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June 2025

Int Advanced Level Chemistry WCH12 01

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Introduction

The mean score of 41 marks in this paper showed that most candidates had an opportunity to demonstrate their knowledge and understanding of material in Unit 2 of the specification. Responses to questions on topics that are familiar such as the use of the Maxwell-Boltzmann distribution of molecular energies to explain the action of a catalyst on a reaction and empirical formula calculations reflected a high level of preparation. The drawing of the substitution mechanism in Question 14(c)(ii) was completed accurately by the majority of candidates but attempts at the supplementary question which required the application of their understanding of the action of a nucleophile were much less successful.

Calculations on the determination of the amount of magnesium carbonate in a sample were less familiar than the more usual titration questions seen in recent papers. There were many examples of candidates who worked logically but missed one or two steps, achieving partial credit. In contrast, the confirmation of the empirical formula in Question 16(b) was usually completely correct.

The mean score for the multiple-choice questions in Section A was 13 marks. Only three questions, Question 2(b), Question 4 and Question 6 were scored by less than 50% of candidates whereas Question 11(b) and Question 13(c) were both scored by over 80% of candidates.

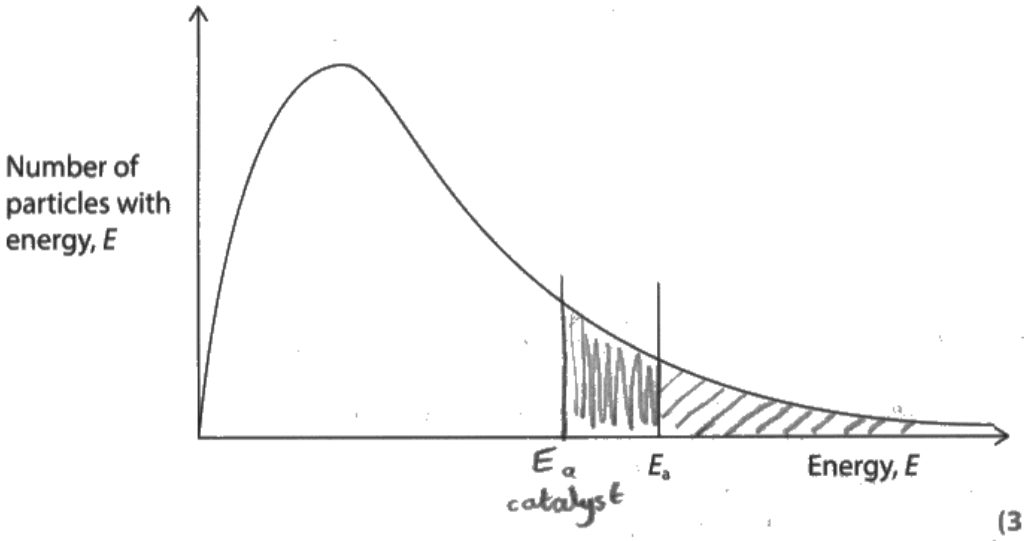
Question 14(a)

This proved a straightforward introduction to the paper, being a familiar topic to most candidates.

14 This question is about nitrogen, hydrogen and their compounds.

(a) Ammonia is produced in the Haber process.
Nitrogen and hydrogen react at a pressure of 200 atmospheres and a temperature of 725 K, using an iron catalyst.

Explain how a catalyst increases the rate of a chemical reaction, using the Maxwell–Boltzmann distribution shown, and the collision theory.



(3)

Addition of catalyst reduces the activation energy so more particles have energy greater than activation energy so more succesful collisions per unit time

ResultsPlus
Examiner Comments

There were many responses that scored all three marks. This response shows clearly the link between the reduction in activation energy and the increase in the frequency of successful collisions.

ResultsPlus
Examiner Tip

When a diagram is given in a question, it is often easier to annotate the diagram in an explanation .

A catalyst decreases the needed activation energy (E_A), because of this a higher amount of molecules have $E > E_A$ causing more successful collisions, thus increasing the rate of reaction.

ResultsPlus
Examiner Comments

The first two marks are scored but there is no reference to the frequency of successful collisions or more successful collisions per unit time so the final mark is not scored. This was the most common omission.

ResultsPlus
Examiner Tip

The statement about the increase in the rate of reaction is stated in the question and is therefore not required in the answer.

Question 14(b)i

Many candidates ignored the advice given in the question and gave detailed descriptions of the intermolecular forces. This had the combined effect of using up precious time and also leaving very limited space to focus on the scoring points. The successful responses focused on the link between the trend in increasing numbers of electrons and consequent increase in the strength of London forces, then considered the anomalously high boiling temperature of ammonia due to the presence of hydrogen bonding in that molecule.

(b) Storing and transporting hydrogen can be difficult due to its low energy density.

This has led to the use of various hydrides which contain a high proportion of hydrogen and are easier to liquefy and transport.

(i) Explain the differences in the boiling temperatures of the Group 5 hydrides shown.
Detailed descriptions of the intermolecular forces are not required.

Hydride	Boiling temperature / K
NH_3	240
PH_3	186
AsH_3	212
SbH_3	256

(4)

the boiling ~~tem~~ points increases down group as the number of electron increases so ~~stronger~~ london force increases so more energy is need to overcome strong intermolecular force of attraction, NH_3 has higher boiling point compared to PH_3 and AsH_3 is because it form hydrogen bonding which is the strongest intermolecular force of attraction

ResultsPlus
Examiner Comments

The link between the number of electrons and the strength of London forces down the group is clear. Although there is no direct comparison of hydrogen bond strength with that of London forces, the reference to it being the strongest intermolecular force of attraction is sufficient to score the mark.

ResultsPlus
Examiner Tip

In multi-mark questions, check that sufficient points have been covered to score all the marks available.

