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June 2025

Int Advanced Level Chemistry WCH14 01

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June 2025

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Introduction

The majority of candidates found the paper accessible and were able to apply their knowledge of the topics in the specification to familiar situations. However, candidates found it more challenging when faced with questions in novel scenarios. These included, explaining the colour changes of an indicator found in bubble bath, deducing conjugate acid base pairs given the Ka values of two acids and explaining why a reaction stopped when a sample was removed from the reacting vessel. Although calculation questions generally scored highly it was sometimes hard to follow the working when candidates were faced with the unfamiliar context of calculating a temperature change from an enthalpy experiment. There was no evidence of candidates running out of time and there were very few pages left blank.

The most accessible multiple choice questions were Q07 (high resolution mass spectrometry), Q10 (reaction orders) and Q13(a) (equilibria) and the least accessible were Q06 (pH), Q01(b) (nucleophilic substitution) and Q02 (acyl chlorides).

Question 14(a)

The majority of candidates scored well on this opening question; however, a number did not read the information carefully enough. Some candidates failed to state the colour or explain why the equilibrium shifted left and a very small minority had the equilibrium wrongly moving to the right.

14 This question is about nitrosyl chloride, NOCl, which is a yellow gas.
Nitrosyl chloride decomposes into yellow-green chlorine, Cl_2, and colourless nitric oxide, NO, as shown.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

(a) A mixture of nitrosyl chloride, chlorine and nitric oxide was placed in a sealed container and allowed to reach equilibrium.

Explain what you would expect to **see** when the pressure of the equilibrium mixture is increased.

(2)

Equilibrium shifts to the left because number of gaseous molecules on left hand side is less than right hand side. So more yellow gas of nitrosyl chloride is produced. Therefore an intense yellow colour is observed.

ResultsPlus
Examiner Comments

Here the candidate has explained how and why the equilibrium shifts and stated what they would see. This excellent response scores both marks.

14 This question is about nitrosyl chloride, NOCl, which is a yellow gas.
Nitrosyl chloride decomposes into yellow-green chlorine, Cl_2, and colourless nitric oxide, NO, as shown.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

2 3

(a) A mixture of nitrosyl chloride, chlorine and nitric oxide was placed in a sealed container and allowed to reach equilibrium.

Explain what you would expect to **see** when the pressure of the equilibrium mixture is increased.

(2)

If the pressure is increased, we would see the mixture of gases becoming ~~darker, a~~ yellow.

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Examiner Comments

This candidate has stated what they would expect to see but they have not explained why the equilibrium moves so only one mark is scored. This was a common mistake.

Question 14(b)i-iii

Although most candidates were able to give the correct expression for K_c in (b)(i), a few drew round brackets instead of square ones or used Cl instead of Cl_2, both of which did not score. Calculating the number of moles at equilibrium proved to be slightly more problematic in (b)(ii) but there were a pleasing number of correct answers.

Most candidates were also able to correctly convert the moles at equilibrium to concentrations by multiplying by two and the majority were able to input their numbers correctly into their equation and determine a correct value for K_c with appropriate rounding and units in (b)(iii). However, some candidates lost a mark by incorrectly rounding or giving their answer to 4 or more significant figures and others were not careful enough transferring their tabulated values into their K_c expression.

(b) 0.250 mol of nitrosyl chloride in a 500 cm^3 sealed container was heated to 200 °C. At equilibrium there was 0.016 mol of chlorine in the mixture.

(i) Write the expression for the equilibrium constant K_c. (1)

$$K_c = \frac{[Cl]\,[NO]^2}{[NOCl]^2}$$

$n = C \times V$

(ii) Complete the table using the equilibrium equation and the data. (2)

Substance	NOCl	NO	Cl_2
Initial mol	0.250	0	0
Equilibrium mol	~~0.218~~	0.032	0.016
Concentration / mol dm^3	0.436	0.064	0.032

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Examiner Comments

Here the candidate has used a single Cl instead of Cl_2 so did not score.

(iii) Using your answers from (b)(i) and (b)(ii), calculate the equilibrium constant, K_c.
Give your answer to an appropriate number of significant figures and include units.

(3)

$K_c = \frac{0.064^2 \times 0.032}{0.436^2}$

$= 6.895 \times 10^{-4}$ mol dm^{-3}

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Examiner Comments

This candidate has given their final answer to four significant figures which lost a mark. This was the most common error in this question.

