ppt dilute ammonia is added.

Result The result ~~not~~ will be the white ppt turns colourless ~~Eet~~. or the white colour disappears

(ii)	Add dilute nitric acid and dilute aqueous silver nitrate to a solution of **Y**	White ~~pr~~ precipitate is formed	The anion in **Y** is probably a chloride	(1)

ResultsPlus

Examiner Comments

The correct test is used here, but the result implies that the precipitate remains with a change in colour. For the mark to be scored it must state that the precipitate dissolves or the precipitate disappears.

(ii)	Add dilute nitric acid and dilute aqueous silver nitrate to a solution of **Y**	a white precipitate forms.	The anion in **Y** is probably a chloride	(1)

(iii) A further test is carried out on the mixture formed in (b)(ii). This confirms that **Y** contains chloride ions, and **not** bromide or iodide ions.

Describe this test and give the result.

(2)

Test Add concentrated sulphuric acid to the mixture

Result Acidic white steamy fumes of HCl are given off.

ResultsPlus

Examiner Comments

The concentrated sulfuric acid reacts with solid silver chloride, so in practice the precipitate would have to be filtered off. This is why the mark for the test required that the concentrated sulfuric acid was added to the precipitate, not to the entire mixture.

Question 1 (b) (iv)

This was well answered, and a number of different descriptions for the observation were allowed. The answer that a silver mirror formed, or the white precipitate changed to a silver colour were not allowed.

The product causing the precipitate to look darker is silver, and candidates who said that silver and chlorine formed were not very clear which substance caused the colour change. Some candidate answered "ultraviolet light" on the product line, and though this causes the decomposition it is not produced.

(iv) What would you observe when the mixture formed in (b)(ii) is left to stand in sunlight?

Name the **product** responsible for this observation.

(2)

Observation The products explode.

Product ~~Silver~~ ~~and~~ chlorine and silver

ResultsPlus
Examiner Comments

Explosions feature quite frequently in answers to chemical questions though very rarely in school laboratories.

This candidate realised that silver formed, but unfortunately included the chlorine as well so neither mark was given.

(iv) What would you observe when the mixture formed in (b)(ii) is left to stand in sunlight?

Name the **product** responsible for this observation.

(2)

Observation It darkens.

Product Chlorine.

ResultsPlus
Examiner Comments

Saying that the precipitate darkens scored the first mark. Chlorine forms when the precipitate decomposes but it is not the product responsible for the colour change.

Question 1 (c)

Candidates had to deduce that the ions reacting to form the precipitate were strontium and carbonate, and not the other ions present which were sodium and chloride.

Many candidates wrote a full equation and then deduced the ionic equation. This was accepted as being use of rough work, though as a general rule two different answers are not allowed. However some candidates stopped after the full equation and did not attempt an ionic one. Quite a few answers showed the sodium ion reacting with the chloride ion. Other common errors had to do with the charge on the strontium ion and the formula of strontium carbonate.

(c) When aqueous solutions of **X** and **Y** are mixed, a white precipitate forms.

$NaCO_3$ $Sr(Cl)_2$

Write an **ionic** equation for the reaction which produces the white precipitate. State symbols are not required.

(1)

$$Sr^{2+} + CO_3^{2-} + OH^- + H^+ \longrightarrow SrCO_3 + H_2O$$

ResultsPlus

Examiner Comments

Spectator ions, which in this case are Na^+ and Cl^- should not be included in the final ionic equation. In this case the hydrogen and hydroxide ions should not have been shown.

Question 2 (a)

The most common answer was to test with phosphorus pentachloride, resulting in the formation of steamy or misty fumes. The description of the fumes as steamy or misty is recommended, as candidates often confuse the appearance of hydrogen chloride and ammonium chloride. The latter is a dense white smoke made of solid particles. Use of potassium pentachloride was a surprisingly common error.

An alternative test was the use of sodium producing effervescence. Just saying that the sodium dissolved is not a precise test for an -OH group and was not accepted here.

When tests are carried out in a laboratory, observations are made, so these had to be given and just giving the name of the product was not allowed. Some candidates describe a test for the product of the reaction, but this is not enough without saying what happens in the test.

2 An organic compound, **Z**, has only one –OH group.

(a) State the test which confirms the presence of an –OH group and give the result of a positive test.

(2)

Test Add sodium

Result Hydrogen bubbles produced, sodium dissolves and a white solid forms.

ResultsPlus

Examiner Comments

This scored both marks. In giving the result, the important word was "bubbles" as this is what would be observed.

2 An organic compound, **Z**, has only one –OH group.

(a) State the test which confirms the presence of an –OH group and give the result of a positive test.

(2)

Test Addition of phorphorous (v) chloride ~~and test gas with~~

Result gas evolved turns damp blue litmus paper red

ResultsPlus

Examiner Comments

This describes how to test the gas evolved, but does not say what the person carrying out the experiment would see before testing for the gas.

Question 2 (b)

Many candidates correctly named the two series as alcohol and carboxylic acid. Primary, secondary **or** tertiary alcohols were acceptable answers but not primary **and** secondary alcohols as their general formulae are the same. General formulae such as RCOOH and $C_nH_{2n+1}OH$ for the two series were allowed but not formulae of any one compound in each series. Some candidates gave the answer -COOH and -OH which did not get the mark as, though they probably knew one series was carboxylic acids, they had not given any information about the -OH.

(b) Name **two** series of organic compounds, with different general formulae, each of which has one –OH group.

(1)

Primary alcohols and Secondary alcohols

ResultsPlus
Examiner Comments

This was a common error which was not allowed as the two general formulae are the same.

(b) Name **two** series of organic compounds, with different general formulae, each of which has one –OH group.

(1)

carboxylic acids and diols

ResultsPlus
Examiner Comments

The question asked for series with one -OH group, so diols were not allowed.

Question 2 (c)

The final identification of the **tertiary** alcohol was deduced by most candidates and scored one mark. The second mark was for justifying their conclusion, but very few did this.

The responses to the test with litmus paper often simply said that **Z** was neutral, without any reference to the functional group it contained. Some candidates concluded that, as oxidation did not occur, the reagent could not be an alcohol at all. A deduction about the functional group could be made from each test, but sometimes contradictory answers were given, in which case a mark was lost.

(c) Neither red nor blue litmus paper changed colour when used to test an aqueous solution of **Z**. A different sample of **Z** was warmed with a mixture of aqueous potassium dichromate(VI) and sulfuric acid. No change was observed.

What can be deduced about the identity of the functional group in **Z** from each of these observations? Justify your answer.

(2)

Test with litmus paper

It's a neutral organic compound

Warming with aqueous potassium dichromate(VI) and sulfuric acid

It is a tertiary alcohol

ResultsPlus
Examiner Comments

This answer scored 1 mark for identifying the tertiary alcohol. However it did not justify why **Z** was said to be neutral and therefore not a carboxylic acid, nor was there any justification for the alcohol being tertiary.