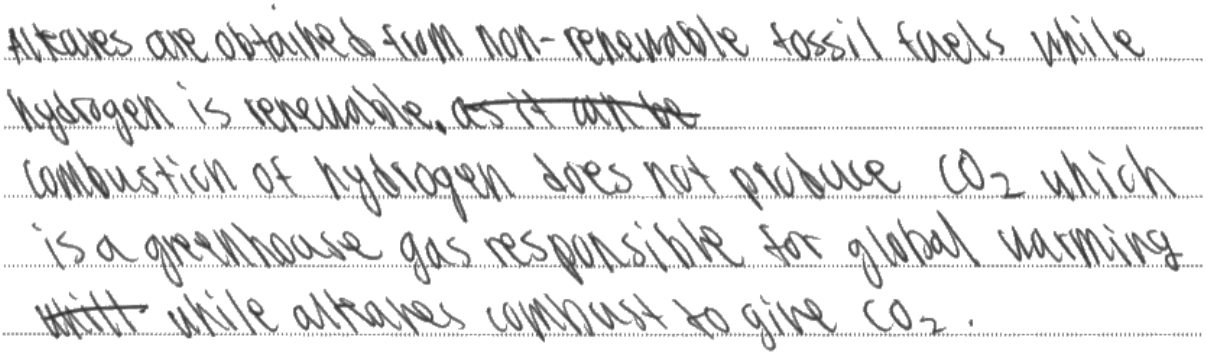
Question 14(b)ii

Most responses showed a clear understanding of the link between the production of carbon dioxide during the combustion of alkanes and global warming but often failed to state that the only combustion product of hydrogen is water.

Some candidates misinterpreted the question as being about the sustainability of fuels – a topic that has appeared in previous series. Sustainability is a way of using resources that could continue forever, like renewable energy. References to this concept were not penalised but were ignored. This is a separate concept to the impact of fossil-fuel use on the environment, such as the production of carbon dioxide leading to enhanced global warming.

(ii) Hydrogen has been proposed as an alternative fuel to petrol.
Explain why hydrogen is a more environmentally friendly fuel than alkanes.

(3)



ResultsPlus
Examiner Comments

In addition to not answering the question, the statement regarding hydrogen as a renewable resource is not correct. In practice, much hydrogen is produced from fossil fuels and some alkanes used as fuels come from biodigestion processes. This response scored two marks for the link between the production of carbon dioxide from alkane combustion and global warming. The remarks on sustainability were not penalised. This candidate has stated a correct feature of the combustion of alkanes and simply stated that hydrogen does not produce carbon dioxide. This type of statement is insufficient. Identifying the product of the combustion of hydrogen was required.

ResultsPlus
Examiner Tip

Learn the meaning of technical terms used in the specification.

Question 14(c)i

(c) Ethylamine may be prepared from the reaction between ammonia and bromoethane.

(i) State the conditions for this reaction.

(2)

heat under pressure in a sealed tube, ethanol used as solvent

ResultsPlus
Examiner Comments

Both the key points are included in this fully correct answer.

ResultsPlus
Examiner Tip

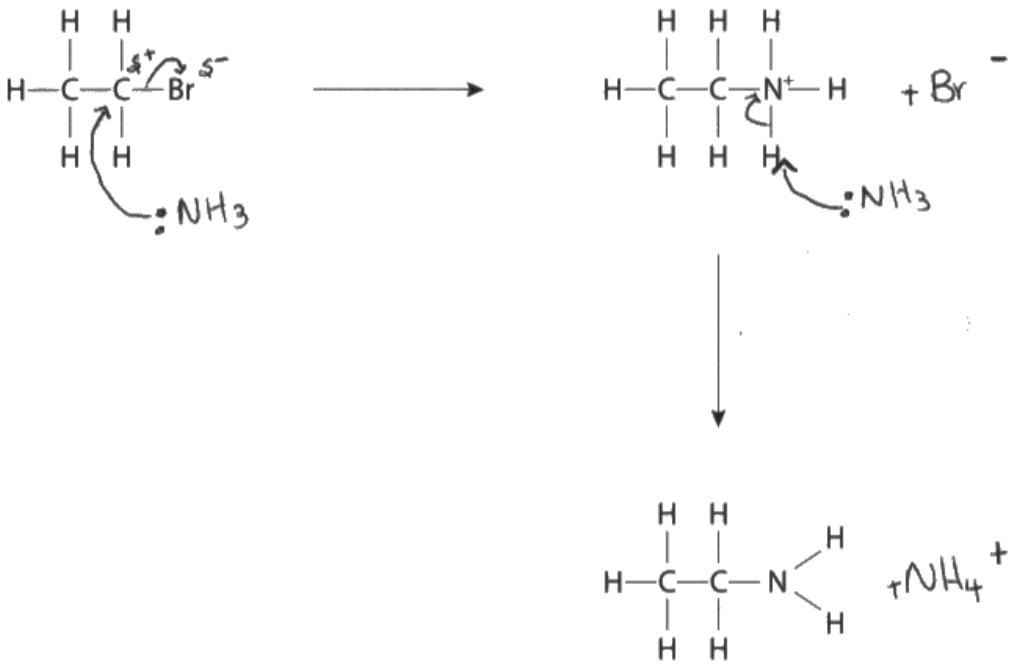
Learn the reaction conditions for all the preparations in the specification.

Question 14(c)ii

This mechanism was well known, frequently scoring two marks. The most common errors were the inclusion of a charge on the ammonia molecule or a failure to include one or both additional products eg NH_4^+ and/or Br^-. It was rare to see the omission of the lone pair on the nitrogen of the ammonia and the placement of the curly arrows had been carefully drawn.

(ii) Complete the mechanism for this reaction.
Include curly arrows, and relevant dipoles and lone pairs.

(3)



ResultsPlus
Examiner Comments

This fully correct answer shows all the required components of the mechanism.

ResultsPlus
Examiner Tip

Learn how to accurately draw curly arrow mechanisms in the specification.

Question 14(c)iii

In contrast to the previous item, the features of the ethylamine molecule which enable it to act as a nucleophile if excess halogenoalkane is present was not well known.

Many candidates had correctly drawn the mechanism in Q14(c)(ii) where ammonia donates a lone pair of electrons from the nitrogen and the resulting ion loses a proton. It was unfortunate that few candidates recognised that ethylamine also had these features.

(iii) Further substitution of the ethylamine molecule may occur if the halogenoalkane is in excess.
State **two** features of the ethylamine molecule that make this possible.

(2)

The lone pair of electrons on the nitrogen atom and the replaceable hydrogen atoms on the nitrogen.

ResultsPlus
Examiner Comments

This is an example of a fully correct answer. Some responses identified that ethylamine had a lone pair but failed to state that it was on the nitrogen.

ResultsPlus
Examiner Tip

Understanding of the chemical principles underlying reaction mechanisms is important.

Question 15(a)

The ability to produce an ionic equation is frequently tested and common mistakes such as inclusion of unreacting ions, lack of balancing of species and/or charges were unfortunately seen often.