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Examiner Tip

When the question asks for an appropriate number of significant figures, it is important to look at the minimum number of significant figures in all the data used.

Question 14(b)iv

Although the majority of candidates correctly deduced the reaction was endothermic, significantly fewer were able to explain the reason for the shift in the equilibrium position.

(iv) When the temperature is reduced, the value of the equilibrium constant, K_c, becomes smaller.

Explain what can be deduced about the nature of the reaction.

(2)

when temperature reduced, Kc becomes smaller
so the equilibrium will shift to the left
because lower temperature favour the exothermic reaction
so the forward reaction of NOCl is endothermic

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Examiner Comments

This candidate demonstrates a good understanding of this reaction and excellent reasoning so scores both marks.

(iv) When the temperature is reduced, the value of the equilibrium constant, K_c, becomes smaller.

Explain what can be deduced about the nature of the reaction.

(2)

Exothermic ↑ K_c K_p ↓
Endo ↑ K_c K_p ↑

The reaction is endothermic because reduction in temperature reduces the value for K_c.

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Examiner Comments

Here the candidate understood the reaction was endothermic but did not explain the direction of movement. Instead they simply rewrote the part of the question about the K_c value, so only one mark was scored.

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Examiner Tip

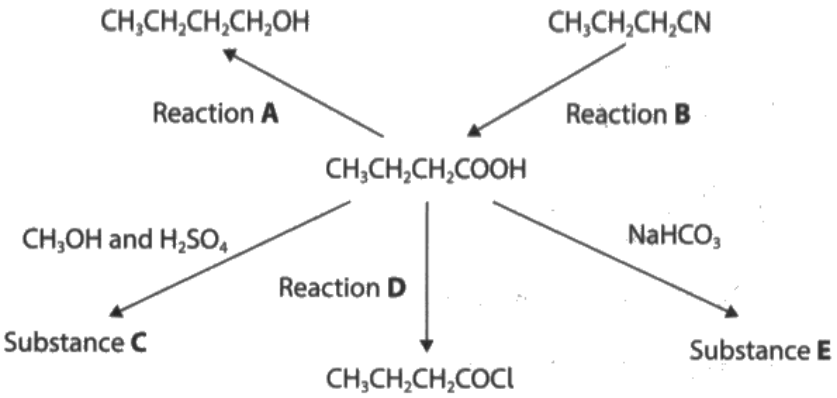
Do not rewrite parts of the question in the answer and remember the command word 'explain' requires some kind of reasoning or justification.

Question 15(a)i

Most candidates were awarded both marks here. The formula of the reagent was well known, the name less so and a number of candidates lost the mark by giving the correct formula and the incorrect name. The conditions were almost as well understood, but additional wrong information such as 'heat under reflux' meant the mark was sometimes lost.

15 This question is about butanoic acid.

(a) Some reactions involving butanoic acid are shown.



(i) Identify the reagent, by name or formula, **and** the conditions required to carry out Reaction **A**.

(2)

$LiAlH_4$ in dry ether

A correct answer.

Question 15(a)ii

Rather surprisingly this question proved much harder than expected with the majority of candidates not scoring.

(ii) Name the type of reaction taking place in Reaction **B**.

(1)

~~Nucleop~~ Nucleophilic substitution.

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Examiner Comments

This was the most common wrong answer seen.

(ii) Name the type of reaction taking place in Reaction **B**.

(1)

Hydrolysis

ResultsPlus
Examiner Comments

This correct answer was rarely seen.

Question 15(a)iii

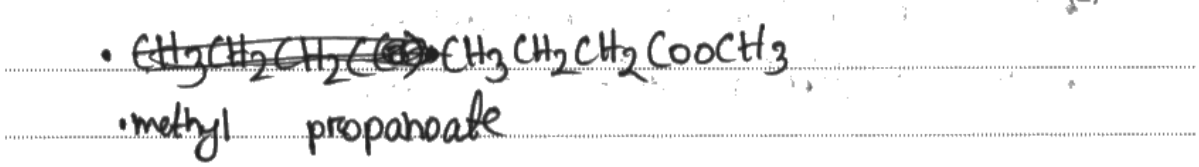
Most candidates scored at least one mark on this question.