(c) Neither red nor blue litmus paper changed colour when used to test an aqueous solution of **Z**. A different sample of **Z** was warmed with a mixture of aqueous potassium dichromate(VI) and sulfuric acid. No change was observed.

What can be deduced about the identity of the functional group in **Z** from each of these observations? Justify your answer.

(2)

Test with litmus paper

It is not a carboxylic acid (doesn't have -COOH) as it is not an acid and doesn't change the colour of litmus paper.

Warming with aqueous potassium dichromate(VI) and sulfuric acid

It is a tertiary alcohol as they do not undergo oxidation with acidified potassium dichromate (VI). ~~This is not~~ (Not secondary or primary alcohol)

ResultsPlus

Examiner Comments

This is an example of a good answer. In (b) the compound was recognised to be a carboxylic acid or an alcohol, and here it was identified as a tertiary alcohol using justification from each test.

Question 2 (d)

This question was often poorly answered. Many candidates scored only the first mark for the number of moles of carbon dioxide produced. A significant number then went on to calculate the mass of the gas, concluding there were **5** carbon atoms, or did an Avogadro constant calculation for the number of carbon atoms in one mole of **Z**.

Those who drew the structure, despite having the correct molecular formula, failed to use the evidence of previous part of the question, producing the **primary** alcohol.

(d) **Z** was investigated by measuring the volume of carbon dioxide formed on complete combustion.

A sample of 0.10 mol of **Z** produced 9.6 dm^3 of carbon dioxide.

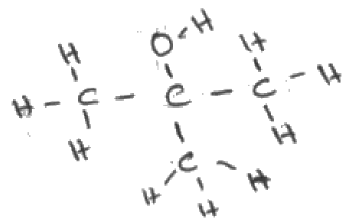
Under the conditions of the experiment, the molar volume of a gas is 24 dm^3 mol^{-1}.

Use this information to calculate the number of carbon atoms in one molecule of **Z**. Use the result of your calculation and your deduction in (c) to draw the displayed formula of **Z**. Show your working.

(3)

no of moles of carbon dioxide $= \frac{9.6}{24} = 0.4$ moles

no of carbon atoms $= \frac{0.4}{0.1} = 4$ atoms



ResultsPlus
Examiner Comments

This is an example of a good answer and it is pleasing to see a calculation where there is an indication what each number refers to. The formula is fully displayed and the bonds from the central carbon atom go to the correct atoms rather than going roughly in the direction of a group.

(d) **Z** was investigated by measuring the volume of carbon dioxide formed on complete combustion.

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Under the conditions of the experiment, the molar volume of a gas is 24 dm³ mol⁻¹.

Use this information to calculate the number of carbon atoms in one molecule of **Z**. Use the result of your calculation and your deduction in (c) to draw the displayed formula of **Z**. Show your working.

(3)

$\text{mol} = \frac{\text{vol}}{\text{mol vol}} = \frac{9.6}{24} = 0.4$ mol of CO_2.

CO_2

↑

3 atoms.

~~0.4 x 6.0~~

Ratio 0.1 : 0.4

$0.4 \times 6.023 \times 10^{23} = \boxed{2.4092 \times 10^{23}}$

$\frac{2.4092 \times 10^{23}}{3} = \boxed{8.03067 \times 10^{22}}$ carbon atoms.

ResultsPlus

Examiner Comments

This candidate scored the first mark only and then failed to realise that the number of carbon atoms per molecule, not per mole of **Z** was needed.

ResultsPlus

Examiner Tip

Read the question carefully! Once you know how many C atoms are in each molecule you can deduce the formula of the compound.

The Avogadro constant calculation shown here does not help to find a formula, so the next step is to go back and read the question again.

Question 2 (e)

This question showed that many candidates are unsure how to use data from spectroscopy.

Answers about mass spectra were often poorly expressed. A frequent wrong response was to refer to the *m/e* of the highest peak, which is not necessarily the same as the peak with the highest *m/e* value. The term molecular peak was rejected as it should have stated molecular **ion** peak. Many candidates thought that isomers would have the same fragments, and some candidates were thinking about the mass spectrum of an element and wrote about the relative abundance of each fragment.

Use of infrared spectroscopy should have been simple, as the only requirement was to say that both isomers would have an absorption peak at a value corresponding to the -OH group, but many answers were very vague just saying that the same peaks would occur, or that broad peaks would be present.

(e) **Z** has several isomers, only some of which contain an –OH group.

(i) Give **one** piece of evidence from their mass spectra which would show that two compounds could be isomers.

(1)

~~A peak at the OH group~~. Both mass spectras would have the same value for the highest peak.

(ii) How could infrared spectroscopy be used to show that two isomers of **Z** both have an –OH group? You are not required to give wavenumber values.

(1)

It would show similar peaks (wavenumber values) for both which signifies that they have a similar functional group

(Total for Question 2 = 10 marks)

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Examiner Comments

Neither mark was awarded here.

The highest peak in the mass spectrum is not necessarily the peak of the molecular ion, so the first mark was lost.

The peaks in an infrared spectrum indicate which bonds are present, so for example there could be C-H stretches and C-O stretches which are at similar wavenumbers without the two compounds having -OH groups.

(e) **Z** has several isomers, only some of which contain an –OH group.

(i) Give **one** piece of evidence from their mass spectra which would show that two compounds could be isomers.

(1)

The highest m/e peak will be the same for both the isomers.

(ii) How could infrared spectroscopy be used to show that two isomers of **Z** both have an –OH group? You are not required to give wavenumber values.

(1)

Both of the isomers will ~~a~~ have a broad OH stretching peak.

ResultsPlus
Examiner Comments

This is an example of an answer which scored both marks.

Question 3 (a) (i)

Most candidates scored the first mark, and if they included a sign here it was ignored.

The question asked for the final answer to be given to three significant figures. Candidates should be advised not to round numbers in early stages of their calculations as an answer of 1100 J at the first stage will lead to an incorrect final answer. They should use at least four significant figures and round to three at the final stage, and a mark was often lost due to early rounding or to an incorrect number of significant figures at the end. If the final answer is correct, examiners assume that the correct number of significant figures has been used, but if the value in the final answer is incorrect then earlier marks can only be scored where a sensible number of significant figures has been shown.

The second mark was for calculating the number of moles of ammonium chloride in 5.00g, and the final mark was for the enthalpy change with sign and unit. Many candidates did not understand that the energy transferred in an experiment with 5.00g ammonium chloride would not be the same as when 1 mol was used, and calculated the enthalpy change per mol by dividing the energy transferred in the experiment by 1.

Another very common error was to give a negative sign for the enthalpy change, even though there was a temperature drop.

3 This question is about enthalpy changes which occur on dissolving different substances.

(a) The enthalpy change which occurs when solid ammonium chloride, NH_4Cl, dissolves in water was found using the method below.

25.0 cm^3 of water was measured using a burette and put into a small beaker. The temperature of the water was measured.

5.00 g of powdered ammonium chloride was added to the water, the mixture was stirred continuously and the lowest temperature of the resulting solution was recorded.