15 This question is about the reactions of some elements in Group 7.

(a) When chlorine water is added to a solution of potassium bromide, a pale brown colour is seen.

Write an ionic equation for this reaction.
State symbols are not required.

ResultsPlus
Examiner Comments

This is a balanced equation but the potassium ions, which do not react, are shown.

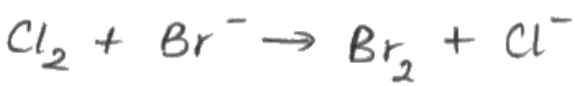
ResultsPlus
Examiner Tip

Cancel unreacting ions in ionic equations.

15 This question is about the reactions of some elements in Group 7.

(a) When chlorine water is added to a solution of potassium bromide, a pale brown colour is seen.

Write an ionic equation for this reaction.
State symbols are not required.



ResultsPlus
Examiner Comments

This response does not include potassium ions but the species on each side of the equation do not balance.

ResultsPlus
Examiner Tip

Check all ionic equations for balancing of both species and charge.

$2Cl_{(aq)} + 2KBr \longrightarrow 2KCl + \frac{1}{2}Br_2$

15 This question is about the reactions of some elements in Group 7.

(a) When chlorine water is added to a solution of potassium bromide, a pale brown colour is seen.

Write an ionic equation for this reaction.
State symbols are not required.

$2Cl + 2Br^- \longrightarrow 2Cl^- + Br_2$

ResultsPlus
Examiner Comments

This candidate has removed the potassium ions and has used the correct formula for bromine but the incorrect formula for chlorine, which is also molecular in solution.

ResultsPlus
Examiner Tip

Remember that the elements in Group 7 are diatomic.

15 This question is about the reactions of some elements in Group 7.

(a) When chlorine water is added to a solution of potassium bromide, a pale brown colour is seen.

Write an ionic equation for this reaction.
State symbols are not required.

~~$Cl_2 + 2KBr \rightarrow 2KCl + Br_2$~~

$Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$

ResultsPlus
Examiner Comments

This candidate has used the symbol equation as "working" and crossed it through, indicating that it is not the final answer. The equation includes the reacting ions, correctly balanced for charge and species.

Question 15(b)

The procedure of using oxidation numbers to identify oxidation and reduction was well known, with over half the candidates scoring both marks.

(b) Chlorine is used to treat drinking water.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HClO(aq) + HCl(aq)$$

By considering oxidation numbers, show that this equation represents a disproportionation reaction.

(2)

Cl_2 reactant has an oxidation number of 0 (element)
But when chlorine is in HClO in product its oxidation number is +1 and in HCl it is -1 so it is both reduced and oxidised there disproportionation occurs

This response clearly identifies the oxidation numbers of chlorine in both reactants and products. Although oxidation and reduction are both mentioned, it is not clear which product is the result of oxidation and which reduction so neither mark is scored. A mark for the correct identification of the oxidation numbers is awarded.

$\Rightarrow H^+ + O^{2-} + K^+ + Cl^- \rightarrow KCl + H_2O$

(b) Chlorine is used to treat drinking water.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HClO(aq) + HCl(aq)$$

By considering oxidation numbers, show that this equation represents a disproportionation reaction.

(2)

=> Cl_2 is reduced in HCl as oxidation number when from 0 to -1.

=> Cl_2 in HClO cha ~~undergoes~~ is oxidised

ResultsPlus
Examiner Comments

This response clearly states that HCl is formed from the reduction of chlorine and scores the second mark but the oxidation number of chlorine in the chlorate (1) ion has not been included.

Question 15(c)i

The concept of a redox reaction was well known and the mark was scored by just over half the candidates. A link to no change in oxidation number was required rather than just to oxidation/reduction.

(c) Concentrated sulfuric acid, H_2SO_4, reacts with solid potassium halides. Some observations are shown in the table.

Halide	Observations
Potassium chloride	Misty fumes
Potassium bromide	Misty fumes and brown vapour
Potassium iodide	Misty fumes and purple vapour

(i) The equation for the reaction of concentrated sulfuric acid with potassium chloride is shown.

$$\overset{+2+6-8}{H_2SO_4} + \overset{+1\ -1}{KCl} \rightarrow \overset{+1\ -1}{HCl} + \overset{+1+1+6-8}{KHSO_4}$$

State why this is **not** a redox reaction.

no oxidation and reduction occur

no change in oxidation numbers

ResultsPlus
Examiner Comments

The initial comment was insufficient but the addition of the reference to "no change in oxidation numbers" scored the mark. The annotation of the equation with oxidation numbers, none of which change, is also acceptable but the additional statement is useful for examiners.

Question 15(c)ii

Only half the responses scored the mark. Alternatively, there were a range of errors including adding the two half-equations incorrectly or failing to multiply the iodide half-equation by 4; so many equations had uncancelled electrons, usually 6.

(ii) The half-equation for the oxidation of iodide ions is shown.

$2I^- \rightarrow I_2 + 2e^-$ ×4 $\quad 4I^- \rightarrow 4I_2 + \cancel{8e}$

The half-equation for the reduction of concentrated sulfuric acid to hydrogen sulfide is shown.

$8H^+ + H_2SO_4 + \cancel{8e} \rightarrow H_2S + 4H_2O$

Deduce the ionic equation for the reaction between iodide ions and concentrated sulfuric acid by combining these two half-equations.

(1)

$8H^+ + H_2SO_4 + 4I^- \rightarrow H_2S + 4H_2O + 4I_2$

ResultsPlus
Examiner Comments

The multiplication of the iodide half-equation by 4 is incorrect and has been carried forward into the final answer, rendering it unbalanced in iodine and charge.

ResultsPlus
Examiner Tip

Check equations for balancing and charge.

(ii) The half-equation for the oxidation of iodide ions is shown.

$$2I^- \rightarrow I_2 + 2e^-$$

The half-equation for the reduction of concentrated sulfuric acid to hydrogen sulfide is shown.

$$8H^+ + H_2SO_4 + 8e^- \rightarrow H_2S + 4H_2O$$

Deduce the ionic equation for the reaction between iodide ions and concentrated sulfuric acid by combining these two half-equations.

(1)

$2I^- + 8H^+ + H_2SO_4 + 6e^- \rightarrow H_2S + 4H_2O + I_2$

ResultsPlus
Examiner Comments

No attempt has been made to multiply the iodide half-equation by 4 in order to balance the electrons produced in the oxidation with those in the reduction. Although the final answer is balanced for species and charge, there are uncancelled electrons so no marks scored.