Rather surprisingly, it was common for just the name or the formula to be given despite the question asking for both.

Other errors relating to the naming of the ester were also seen quite regularly, with methyl propanaote and butyl methanonate being the main ones.

(iii) Give the structural formula **and** name of Substance **C**.

(2)



ResultsPlus
Examiner Comments

This candidate has drawn the correct structure, but they have not counted the ester carbon when deducing the name. The name methyl propanoate was quite a common wrong answer.

(iii) Give the structural formula **and** name of Substance **C**.

(2)

methyl butanoate , ester.

Despite the question asking for two pieces of information only one has been given.

Read the question carefully and ensure the answer covers all points.

Question 15(a)iv

This reaction was particularly well understood by the majority of candidates.

Although errors were rare, they included suggesting HCl was a reagent rather than a product and also converting the carboxylic acid into an ester.

(iv) Identify, by name or formula, the reagent required to carry out Reaction **D**, giving **one** observation.

(2)

Reagent ~~KOH~~ PCl_5

Observation ~~mis~~ misty fumes of HCl is seen.

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Examiner Comments

A fully correct response.

Question 15(a)v

Most candidates knew how to construct this equation. However, missing an oxygen atom in the salt, or missing a charge on the O lost some marks.

(v) Write the full equation for the formation of Substance **E**.

State symbols are not required.

(1)

ResultsPlus
Examiner Comments

A correct equation.

(v) Write the full equation for the formation of Substance **E**.

State symbols are not required.

(1)

$CH_3CH_2CH_2COOH + NaHCO_3 \rightarrow CH_3CH_2CH_2COONa + H_2CO_3$

ResultsPlus
Examiner Comments

A fully correct answer using carbonic acid instead of water and carbon dioxide as the products.

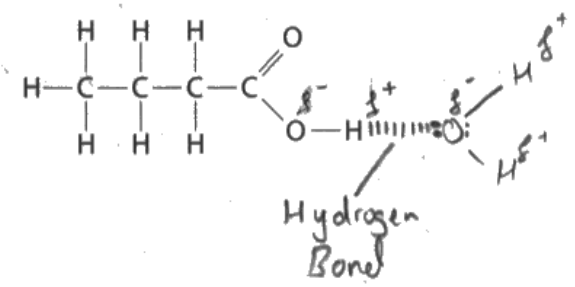
Question 15(b)

The unfamiliar context of this question meant that very few candidates scored all three marks. Many simply did not follow the instructions, missing simple things like labelling the hydrogen bond or missing off lone pairs or partial charges. A number of candidates also drew multiple water molecules or multiple bonds to one water molecule which usually led to inaccuracies.

(b) Butanoic acid is very soluble in water. This is due to strong intermolecular forces between butanoic acid molecules and water molecules.

Complete the diagram by adding **one** water molecule to show this intermolecular force. Include relevant dipoles and lone pairs.
Label the intermolecular force involved.

(3)



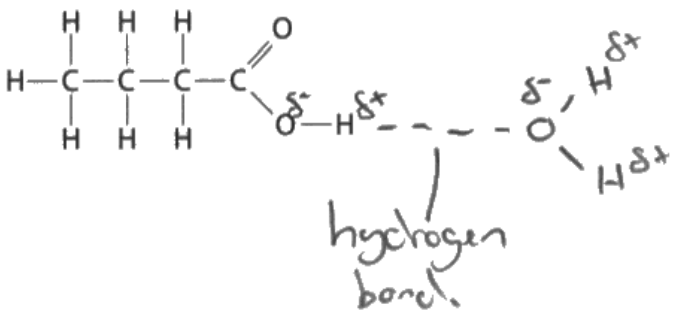
ResultsPlus
Examiner Comments

A fully correct labelled diagram.

(b) Butanoic acid is very soluble in water. This is due to strong intermolecular forces between butanoic acid molecules and water molecules.

Complete the diagram by adding **one** water molecule to show this intermolecular force. Include relevant dipoles and lone pairs.
Label the intermolecular force involved.

(3)



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Examiner Comments

This is a good attempt but they have not included the lone pair on the oxygen so a mark is lost.