Results:

Initial temperature of water = 22.0 °C

Lowest recorded temperature = 11.5 °C

(i) Calculate the energy transferred when 5.00 g of ammonium chloride dissolves in 25.0 cm^3 of water.

Hence calculate the enthalpy change, $\Delta H_{solution}$, which occurs when 1 mol of ammonium chloride dissolves in water.

Give your final answer to **three** significant figures and include a sign and units.

Use the equation:

Energy transferred (J) = mass of water × 4.18 × temperature change.

The density of water is 1.00 g cm^{-3}

(3)

(3)

$Q = M \times C \times \Delta T$

$25 \times 4.18 \times (22 - 11.5) = 1097.25\ J$

$\hookrightarrow \frac{1097.25}{1000} = 1.09725\ kJ.$

Molar mass NH_4Cl = 53.5.

Number moles = $\frac{5}{53.5} = 0.093$

$\left.\right\} \frac{1.09725}{0.093} = 11.74058$

$11.7\ kJ\ mol^{-1}$.

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Examiner Comments

This candidate has carried out the calculation correctly and the method is reasonably easy to follow. The answer scored 2 marks, as the sign is missing from the final answer.

ResultsPlus

Examiner Tip

If you are asked to include a sign in an answer you must do so, even for a positive number. This reaction is endothermic as the temperature dropped, so the sign of the enthalpy change is positive.

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5.00 g of powdered ammonium chloride was added to the water, the mixture was stirred continuously and the lowest temperature of the resulting solution was recorded.

Results:

Initial temperature of water = 22.0 °C

Lowest recorded temperature = 11.5 °C

↓ endo

(i) Calculate the energy transferred when 5.00 g of ammonium chloride dissolves in 25.0 cm^3 of water.

Hence calculate the enthalpy change, $\Delta H_{solution}$, which occurs when 1 mol of ammonium chloride dissolves in water.

Give your final answer to **three** significant figures and include a sign and units.

Use the equation:

Energy transferred (J) = mass of water × 4.18 × temperature change.

The density of water is 1.00 g cm^{-3}

(3)

$E = mc\Delta T$

$E = (30g)(4.18)(10.5°C)$

$E = 1316.7\,J = 1.32\,kJ$

moles of NH_4Cl = 0.093458

$E = \dfrac{1.32\,kJ}{0.093\,moles}$ = ~~1.32 kJ mol^-1~~ = +14.1 kJ mol^{-1}

ResultsPlus
Examiner Comments

This candidate has used the mass of 30g when calculating the energy transferred. As the final two stages of the calculation are correct the answer scored 2 marks.

ResultsPlus
Examiner Tip

Always read the information given in the question carefully, even if you think you know what to do.

The equation for the energy transferred was based on the mass of the water which is 25.00g and does not include the mass of the ammonium chloride.

Question 3 (a) (ii)

This question caused difficulty and often no marks were scored.

Candidates must realise that, to find an error in mass, two balance readings are needed, hence 0.005 x 2 is required in the calculation. The answer 0.1% appeared regularly.

For the second mark the answer had to make clear that the uncertainty in the balance reading is less than in the thermometer reading. It was not enough just to say that the uncertainty in the balance reading was very small. Frequently there was no comparison with the uncertainty associated with the thermometer.

A number of candidates thought they had to calculate a percentage error in the temperature measurement even though it was given in the question.

(ii) The thermometer used in this experiment gave a total uncertainty in the temperature measurement of just under ±5%.

The mass of ammonium chloride was measured using a balance which had an uncertainty of ±0.005 g in each reading.

Show by calculation that the uncertainty of the result of the experiment would not be improved significantly if a more precise balance was used.

(2)

1) % error (ammonium chloride) = $100\,\% \times \frac{\pm 0.005}{5.00}$ =

= $\pm 0.001 \times 100\%$ =

= $\pm 0.1\,\%$

2) % error of the balance is smaller than the % error of the thermometer, therefore using a more precise balance would not make a big difference. It is not the main source of uncertainty.

ResultsPlus
Examiner Comments

This candidate has not used the factor of 2 in calculating the uncertainty in the mass. The second mark was awarded for a good comment, making a comparison of the two uncertainties.

(ii) The thermometer used in this experiment gave a total uncertainty in the temperature measurement of just under ±5%.

The mass of ammonium chloride was measured using a balance which had an uncertainty of ±0.005 g in each reading.

Show by calculation that the uncertainty of the result of the experiment would not be improved significantly if a more precise balance was used.

(2)

$\cancel{\frac{2 \times 0.005}{10.5} \times 100} =$

$\frac{2 \times 0.005}{5} \times 100 = 0.2\%$

~~⇒ small % uncertainty,~~

⇒ the % uncertainty is relatively small, meaning it would not affect the results.

ResultsPlus
Examiner Comments

This candidate scored the first mark for a correct calculation, but simply says the uncertainty is small. The answer does not make a comparison with the uncertainty in temperature measurement so does not score the second mark.

Question 3 (b) (iii)

This was well answered and candidates found many different ways of stating that the temperature of the water would need to be constant. However, a few thought that minerals in tap water would cause temperature changes.

Some referred to the need to know the initial temperature, without making it clear that this would have to be constant.

(iii) A student carried out the experiment using water from a tap. What is the purpose of measuring the temperature of the water at 0, 1 and 2 minutes from the time of starting the clock?

(1)

~~To measure the maximum temperature and~~

To compensate for heat ~~loses~~ losses

ResultsPlus
Examiner Comments

This is a common response in a question about temperature changes and suggests that the candidate did not actually think about this particular experiment. If the answer had been "to draw the first points on a graph which can be used to calculate heat loss" it could have been given the mark.

(iii) A student carried out the experiment using water from a tap. What is the purpose of measuring the temperature of the water at 0, 1 and 2 minutes from the time of starting the clock?

(1)

To make sure its temperature is in equilibrium with its surroundings.

ResultsPlus
Examiner Comments

This is typical of the answers which scored the mark.

Question 3 (b) (i)-(ii)

Candidates should have experience in estimating errors due to cooling by plotting temperature changes over ten minutes or more in an exothermic reaction. The reaction in this question was endothermic, so the surroundings would warm the mixture and the minimum temperature detected might therefore not be as low as it should be. The points should have shown a drop in temperature after the ammonium chloride was added and then an increase due to transfer of energy from the surroundings.

About half the candidates realised the reaction was endothermic and showed points on the grid with a temperature drop. However many candidates showed a reaction in which the temperature increased, and then fell due to cooling. These candidates could score the first mark in (i).

In (ii), the line through the points where warming occurred should have been extrapolated back to three minutes, and the maximum temperature change marked. Candidate who drew a cooling curve could still score here by extrapolating their cooling line back to three minutes.

Many candidates lost a mark by labelling the minimum temperature (or maximum in the case of a cooling curve) and not the temperature change.