Question 15(c)iii

The majority of responses scored neither mark. Many candidates focused on a list of observations and/or a comparison of the products or the types of reaction. Others mentioned reactivity rather than reducing ability.

(iii) Explain the difference in the reaction of concentrated sulfuric acid with chloride ions and with iodide ions.

(2)

- Iodide ions ~~has~~ have more reducing power than chloride ions.
- So, purple vapour (I_2), colourless gas with rotten egg smell (H_2S) and yellow solid (S) are produced when concentrated H_2SO_4 reacts with iodide ions.

ResultsPlus Examiner Comments

The first mark is scored as "more reducing power" is an acceptable answer. The second mark is not scored as a description of the reaction products does not explain the difference. An explanation should contain some element of reasoning or justification.

ResultsPlus Examiner Tip

Learn the meanings of the command words used in the specification. These are detailed in Appendix 7.

(iii) Explain the difference in the reaction of concentrated sulfuric acid with chloride ions and with iodide ions.

(2)

Going down group 7, the reducing ability of the halide ions increases as the ionic radius increases and the attraction between the nucleus and outer e⁻s decreases. The ionisation energy decreases down the group.

ResultsPlus
Examiner Comments

This response scores the first mark for the comparison and the explanation for the relative ease with which iodide loses its electron. The statement about the ionisation energy refers to iodine atoms so it is ignored here.

Question 16(a)

16 This question is about secondary alcohols.

(a) Give a chemical test, including the result, to show that alcohols contain an OH group.

(2)

add PCl_5 (s) to the alcohol. misty fumes HCl will be produced.

ResultsPlus
Examiner Comments

This is a correct test and positive result. The identification of the gas observed as HCl is not required.

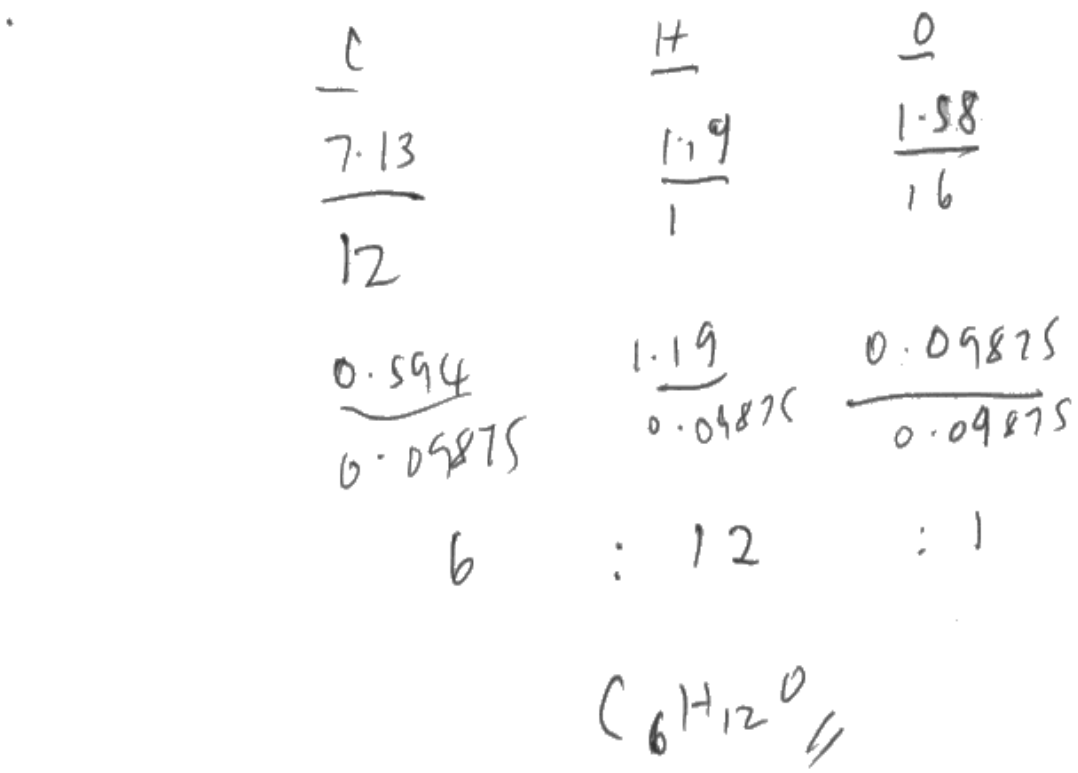
ResultsPlus
Examiner Tip

Learn the tests and observations for organic functional groups.

Question 16(b)

Both marks were scored by nearly 90% of candidates.

(b) A sample of cyclohexanol contains 7.13 g of carbon, 1.19 g of hydrogen and 1.58 g of oxygen.
Show that this data is consistent with the empirical formula $C_6H_{12}O$.



ResultsPlus
Examiner Comments

Both marks are scored and the working is clearly shown, including the evaluation of the mole ratios and the empirical formula.

ResultsPlus
Examiner Tip

Showing your working makes awarding marks straightforward, especially if your final answer is incorrect.

Question 16(c)i

(c) Cyclohexanol can be converted to cyclohexanone.

(i) Name the reagents and conditions for this conversion.

(2)

Acid acidified ~~pot~~ $K_2Cr_2O_7$ and heat under reflux.

ResultsPlus
Examiner Comments

This response does not identify the acid used so does not score the mark for reagents.

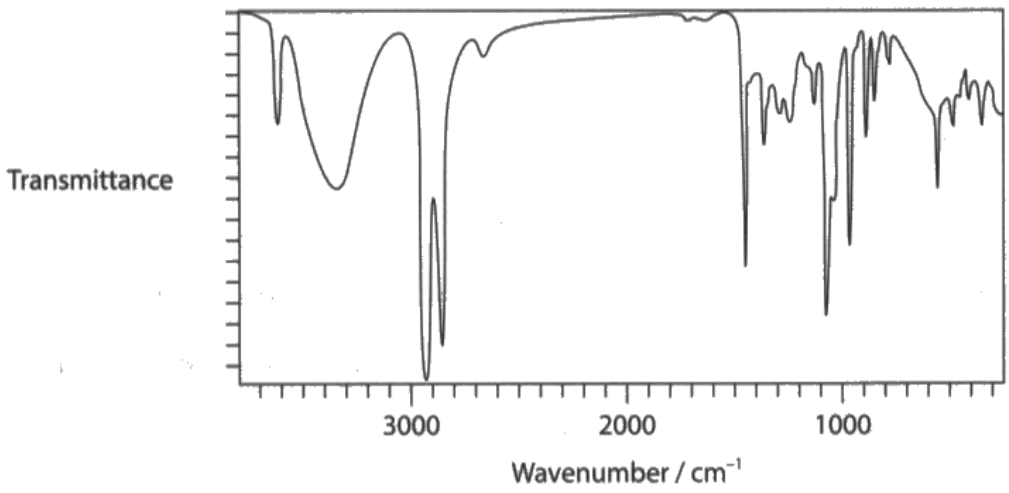
ResultsPlus
Examiner Tip

Learn the reagents and conditions for all the preparations in the specification.