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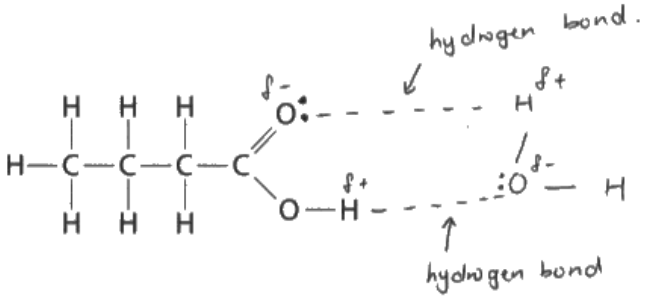
Examiner Tip

Read the question carefully and make sure all the points are covered in the answer.

(b) Butanoic acid is very soluble in water. This is due to strong intermolecular forces between butanoic acid molecules and water molecules.

Complete the diagram by adding **one** water molecule to show this intermolecular force. Include relevant dipoles and lone pairs.
Label the intermolecular force involved.

(3)



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Examiner Comments

By drawing two hydrogen bonds from the same water molecule this candidate was unable to get the correct bond angle of the upper hydrogen bond.

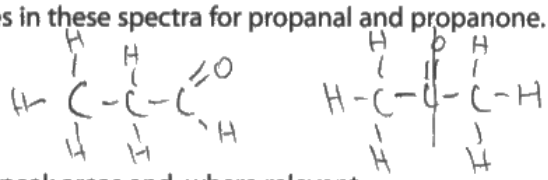
Question 16

This six-mark question proved to be a good discriminator with a mean score of just over three and the full range of marks seen. Common errors were not linking the number of proton environments to the number of peaks in IP1 and 1P3 or not linking the m/z to the formula of the fragments in IP6. Correctly identifying the splitting patterns of the propanal protons was found to be the most challenging IP, with the majority of candidates suggesting a quartet instead of a quintet split. A number of candidates also wasted time by quoting chemical shift value which were unnecessary and ignored.

***16** Proton NMR spectroscopy and mass spectrometry give detailed information about the structure of organic compounds.

Discuss the similarities and differences in these spectra for propanal and propanone.

Include in your answer:



Proton NMR Spectroscopy

- the number of peaks, the relative peak areas and, where relevant, splitting patterns

Mass spectrometry

- any *m*/*z* peaks that show one similarity and one difference between the spectra of the two compounds.

(6)

In Proton NMR, for propanal, there will be 3 peaks as there are 3 environment. One triplet, a singlet and quartet splitting pattern. Integratio will be 3, 2, 1. Due to adjacent carbon.

But for propanone, there will be one peak due to symmetry. Integration will be 6. No splitting patterns.

In mass spectrometry, there will be a similarity in a peak because they both have C=O.

~~One difference is that they~~

Here the candidate has correctly stated there are three peaks for propanal as there are three hydrogen environments so is awarded IP1. However, the splitting patterns are wrong as they say a triplet, singlet and quartet, instead of two triplets and a quintet, so no IP4 is awarded. This was a common wrong answer.

***16** Proton NMR spectroscopy and mass spectrometry give detailed information about the structure of organic compounds.

Discuss the similarities and differences in these spectra for propanal and propanone.

Include in your answer:

Proton NMR Spectroscopy

- the number of peaks, the relative peak areas and, where relevant, splitting patterns

Mass spectrometry

- any *m*/*z* peaks that show one similarity and one difference between the spectra of the two compounds.

(6)

C-C-C=O C-C(=O)-C

The proton NMR spectroscopy for propanal will have 3 peaks as there are 3 proton environments. One peak will be at 9.0-10.0ppm, have a reletive area of 1 and a triplet splitting pattern. There is only 1 hydrogen in this environment and it is bonded to 2 other hydrogens so will have a triplet splitting pattern. Another peak will be at 1.0-1.8 ppm, have a reletive area of 2 and a quintet splitting pattern. The third peak will be at 0.0-1.0 ppm, will have a reletive area of 3 and a triplet splitting pattern.

The proton NMR for propanone only has 1 peak as it only has 1 hydrogen environment. This will be at the same chemical shift, 0.0-1.0 ppm, as for the 3rd peak in propanal. It will have a splitting pattern of a singlet and a relative peak area of 6 compared to peaks for propanal.