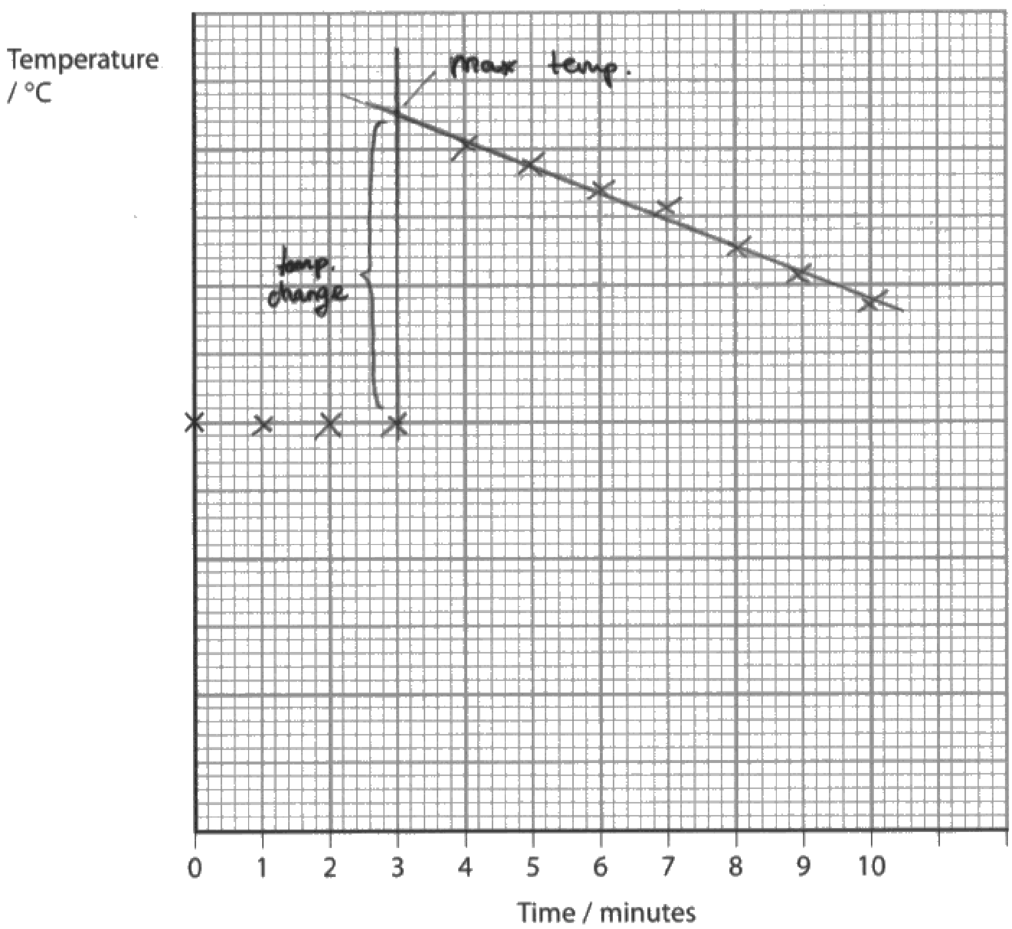
Some answers showed a lack of understanding of the method, with a distribution of points found in a thermometric titration.

(b) In order to determine a more accurate value for the temperature change, the experiment in (a) was repeated with some modifications to the procedure.

The temperature of the water was measured as a stop clock was started, and again after one minute and two minutes. Three minutes after starting the clock, the ammonium chloride was added to the water. The temperature was then read each minute from the fourth to the tenth minute, while stirring the mixture continuously.

(i) On the grid below, mark where you would expect to find the points when the temperature measurements are plotted against time. The initial temperature has been plotted for you. You are **not** expected to plot the position of the points accurately; simply indicate their approximate position relative to the starting point.

(2)



(ii) On the grid, draw the lines needed to determine the maximum temperature change. Add a label to show the maximum temperature change on the graph.

(2)

ResultsPlus
Examiner Comments

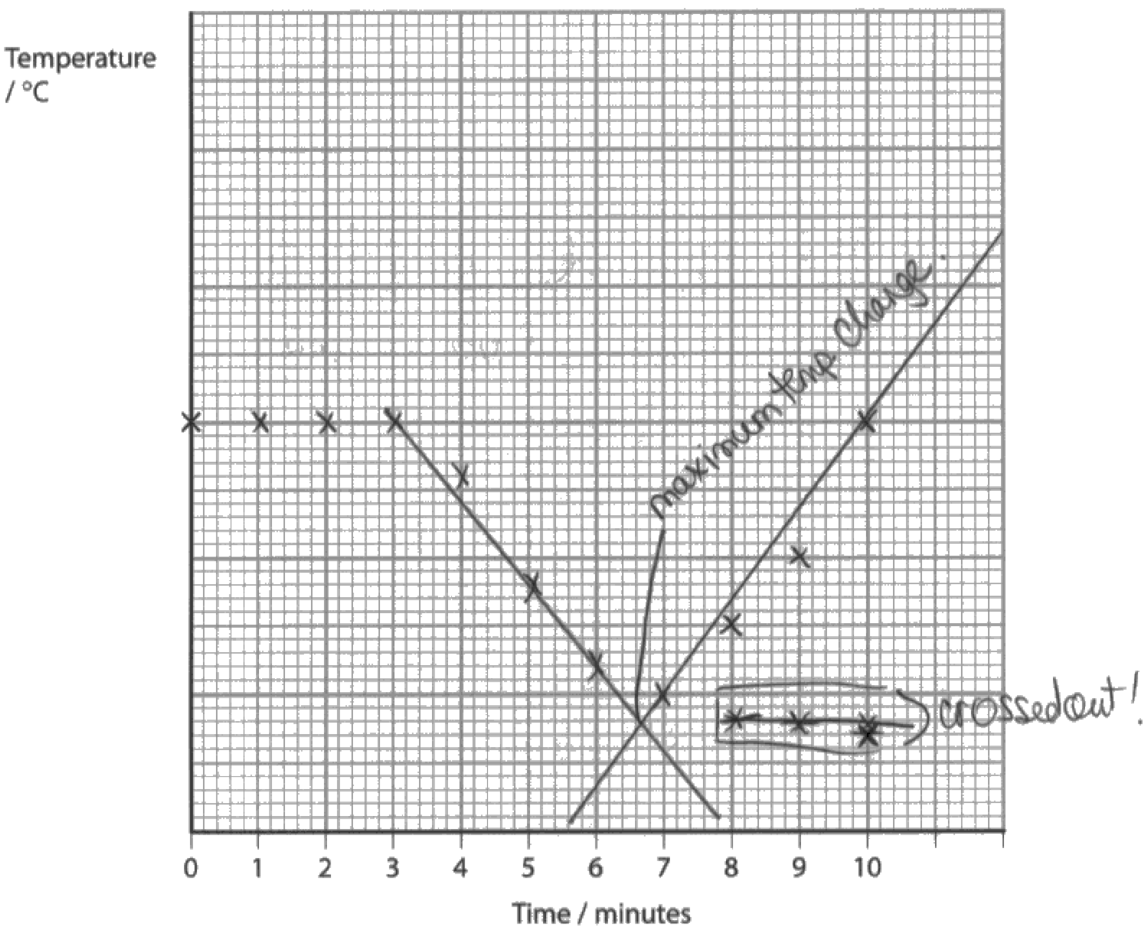
This answer scored only the first mark in (i) as it shows an exothermic reaction, but it continued logically from this and scored both marks in (ii).