Question 16(c)ii

This question had a familiar format but many candidates confused the range for the C=O stretching vibration in an aryl ketone with the correct one for an alkyl ketone.

(ii) The infrared spectrum of cyclohexanol is shown.



Describe **two** differences, other than the fingerprint region, that would be expected in the infrared spectrum of cyclohexanone.

(2)

There will be a peak from 1725 – 1700 for C=O stretching

The O-H stretching from 3750 - 3200 will be absent

ResultsPlus
Examiner Comments

The wavenumber range for the C=O bond is incorrect – it should be 1720-1700 cm^{-1} for an alkyl ketone. The range given is for an alkyl carboxylic acid. One mark is scored for an O-H stretching vibration in an alcohol.

ResultsPlus
Examiner Tip

Take care when using data from the Data Booklet.

Question 16(c)iii

Correct answers were in a minority with only about a third of responses scoring the mark. Many candidates sought deeper explanations than necessary, citing intermolecular forces, miscibility or that the boiling temperatures were high.

(iii) Give a reason why cyclohexanol and cyclohexanone can be separated by fractional distillation but not by simple distillation.

(1)

because they have different boiling points/temperatures but the difference between them isnt every large.

ResultsPlus
Examiner Comments

The first phrase does not score, as just a difference in the boiling points does not adequately answer the question and so is ignored. The additional information regarding the closeness of the boiling temperatures scores the mark.

Question 16(d)

This six-mark extended response item offered an opportunity for candidates to demonstrate their knowledge of the differences in the reaction between hydroxide ions and a halogenoalkane, depending on the conditions. More than 10% of candidates scored the maximum mark with about half the candidates scoring at least half the marks available.

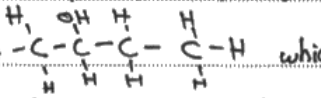
*(d) Discuss the reactions between sodium hydroxide and 2-chlorobutane.

The hydroxide ion acts in **two** different ways depending on the reaction conditions.

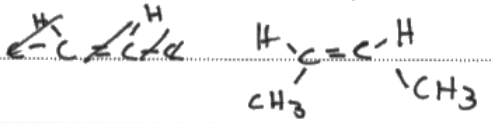
Include the structures of **four** possible products, the reaction conditions needed and the roles of the hydroxide ion.

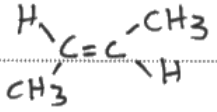
Detailed mechanisms are not required.

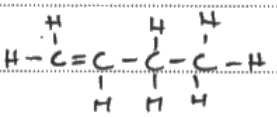
(6)

If the sodium hydroxide is dissolved in aqueous solution, the hydroxide ion will act as a neucleophile, so a neucleophilic substitution will occur to form an alcohol with a displayed formula of ~~$CH_3CH_2CHOHCH_2CH_3$~~  which is butan-2-ol.

If the sodium hydroxide is dissolved in ~~eth~~ alcoholic solution, the hydroxide ion will act as a base and an elemination reaction will occure that will form ~~an alkene, the~~ butene, the butene has three isomers:-

1.  which is Z-but-2-ene.

2.  E-but-2-ene.

3.  which is but-1-ene.

This succinct response successfully included all the Indicative Points and scored six marks. The two different types of reaction and the action of the hydroxide ion as a base and as a nucleophile are clearly linked to the conditions. The structures of the four different products are clearly shown.

Note the key words in the question which are frequently printed in bold type.

Question 17(a)

This question differentiated candidates. The moles of acid found from the titration with sodium hydroxide represented the amount of acid remaining **after** the reaction with magnesium carbonate so it was necessary to subtract that value from the 0.06 moles acid used in order to find the amount that had reacted with the carbonate.

The failure to complete the subtraction was very common but there were opportunities for marks to be scored as transferred errors, provided working was clearly shown.

17 Magnesium carbonate has been studied recently as a potential material for the removal of carbon dioxide from the atmosphere.

(a) The value of n in a sample of a hydrated magnesium carbonate, $MgCO_3 \cdot nH_2O$, can be determined by the reaction with hydrochloric acid.
The equation for the reaction is shown.

$$MgCO_3 \cdot nH_2O(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + (n+1)H_2O(l)$$

Procedure
Step **1** Add 0.0600 mol of hydrochloric acid (an excess) to a 2.35 g sample of the hydrated magnesium carbonate.

Step **2** When the reaction is complete, transfer the resulting solution to a 250 cm^3 volumetric flask, make up to the mark with deionised water, and mix thoroughly.

Step **3** Titrate 25.0 cm^3 portions of the solution with sodium hydroxide solution of concentration 0.0960 mol dm^{-3}.

Data
The mean titre volume = 27.15 cm^3

Determine the value of n in the hydrated salt.

(7)

$MgCl_{2(aq)} + (n+1)H_2O_{(l)} + 2NaOH_{(aq)} \rightarrow (n+1)H_2O + Mg(OH)_2 + 2NaCl$

$0.0960 \times \left(\frac{27.15}{25} \times 10^{-3}\right) = 2.61 \times 10^{-3}$ mol of NaOH,

$\frac{2.61 \times 10^{-3}}{2} = 1.3 \times 10^{-3}$ mol of $MgCl_2$,

$\frac{2.35}{(24.3+12+(16\times3)+18)} =$

1.2×10^{-3}

ResultsPlus
Examiner Comments

This scores M1 for the use of the titre value to calculate the moles of acid in the aliquot. The ratio of 1:2 in the reaction of the acid with magnesium carbonate is clear so M4 is scored. There is no subtraction or scaling (x10) or evaluation of the moles of water so this response scores 2 marks.