Both have a peak between 0.0 ppm - 1.0 ppm. Propanal has 3 peaks, reletive areas 3:2:1 while propanone only has

one peak, relative area 6.

The mass spectra for propanal ~~and~~ and propanone would have a peak at 58 m/z. Only propanal would have a peak at 29 m/z.

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Examiner Comments

This excellent answer gains all the IPs relating to proton NMR spectroscopy (IP1-IP4). They also gain IP5 for the m/z of 58 for both compounds. However, IP6 is not awarded as the peak at m/z 29 seen in the mass spectrum of propanal needs the formula of the fragment and a positive charge. This was a common omission.

Question 17(a)i-ii

The vast majority of candidates were able to write the Ka expression and calculate the pH of this solution of ethanoic acid.

17 This question is about weak acids.

The values for the acid dissociation constant of ethanoic acid and chloroethanoic acid are shown.

Acid	K_a / mol dm^{-3}
ethanoic acid	1.70×10^{-5}
chloroethanoic acid	1.30×10^{-3}

a) acid

(a) (i) Write the expression for K_a for ethanoic acid, CH_3COOH.

(1)

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

(ii) Calculate the pH of a 0.25 mol dm^{-3} solution of ethanoic acid.

(2)

$$K_a = \frac{[H^+]^2}{[CH_3COOH]}$$

$$[H^+] = \sqrt{K_a \times [CH_3COOH]} = \sqrt{(1.70 \times 10^{-5})(0.25)}$$

$$= 2.06155 \times 10^{-3} \text{ mol dm}^{-3}$$

$$pH = -\log[H^+] = 2.69$$

ResultsPlus
Examiner Comments

A fully correct answer.

17 This question is about weak acids.

The values for the acid dissociation constant of ethanoic acid and chloroethanoic acid are shown.

Acid	K_a / mol dm^{-3}
ethanoic acid	1.70×10^{-5}
chloroethanoic acid	1.30×10^{-3}

(a) (i) Write the expression for K_a for ethanoic acid, CH_3COOH.

(1)

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} \qquad K_a = \frac{[H^+]^2}{[CH_3COOH]}$$

(ii) Calculate the pH of a 0.25 mol dm^{-3} solution of ethanoic acid.

(2)

$$[H^+] = \sqrt{K_a \times [CH_3COOH]}$$

$$= \sqrt{1.7 \times 10^{-5} \times 0.25}$$

$$-\log(4.25 \times 10^{-6}) = 5.37$$

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Examiner Comments

Occasionally calculation mistakes were seen, but here the candidate was able to score a transfer error mark for the correct conversion of the wrong hydrogen ion concentration to pH in (a)(ii).

Question 17(a)iii

There were plenty of correct options to choose from for this question and so candidates who didn't score were in a very small minority. One unusual error was to state that [H+] initial = [H+] eqm.

A small number of candidates simply stated the definition of a weak acid which was insufficient, whilst a few others appeared confused between weak and strong acids giving the assumption that the acid fully dissociated.

(iii) State **one** assumption you have made when calculating the pH in (a)(ii).

(1)

$[HA]_{initional} = [HA]_{equilibrium}$

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Examiner Comments

This was one of the possible correct answers as HA was an acceptable alternative to ethanoic acid.

(iii) State **one** assumption you have made when calculating the pH in (a)(ii).

(1)

$[CH_3COO^-]$ and $[H^+]$ concentration is same at equilibrium

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Examiner Comments

Another correct alternative.

(iii) State **one** assumption you have made when calculating the pH in (a)(ii).

(1)

$[H^+]_{initial} = [OH^-]_{final}$

- Initial and final are equal.

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Examiner Comments

Although not common some confused wrong answers like this were seen.

Question 17(b)i

This proved to be one of the most challenging questions on the paper. Although the majority of candidates made a correct statement about the electron withdrawing nature of the chlorine atom, only a very few were able to link this to the strength of the O-H bond or the stability of the anion. Instead, many candidates just rewrote the question and stated the chloroethanoic acid was stronger or commented on the relative magnitude of Ka or pKa, neither of which were sufficient to score the mark.

(b) (i) Suggest a reason why chloroethanoic acid, $CH_2ClCOOH$, is a stronger acid than ethanoic acid.