(b) In order to determine a more accurate value for the temperature change, the experiment in (a) was repeated with some modifications to the procedure.

The temperature of the water was measured as a stop clock was started, and again after one minute and two minutes. Three minutes after starting the clock, the ammonium chloride was added to the water. The temperature was then read each minute from the fourth to the tenth minute, while stirring the mixture continuously.

(i) On the grid below, mark where you would expect to find the points when the temperature measurements are plotted against time. The initial temperature has been plotted for you. You are **not** expected to plot the position of the points accurately; simply indicate their approximate position relative to the starting point.

(2)



(ii) On the grid, draw the lines needed to determine the maximum temperature change. Add a label to show the maximum temperature change on the graph.

ResultsPlus
Examiner Comments

This scored both marks in (i) as an endothermic reaction was shown which began to warm up after a few minutes.

However it did not score in (ii) as the line was not extrapolated to 3 minutes, when the ammonium chloride was added. No temperature change was shown, only the minimum temperature.

Question 3 (c) (i)

This question was not well answered. Candidates did not realise the significance of the reaction being a thermal decomposition which requires the supply of heat, and most answers referred to the difficulty of finding the temperature of gaseous products which would escape. Many of those who did achieve the mark based their answer on the fact that the reaction was reversible.

Other errors were to say that the reaction was very hazardous, or that heat losses would occur.

(c) The equation for the thermal decomposition of ammonium chloride is shown below.

$$NH_4Cl(s) \rightarrow NH_3(g) + HCl(g)$$

(i) Suggest why the enthalpy change for this reaction, $\Delta H_{reaction}$, is difficult to determine directly by experiment.

(1)

Because both the products are in a gaseous state ~~[illegible]~~ and this reaction is reversible since $NH_{3(g)}$ reacts with $HCl_{(g)}$ to reform $NH_4Cl_{(s)}$.

ResultsPlus
Examiner Comments

This answer was allowed for the comment that the reaction is reversible.

(c) The equation for the thermal decomposition of ammonium chloride is shown below.

$$NH_4Cl(s) \rightarrow NH_3(g) + HCl(g)$$

(i) Suggest why the enthalpy change for this reaction, $\Delta H_{reaction}$, is difficult to determine directly by experiment.

(1)

Because of gas produced being toxic and hard to measure temperature change for gasses

ResultsPlus
Examiner Comments

This answer shows a very typical set of misconceptions.

Question 3 (c) (ii)-(iii)

Many candidates scored both marks in this question. Those who failed to do so often failed because they omitted one ΔH value, or had arrows going from the top right to bottom left box.

In (iii) the most common error was the reversal of the four ΔH signs.

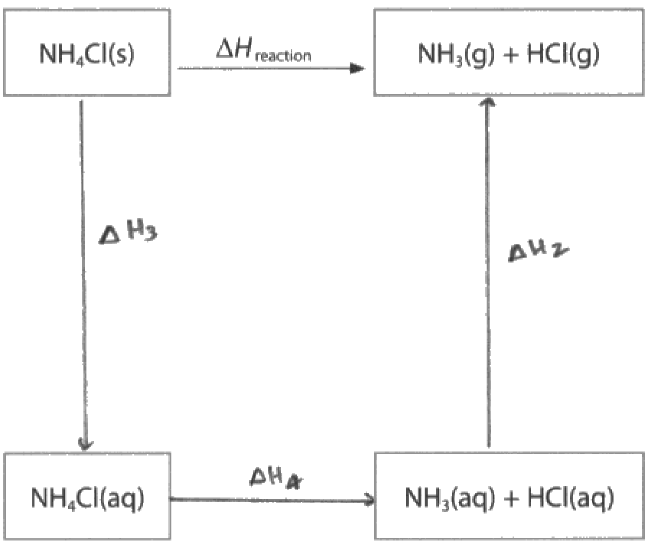
(ii) Some enthalpy changes which can be determined experimentally are listed below.

$NH_4Cl(s)$	+ water	$\rightarrow$	$NH_4Cl(aq)$	ΔH_1
$NH_3(g)$	+ water	$\rightarrow$	$NH_3(aq)$	ΔH_2
$HCl(g)$	+ water	$\rightarrow$	$HCl(aq)$	ΔH_3
$NH_3(aq)$	+ $HCl(aq)$	$\rightarrow$	$NH_4Cl(aq)$	ΔH_4

By adding arrows to the diagram below, construct a Hess cycle which can be used to calculate the enthalpy change, $\Delta H_{reaction}$, for the thermal decomposition of ammonium chloride.

Label each arrow with the appropriate symbol chosen from the list above for the enthalpy change. Assume that water is added where necessary to make a solution.

(1)



(iii) Give the expression for the enthalpy change, $\Delta H_{reaction}$, for the thermal decomposition of ammonium chloride, in terms of the other enthalpy changes in the cycle.

(1)

$\Delta H_{reaction} = \Delta H_2 + \Delta H_3 + \Delta H_4$

ResultsPlus

Examiner Comments

This candidate did not match the direction of the arrows to the chemical equations in the question. If a negative sign had been given in front of ΔH_2 and ΔH_4 the cycle would have been correct.

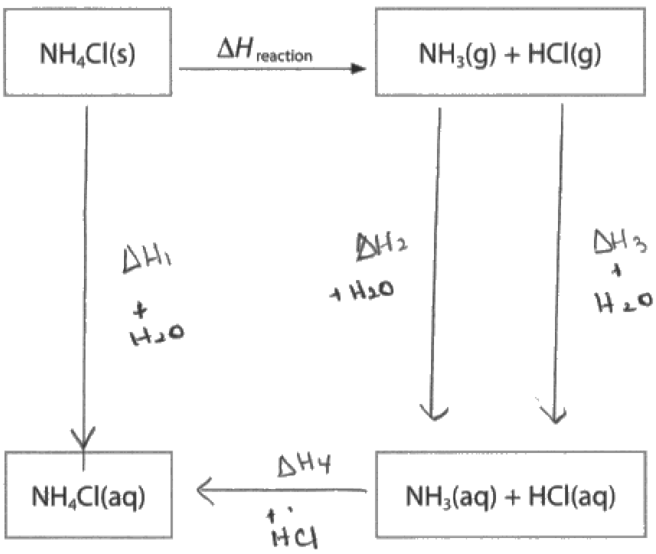
(ii) Some enthalpy changes which can be determined experimentally are listed below.