ResultsPlus
Examiner Tip

Even if the calculation cannot be completed, it is possible to gain partial credit.

17 Magnesium carbonate has been studied recently as a potential material for the removal of carbon dioxide from the atmosphere.

(a) The value of n in a sample of a hydrated magnesium carbonate, $MgCO_3 \cdot nH_2O$, can be determined by the reaction with hydrochloric acid.
The equation for the reaction is shown.

2.35g 0.06ucl

$$MgCO_3 \cdot nH_2O(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + (n+1)H_2O(l)$$

Procedure **Step 1** Add 0.0600 mol of hydrochloric acid (an excess) to a 2.35 g sample of the hydrated magnesium carbonate.

Step 2 When the reaction is complete, transfer the resulting solution to a 250 cm^3 volumetric flask, make up to the mark with deionised water, and mix thoroughly.

$MgCl_2$ = 25 cm^3

Step 3 Titrate 25.0 cm^3 portions of the solution with sodium hydroxide solution of concentration 0.0960 mol dm^{-3}.

Data The mean titre volume = 27.15 cm^3

$MgCl_2 + NaOH \rightarrow Mg(OH)_2 + H_2O$

Determine the value of n in the hydrated salt.

(7)

~~moles HCl = $MgCl_2$ =~~

~~(25 ÷ 1000) × 0.096 = 2.4×10^{-3} mol^{-1}~~

(27.15 ÷ 1000) × 0.096 = 2.6064×10^{-3} moles NaOH

1 ÷ 2

2.6064×10^{-3}

= 1.3032×10^{-3} moles $MgCl_2$ × 10 = 0.013032 mol

0.013032 mol $MgCO_3 \cdot nH_2O$ 10.6

2.35 ÷ 0.013032 = 180.3 mr

24.3 + 12 + 48 = 84.3

180.3 − 84.3 = 96

n = 5.33

2 + 16 = 18

96 ÷ 18 = 5.33

$MgCl_2 + 2NaOH \rightarrow Mg(OH)_2 + 2NaCl$

ResultsPlus
Examiner Comments

This scored 5 marks as the moles of sodium hydroxide were correctly calculated and scaled up to represent the moles of hydrochloric acid in 250cm^3 solution, thus scoring M1 and M2. The subtraction step was not done, losing M3, but the candidate has carried on to divide by 2, representing the reacting ratio between hydrochloric acid and magnesium carbonate. M4 was scored for the moles of hydrated salt. The Mr of the hydrated salt has been calculated from the incorrect moles (M5) and the candidate has carried on to calculate the mass of water scoring M6. Unfortunately, the answer, n, in moles, was not rounded to a whole number, losing M7.

ResultsPlus
Examiner Tip

Completing a calculation logically and showing steps clearly enables partial credit to be given.

17 Magnesium carbonate has been studied recently as a potential material for the removal of carbon dioxide from the atmosphere.

(a) The value of n in a sample of a hydrated magnesium carbonate, $MgCO_3 \cdot nH_2O$, can be determined by the reaction with hydrochloric acid.
The equation for the reaction is shown.

$$MgCO_3 \cdot nH_2O(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + (n+1)H_2O(l)$$

Procedure Step **1** Add 0.0600 mol of hydrochloric acid (an excess) to a 2.35 g sample of the hydrated magnesium carbonate.

Step **2** When the reaction is complete, transfer the resulting solution to a 250 cm^3 volumetric flask, make up to the mark with deionised water, and mix thoroughly.

Step **3** Titrate 25.0 cm^3 portions of the solution with sodium hydroxide solution of concentration 0.0960 mol dm^{-3}.

Data The mean titre volume = 27.15 cm^3

$2NaOH + MgCl_2 \rightarrow 2NaCl + Mg(OH)_2$

Determine the value of n in the hydrated salt.

(7)

$(27.15 \times 10^{-3})(0.096) = 2.6064 \times 10^{-3}$ mol of NaOH

~~2.6064×10^{-3} of $MgCl_2$ in 25cm^3~~ 2 NaOH : 1 $MgCl_2$

$\frac{2.6064 \times 10^{-3}}{2} = 1.3032 \times 10^{-3}$ mol of $MgCl_2$ in 25cm^3

0.013032 mol of $MgCl_2$ in 250cm^3

1 → 1

~~(0.013032)~~ $\frac{2.35}{0.013032} = 180.325$

Mr $MgCO_3$: 84.3

$84.3 + n18 = 180.325$

$n18 = 96.025$

$n = 5.33$ or $5\frac{1}{3}$

$n \approx 5$

n=5

ResultsPlus
Examiner Comments

This response scored M1 for calculating the moles of sodium hydroxide in the titre, and hence the moles of hydrochloric acid in 25cm^3 of the solution. M4 was scored for recognising that the reacting ratio of the carbonate:acid was 1:2. M2 was scored for scaling up the moles acid to 250cm^3. There was no subtraction of the amount from the initial moles of acid added to the sample so M3 was not scored. M5, M6 and M7 were scored for the calculation of the Mr. mass of water and n to the nearest whole number.

ResultsPlus
Examiner Tip

Set out calculations clearly showing all steps so that partial credit can be given.

SECTION C

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

17 Magnesium carbonate has been studied recently as a potential material for the removal of carbon dioxide from the atmosphere.

(a) The value of n in a sample of a hydrated magnesium carbonate, $MgCO_3 \cdot nH_2O$, can be determined by the reaction with hydrochloric acid.
The equation for the reaction is shown.

$$\underset{2.35}{MgCO_3 \cdot nH_2O(s)} + \underset{0.06}{2HCl(aq)} \rightarrow MgCl_2(aq) + CO_2(g) + (n+1)H_2O(l)$$

Procedure Step **1** Add 0.0600 mol of hydrochloric acid (an excess) to a 2.35 g sample of the hydrated magnesium carbonate.

Step **2** When the reaction is complete, transfer the resulting solution to a 250 cm^3 volumetric flask, make up to the mark with deionised water, and mix thoroughly.

Step **3** Titrate 25.0 cm^3 portions of the solution with sodium hydroxide solution of concentration 0.0960 mol dm^{-3}.

Data The mean titre volume = 27.15 cm^3

Determine the value of n in the hydrated salt.

(7)

$27.15 \times 10^{-3} \times 0.096 = 0.0026064$

$\times 10 = 0.026064$

$0.06 - 0.026064$

$= 0.033936$ mol

$\frac{2.35 \times 2}{0.033936} = 138.4$

$138.4 - (24.3 + 60) = 54.1$

$\frac{54}{18} = 3$

$n = 3$

ResultsPlus
Examiner Comments

This response scored 7 marks. Slight rounding errors have been ignored and the answer has been rounded to the nearest whole number.

Question 17(b)i-ii

In (b)(i), many candidates were successful in calculating the enthalpy change for the reaction between magnesium oxide and hydrochloric acid.

A fairly common error was to use the wrong mass for the resulting solution.

Some candidates added 1.92g which was the mass of the solid oxide to the mass of the acid (40g). It is conventional to ignore the additional mass of the solution and also the change in specific heat capacity compared with water. These differences are assumed to cancel.

In (b)(ii), very few candidates completed the Hess cycle correctly, often forgetting state symbols, which are important in thermochemistry.

(b) The enthalpy change for the thermal decomposition of anhydrous magnesium carbonate, $\Delta_r H$, was measured indirectly using the enthalpy changes for the two reactions shown and applying Hess's Law.

Reaction **1**
$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$ $\Delta_r H_1$

Reaction **2**
$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$ $\Delta_r H_2 = +3.58\,kJ\,mol^{-1}$

An experiment was carried out to measure the enthalpy change of reaction, $\Delta_r H_1$, for Reaction **1**.

1.92 g of magnesium oxide was added, with stirring, to 40.0 cm^3 dilute hydrochloric acid (an excess) in an insulated container. The temperature rise was 30.8 °C.

(i) Calculate $\Delta_r H_1$ for Reaction **1**. Include a sign and units in your answer.

[Assume the specific heat capacity of the solution = 4.18 $J\,g^{-1}\,°C^{-1}$
the density of the solution = 1.00 $g\,cm^{-3}$]

(3)

$Q = mc\Delta T = 40 \times 4.18 \times 30.8 = 5149.8$

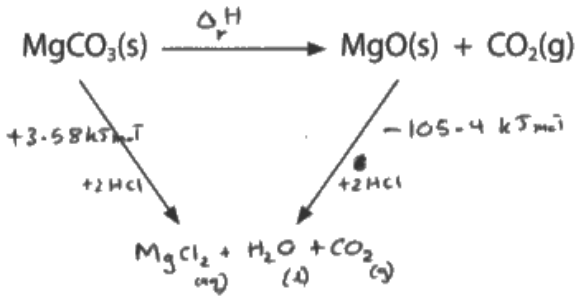
$\Delta_r H_1 = \frac{5.1498}{\frac{1.92}{39.3}} = 105.4$

$\Delta_r H_1 = -105.4\ kJ\ mol^{-1}$

(ii) The enthalpy change of decomposition, $\Delta_r H$, of magnesium carbonate can be found using a Hess cycle.
Calculate the enthalpy change of decomposition by using a completed Hess cycle, your answer to (b)(i) and the enthalpy change of reaction for Reaction **2**.

Give your answer to an appropriate number of significant figures.

(3)



$\Delta_r H = 3.58 + 105.4 = +108.98 \text{ kJ mol}^{-1}$

ResultsPlus
Examiner Comments

In (b)(i), the energy produced has been correctly evaluated so scores M1 but the Mr of magnesium oxide is incorrect so M2 is not scored. However, a transferred error mark can be awarded for M3 as the sign and units are correct. In (b)(ii), M1 is scored as the Hess cycle has been completed, including the equation with state symbols. M2 is scored for a correct calculation of the enthalpy change but the answer is quoted to 5 significant figures so M3 is not awarded.

ResultsPlus
Examiner Tip

All data given in the question is quoted to 3 significant figures so the answer should be quoted to a maximum of 3 significant figures.

(b) The enthalpy change for the thermal decomposition of anhydrous magnesium carbonate, $\Delta_r H$, was measured indirectly using the enthalpy changes for the two reactions shown and applying Hess's Law.

Reaction **1**

$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$ $\Delta_r H_1$

Reaction **2**

$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$ $\Delta_r H_2 = +3.58\,kJ\,mol^{-1}$

An experiment was carried out to measure the enthalpy change of reaction, $\Delta_r H_1$, for Reaction **1**.

1.92 g of magnesium oxide was added, with stirring, to 40.0 cm^3 dilute hydrochloric acid (an excess) in an insulated container. The temperature rise was 30.8 °C.

(i) Calculate $\Delta_r H_1$ for Reaction **1**. Include a sign and units in your answer.

[Assume the specific heat capacity of the solution = 4.18 $J\,g^{-1}\,°C^{-1}$
the density of the solution = 1.00 $g\,cm^{-3}$]

(3)

$E = 4.18(30.8)(1.92+40\times1) = 5396.9\ J$

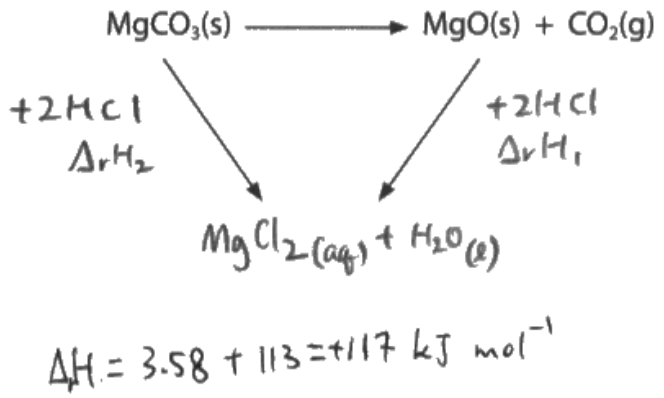
$n(MgO) = \frac{1.92}{24.3+16} = 0.0476\ mol$

$\Delta_r H_1 = -\frac{5396.9}{0.0476} = -113\ kJ\ mol^{-1}$

(ii) The enthalpy change of decomposition, $\Delta_r H$, of magnesium carbonate can be found using a Hess cycle.
Calculate the enthalpy change of decomposition by using a completed Hess cycle, your answer to (b)(i) and the enthalpy change of reaction for Reaction **2**.

Give your answer to an appropriate number of significant figures.