$NH_4Cl(s)$	+ water	$\rightarrow$	$NH_4Cl(aq)$	ΔH_1
$NH_3(g)$	+ water	$\rightarrow$	$NH_3(aq)$	ΔH_2
$HCl(g)$	+ water	$\rightarrow$	$HCl(aq)$	ΔH_3
$NH_3(aq)$	+ $HCl(aq)$	$\rightarrow$	$NH_4Cl(aq)$	ΔH_4

By adding arrows to the diagram below, construct a Hess cycle which can be used to calculate the enthalpy change, $\Delta H_{reaction}$, for the thermal decomposition of ammonium chloride.

Label each arrow with the appropriate symbol chosen from the list above for the enthalpy change. Assume that water is added where necessary to make a solution.

(1)



(iii) Give the expression for the enthalpy change, $\Delta H_{reaction}$, for the thermal decomposition of ammonium chloride, in terms of the other enthalpy changes in the cycle.

(1)

$\Delta H_{reaction} = \Delta H_1 - \Delta H_2 - \Delta H_3 - \Delta H_4$

ResultsPlus

Examiner Comments

This candidate scored both marks. The water involved in two reactions was shown in the cycle, but this was ignored as it did not affect the calculation.

Question 4 (a)

Many candidates did not read the question carefully and included toxicity as a hazard. Others suggested hazards due to glass wool, ant-bumping granules and calcium chloride which were not accepted.

Candidates should be aware that concentrated acids are corrosive. Saying that they irritate the skin does not indicate the extent of the hazard. The answer "irritant" was allowed for cyclohene and cyclohexanol, though the fact that they are flammable was a much more obvious hazard.

4 Cyclohexene, C_6H_{10}, can be prepared by dehydrating cyclohexanol, $C_6H_{11}OH$, with phosphoric acid.

$$C_6H_{11}OH \xrightarrow{H_3PO_4} C_6H_{10} + H_2O$$

mass ?? 10g   10g

Procedure

Step 1 12.0 cm^3 of cyclohexanol was put into a small flask. 5 cm^3 of concentrated phosphoric acid, an excess, was added slowly to the cyclohexanol using a dropping pipette. Some anti-bumping granules were added to the mixture and the flask was set up for distillation.

Step 2 The portion of the distillate collected between 80 °C and 90 °C contained only cyclohexene and water.

Step 3 The distillate of cyclohexene and water was transferred to a separating funnel and a saturated solution of sodium chloride was added. Most of the water which was in the distillate went into the saturated sodium chloride layer.

Step 4 The crude cyclohexene was run out of the separating funnel and dried with anhydrous calcium chloride.

Step 5 The calcium chloride was removed by filtration through glass wool, and the liquid was redistilled to collect pure cyclohexene.

Cyclohexene has an unpleasant smell and irritates the eyes, so the entire experiment was carried out in a fume cupboard. In **Step 1**, tubing was connected to carry any uncondensed cyclohexene to a drain.

(a) The chemicals involved in this reaction are all hazardous if they make contact with the eyes, or if swallowed or inhaled.

Other than their effect on the eyes or their toxicity, state **two** different hazards of the chemicals involved in this reaction. Name the chemical associated with each hazard.

Chemical	Hazard
Phosphoric acid	toxic and flammable, corrosive for skin
Cyclohexanol	irritant for skin.

ResultsPlus
Examiner Comments

Phosphoric acid is corrosive but not flammable so this mark was not allowed.

ResultsPlus
Examiner Tip

Do not give a list of possible hazards, as if one is incorrect you will lose the mark.

4 Cyclohexene, C_6H_{10}, can be prepared by dehydrating cyclohexanol, $C_6H_{11}OH$, with phosphoric acid.

$$C_6H_{11}OH \xrightarrow{H_3PO_4} C_6H_{10} + H_2O$$

Procedure

Step 1 12.0 cm^3 of cyclohexanol was put into a small flask. 5 cm^3 of concentrated phosphoric acid, an excess, was added slowly to the cyclohexanol using a dropping pipette. Some anti-bumping granules were added to the mixture and the flask was set up for distillation.

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Other than their effect on the eyes or their toxicity, state **two** different hazards of the chemicals involved in this reaction. Name the chemical associated with each hazard.

(2)

Chemical	Hazard
$CaCl_2$	Irritant
H_3PO_4	pungent smell

ResultsPlus
Examiner Comments

Neither of these answers were allowed.

ResultsPlus
Examiner Tip

A substance with a pungent smell is not necessarily hazardous.

Question 4 (b)

Most candidates first calculated the mass of cyclohexanol in 12 cm^3 and then calculated the number of moles present.

Candidates often combined the two steps into one, and scored 2 marks as long as the final answer was correct.

A common error was to think that the mass of cyclohexanol was the number of moles. Other candidates tried to use the formula for the number of moles in a solution or the number of moles of a gas and lost both marks.

(b) Calculate the number of moles of cyclohexanol used in this experiment. The density of cyclohexanol is 0.962 g cm^{-3}.

$C_6H_{11}OH$ **(2)**

$$\text{moles} = \frac{12 \times 0.962}{12 \times 6 + 12 + 17}$$

$= 0.11\text{mol}$

ResultsPlus

Examiner Comments

This candidate has combined the two stages of the calculation into one. However there is an error in calculating the molar mass of cyclohexanol as an extra H atom has been included, so the second mark was not given.

(b) Calculate the number of moles of cyclohexanol used in this experiment. The density of cyclohexanol is 0.962 g cm^{-3}.

(2)

$m = v \times d$

$\text{Mole} = 12.0 \times 0.962$

$= 11.5 \text{ mol}$

ResultsPlus

Examiner Comments

This candidate has done the first stage of the calculation but stated that the result is a number of mol, not a mass so the mark was not given.

ResultsPlus

Examiner Tip

Think what you are calculating at each stage and be careful with units.

Question 4 (c)

Many diagrams of the apparatus were correct in principle, but the standard of drawing was very low. Candidates should be shown how to draw cross-section diagrams, as it is often difficult for examiners to decide whether a flask has been shown as being stoppered or the drawing just shows the top.