(3)



$\Delta H = 3.58 + 113 = +117\ kJ\ mol^{-1}$

ResultsPlus
Examiner Comments

In (b)(i), M1 is not scored as the mass of magnesium oxide has been added to the mass of acid. M2 and M3 are scored as transferred error as the sign and units of the final answer are correct. In (b)(ii), M1 is not scored as the CO_2 (g) has been omitted from the equation. M2 is scored as transferred error from part (b)(i). M3 is scored as the answer is quoted to 3 significant figures.

(b) The enthalpy change for the thermal decomposition of anhydrous magnesium carbonate, $\Delta_r H$, was measured indirectly using the enthalpy changes for the two reactions shown and applying Hess's Law.

Reaction **1**
$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$ $\Delta_r H_1$

Reaction **2**
$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$ $\Delta_r H_2 = +3.58\,kJ\,mol^{-1}$

An experiment was carried out to measure the enthalpy change of reaction, $\Delta_r H_1$, for Reaction **1**.

1.92 g of magnesium oxide was added, with stirring, to 40.0 cm^3 dilute hydrochloric acid (an excess) in an insulated container. The temperature rise was 30.8 °C.

(i) Calculate $\Delta_r H_1$ for Reaction **1**. Include a sign and units in your answer.

[Assume the specific heat capacity of the solution = 4.18 $J\,g^{-1}\,°C^{-1}$
the density of the solution = 1.00 $g\,cm^{-3}$]

(3)

$Q = 40 \times 4.18 \times 30.8$
$= 5149.76$ J

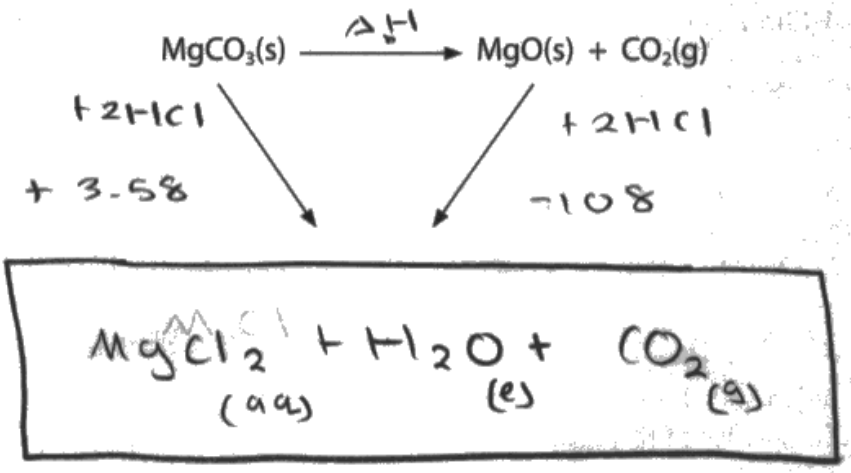
$mol = \frac{1.92}{24.3+16} = 0.0476$

$\Delta H_1 = -\frac{5149.76}{0.0476 \times 1000}$

$= -108$ kJ mol^{-1}

(ii) The enthalpy change of decomposition, $\Delta_r H$, of magnesium carbonate can be found using a Hess cycle.
Calculate the enthalpy change of decomposition by using a completed Hess cycle, your answer to (b)(i) and the enthalpy change of reaction for Reaction **2**.

Give your answer to an appropriate number of significant figures. **(3)**



$\Delta_r H = 3.58 - (-108)$

$= +112 \text{ kJmol}^{-1}$

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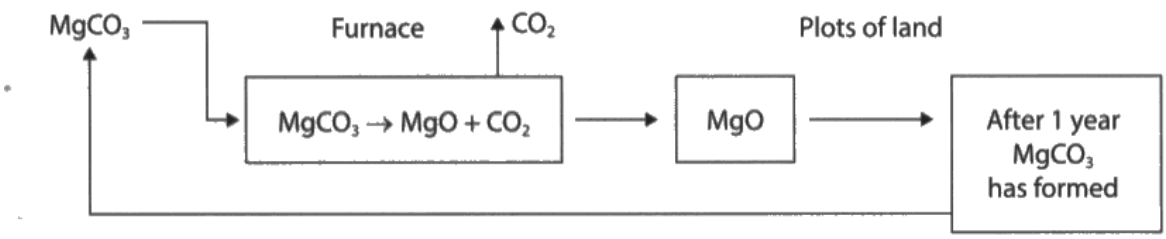
Examiner Comments

This is an example of a fully correct answer.

Question 17(c)i

The trend in stability was well known and many candidates scored the first mark. An **explanation** of the trend was required but this was not offered by many candidates. The size of the cation and polarising ability were often quoted for M2, however, there was evidence of confusion over what was being polarised. The third mark was rarely awarded as the lack of bond weakening was either not mentioned or it was not clear which bond was affected.

(c) The steps involved in using magnesium carbonate ore in a process to capture carbon dioxide from the air are shown.



- the magnesium carbonate ore is heated in a furnace and decomposes and the carbon dioxide produced is stored
- the magnesium oxide produced is transported to plots of land where it is spread to a depth of 0.1 m and reacts with carbon dioxide over a year
- the magnesium carbonate formed is then returned to the furnace and the process repeated.

Heating the furnace to decompose the magnesium carbonate accounts for most of the energy requirements of the process.

(i) Explain, with reference to the thermal stability of the Group 2 carbonates, why the use of calcium carbonate rather than magnesium carbonate would increase the cost of the process.

(3)

Thermal stability increases down the group. Therefore calcium carbonate is more ~~to~~ thermally ~~stable~~ stable than magnesium carbonate. ~~This means~~ This is because as ionic radius increases, charge remains the same, making the ion less polarising of the C=O bond, meaning the C=O bond is stronger in $CaCO_3$. meaning more energy is required to break the C=O bond in calcium carbonate. More energy would be more expensive, ~~so~~ increasing cost.

ResultsPlus
Examiner Comments

The first statement scores M1. The explanation for the trend is clearly linked to the change in ionic radius so scores M2. The reduction in the weakening of the carbon-oxygen bond in the carbonate ion is clearly stated so M3 is scored.

Paper Summary

Based on their performance on this paper, candidates should:

- Read questions carefully, noting any **bold** text and taking care with the command words.
- Learn reagents and conditions for organic chemistry reactions.
- Practise the writing of balanced equations including ionic equations and half-equations.
- Set out calculations clearly and quote answers to an appropriate level of precision.
- Practise answering questions from previous papers where explanations or comparisons are required in order to develop communication skills.

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