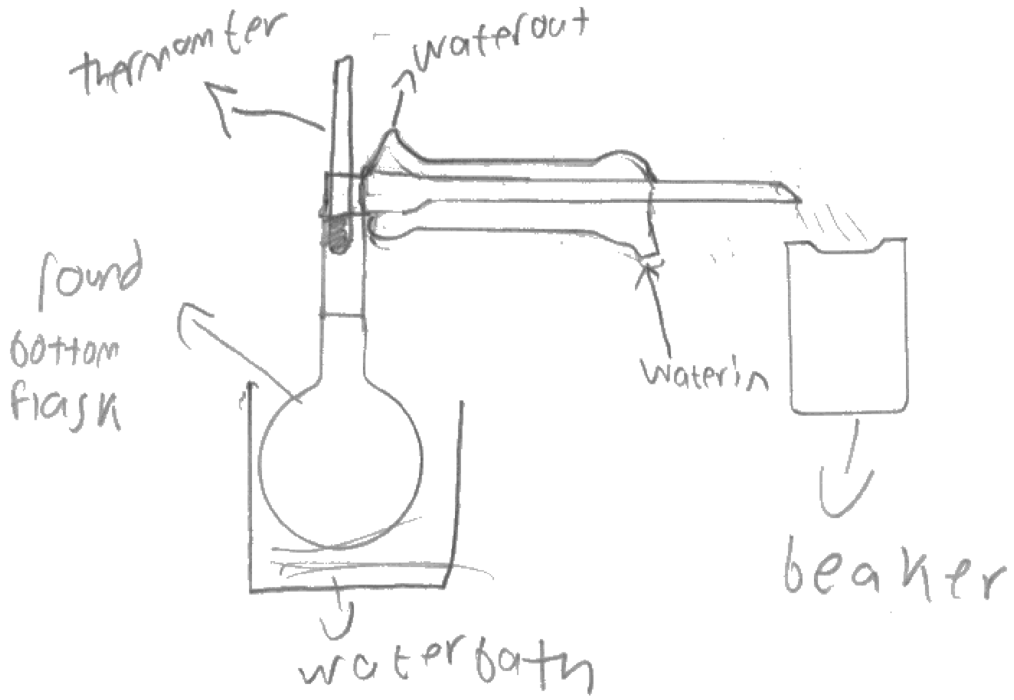
Most candidates who scored 3 lost a mark for drawing an open beaker as a receiver, allowing further loss of volatile product.

Some who drew otherwise acceptable diagrams had the water direction within the condenser the wrong way around. Condensers were often shown without a central tube around which the water flowed.

Most who drew thermometers (a few missed this out) had a good attempt at getting the bulb in the correct position.

(c) Draw a labelled diagram showing how to distil the reaction mixture in **Step 1** and collect the distillate boiling between 80 °C and 90 °C.

(4)



ResultsPlus
Examiner Comments

The condenser in this apparatus should not be horizontal, and the thermometer bulb should be opposite the opening to the condenser. A beaker should not be used to collect a volatile liquid, and if a beaker had been needed it should have been drawn without a line across the top, indicating it is open.

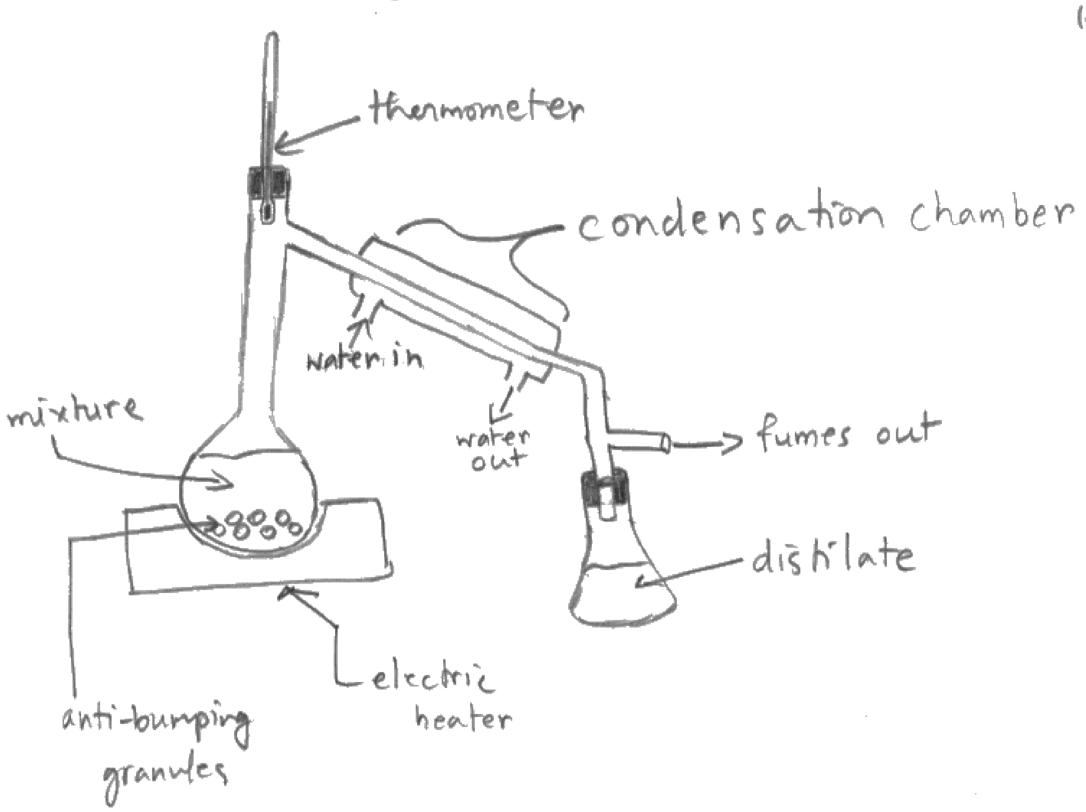
There are lines across the neck of the flask half way up the stem and across the thermometer and a line across the end of the condenser tube. These were assumed to be pictorial representations of the top of the flask and the adaptor, but to avoid ambiguity a cross-section diagram would be better.

ResultsPlus
Examiner Tip

Learn to draw cross-section diagrams. These show clearly where there are open tubes and where there are stoppers.

(c) Draw a labelled diagram showing how to distil the reaction mixture in **Step 1** and collect the distillate boiling between 80 °C and 90 °C.

(4)



ResultsPlus
Examiner Comments

The thermometer is above the opening to the condenser here, and the water direction in the condenser is incorrect.

As the vent tube is shown pictorially, the line across the bung of the conical flask was ignored and assumed to be the neck of the flask. This scored 2 marks. However a cross-section diagram whould have been better as it would have shown that the vent tube and the tube leading into the flask were both open.

Question 4 (d)

The difference between a drying agent and a dehydrating agent was not well known. Indeed, many candidates thought dehydration referred to removing hydrogen or hydroxyl groups. Some thought they were used for adding water. Those who were awarded the mark correctly made reference to the chemistry of the process and realised that a reaction was involved in dehydration. The purpose of the drying agent was much better known and they were commonly described as absorbing water.

Some candidates earned the marks by making the contrast between a physical and a chemical change.

Poor answers referred to drying agents drying water, or to dehydrating agents removing water but drying agents removing all liquids.

(d) Explain the difference between a 'dehydrating agent', such as the phosphoric acid used in **Step 1**, and a 'drying agent', such as the anhydrous calcium chloride used in **Step 4**.

(2)

Dehydrating agent changes the molecular formula of the compound by ~~e~~ eliminating water from the compound and making the compound unsatured, i.e contains (C=C). Drying agents only absorbs water - making the compound dry. ~~It~~ drying agent does not change molecular formula of the compound.

ResultsPlus
Examiner Comments

This is an example of a good answer.

(d) Explain the difference between a 'dehydrating agent', such as the phosphoric acid used in **Step 1**, and a 'drying agent', such as the anhydrous calcium chloride used in **Step 4**.

(2)

A drying agent absorbs water whereas a dehydrating agent will react to get rid of the water

ResultsPlus
Examiner Comments

This answer also scored both marks as it explains that a dehydrating agent removes water in a reaction while a drying agent just absorbs it.

ResultsPlus
Examiner Tip

Make sure you understand the scientific terms used in describing an experimental procedure, like drying and dehydrating.

Question 4 (e)

This was generally well answered though some candidates were unclear that the filtration process was carried out to remove calcium chloride, even though this was stated in the procedure.

Many candidates said correctly that filter paper was more absorbent than glass wool, but then referred to absorption of cyclohexene rather than cyclohexanol. Only a few candidates referred to filtration with glass wool being faster, possibly because they had never seen or used it. It was not enough to say only that the yield was better with glass wool; an explanation was needed for why this was the case.

(e) Suggest **one** advantage of using glass wool, rather than filter paper, when removing the calcium chloride in **Step 5**.

(1)

The filter paper absorbs the calcium chloride.

ResultsPlus
Examiner Comments

The filter paper absorbs liquids but the calcium chloride granules will remain on the surface of the paper, so this did not get the mark.

ResultsPlus
Examiner Tip

Think about the physical states of the substances being separated by filtration so that you do not choose the wrong one.

(e) Suggest **one** advantage of using glass wool, rather than filter paper, when removing the calcium chloride in **Step 5**.

(1)

filter paper absorbs some of the liquid leading to a smaller yield of cyclohexene whereas glass wool absorbs less liquid

ResultsPlus
Examiner Tip

This is an example of a good answer.

Question 4 (f)

The main difficulty candidate had with this calculation was the use of the 75% yield. Many fail to see that more than the theoretical amount of cyclohexanol must be used if the yield is less than 100%.

Answers were often extremely difficult to follow, and consisted of scattered numbers without words of explanation. Candidates should put some statements with their numbers. If they show what they are doing at each step they are more likely to be successful.

Possibly the other most common error amongst those who did have a correct, structured approach to this calculation was in the use of incorrect M_r values for either cyclohexene or cyclohexanol.

(f) Calculate the mass of cyclohexanol needed to obtain 10.0 g cyclohexene if the yield is 75%.

(3)

$$\% \text{ yield} = \frac{\text{practical yield}}{\text{theoretical yield}}.$$

$$\therefore \quad 75\% = \frac{10g}{\text{theoretical yield}}.$$

$$\therefore \text{ theoretical yield} = 13.33g.$$

$$\text{mol of cyclohexene} = \frac{\text{mass}}{\text{molar mass}}$$

$$= \frac{13.33g}{(12\times6)+10}$$

$$= 0.163 \text{ mol}$$

mol ratio of C_6H_{10} : $C_6H_{11}OH$

1 : 1

$\therefore$ mol of $C_6H_{11}OH$ = 0.163 mol

$$\text{mol of } C_6H_{11}OH = \frac{\text{mass}}{\text{molar mass}}$$

$$0.163 = \frac{\text{mass}}{100}$$

$\therefore$ mass = 16.3g

ResultsPlus
Examiner Comments

This answer is well set out and fully correct. There are different approaches to the calculation, and the different steps do not have to be done in this order.

(f) Calculate the mass of cyclohexanol needed to obtain 10.0 g cyclohexene if the yield is 75%.

(3)

cyclohexene mol = $\frac{10}{82}$ = 0.122

~~75% =~~ 11.544

$0.122 = \frac{\text{mass (cyclohexanol)}}{100}$

mass = 12.2.

$75\% = \frac{\text{actual mass}}{12.2}$ ~~x 100~~

mass = 9.15 g.

ResultsPlus

Examiner Comments

This candidate has calculated the number of moles of cyclohexene in 10.0g and the mass of cyclohexanol, but has used the 75% yield figure wrongly.

Question 4 (g) (i)

This was a familiar question and most candidates scored the mark. A few candidates gave only one colour, not both, which were needed to show the change.

(g) The cyclohexene was tested by mixing it with bromine dissolved in an organic solvent.

(i) What colour change would be observed?

(1)

colourless to ~~violet~~ brown

ResultsPlus
Examiner Comments

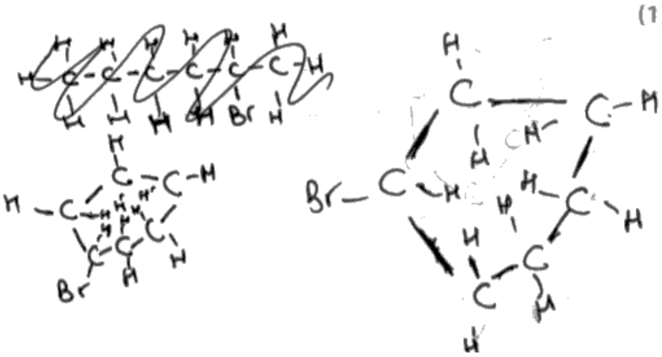
Answers had to be the right way round to score the mark so this was not allowed.

Question 4 (g) (ii)

This question proved surprisingly difficult. A large number of answers showed the product to be a straight chain; other answers showed addition of only one Br atom, and when two Br were added they were sometimes on carbon atoms which were not adjacent. In some cases a Br and an OH were added, despite the question referring to the bromine being in an organic solvent.

(ii) Give the **displayed** formula for the organic product of this reaction.

(1)



ResultsPlus
Examiner Comments

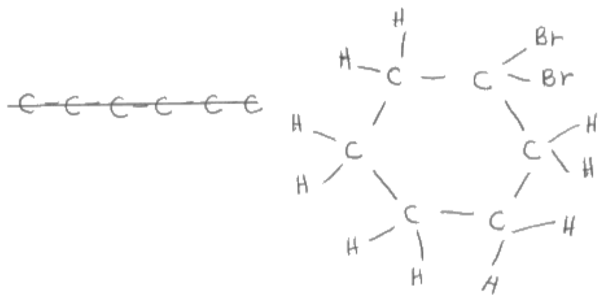
The slightly odd bond angles were ignored as the essential point in this question was the addition of two Br atoms to adjacent carbons. Only one Br has been added here so it did not score.

ResultsPlus
Examiner Tip

Work out the product of the reaction of bromine and ethene. The addition of two Br atoms, one on each side of the double bond, occurs in the same way with other alkenes.

(ii) Give the **displayed** formula for the organic product of this reaction.

(1)



ResultsPlus

Examiner Comments

This candidate has shown the two Br atoms on the same carbon so the mark was not given.

Paper Summary

Hints for candidates:

- Make sure you know how to interpret mass spectra and infrared spectra, and the different information they provide.
- Learn to draw cross-section diagrams. These show clearly whether flasks and tubes are open or sealed.
- If a calculation needs an answer to three significant figures, you should use four figures in the early stages, and not round numbers before the end.
- Always show what you are doing in a calculation. If the final answer is wrong you can get earlier marks.
- Make sure you read the question. Every piece of information in it will be needed at some point.

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