(1)

Chloroethanoic acid has an electron-withdrawing Cl group. It weakens the O-H bond and makes H^+ more easily be dissociated.

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Examiner Comments

This excellent answer scores the mark as the candidate explains the nature of the chlorine atom and the effect on the C-H bond.

(b) (i) Suggest a reason why chloroethanoic acid, $CH_2ClCOOH$, is a stronger acid than ethanoic acid.

(1)

The chlorine is electron withdrawing, reducing the negative charge on the COO^- ion and making it more stable.

ResultsPlus
Examiner Comments

Another excellent answer.

(b) (i) Suggest a reason why chloroethanoic acid, $CH_2ClCOOH$, is a stronger acid than ethanoic acid.

(1)

Because Cl is electron withdrawing.

ResultsPlus
Examiner Comments

The candidate has made a correct statement about chlorine but they have not then explained why it makes the acid stronger so the mark is not scored.

(b) (i) Suggest a reason why chloroethanoic acid, $CH_2ClCOOH$, is a stronger acid than ethanoic acid.

(1)

The ~~a~~ chlorine pulls electrons away from the carbon allowing the H^+ to dissociate easier.

ResultsPlus
Examiner Comments

The candidate has explained what chlorine does but has not explained why the acid loses a proton easier so the mark is not scored.

Question 17(b)ii

The majority of candidates had a reasonable understanding of conjugate acids and bases but a lack of precision often cost marks. Missing a hydrogen on the protonated ethanoic acid or a lack of one or both charges were common mistakes.

Candidates found identifying the conjugate acid/base pairs more challenging and some had B1 and A1 on the same side of the equation.

(ii) When ethanoic acid and chloroethanoic acid are added together an equilibrium is set up containing two acid-base pairs.

Complete the equilibrium equation, labelling the conjugate acid-base pairs as A1, B1 and A2, B2.

(2)

$CH_3COOH + CH_2ClCOOH \rightleftharpoons CH_3COOH_2^+ + CH_2ClCOO^-$

B2 A1 A2 B1

ResultsPlus
Examiner Comments

A fully correct answer.

(ii) When ethanoic acid and chloroethanoic acid are added together an equilibrium is set up containing two acid-base pairs.

Complete the equilibrium equation, labelling the conjugate acid-base pairs as A1, B1 and A2, B2.

(2)

$CH_3COOH + CH_2ClCOOH \rightleftharpoons CH_3COOH_2 + CH_2ClCOO^-$

B1 A1 A2 B2

ResultsPlus
Examiner Comments

The candidate has missed out a charge on the protonated ethanoic acid and numbered the conjugate pairs incorrectly so no marks are scored.

ResultsPlus
Examiner Tip

When writing equations check that both the atoms and charges balance.

(ii) When ethanoic acid and chloroethanoic acid are added together an equilibrium is set up containing two acid-base pairs.

Complete the equilibrium equation, labelling the conjugate acid-base pairs as A1, B1 and A2, B2.

(2)

$CH_3COOH + CH_2ClCOOH \rightleftharpoons CH_3COOH_2^+ + CH_2ClCOO^-$

ResultsPlus
Examiner Comments

The equation is correct but the candidate has not labelled the conjugate pairs so only one mark is awarded.

Question 17(c)

This question was a good discriminator with the full range of marks seen and an average score of about two marks out of four. It was expected that candidates would tackle this buffer question by calculating the number of moles of acid and salt or by calculating the concentration of the acid and salt. However, a large number used the Henderson-Hasselbalch equation, despite it not being in the Edexcel IAL specification. Although there were many fully correct answers, it was often hard to follow some calculations and a confusion between moles and concentrations sometimes made it hard to award transfer error marks. Those candidates who used the Henderson-Hasselbalch equation were more prone to errors than candidates using one of the other two methods.

A few candidates did not remember the Henderson-Hasselbalch equation correctly, some confused Ka with pKa and others got the acid and salt ratio the wrong way round.

(c) A buffer was made by mixing 8.20 g of sodium ethanoate, CH_3COONa, with 250 cm^3 of 0.700 mol dm^{-3} solution of ethanoic acid, CH_3COOH.

Calculate the pH of the buffer.

(4)

$\frac{8.2}{82} = 0.1$ moles

$\frac{0.1}{0.25} = 0.4 \text{ mol dm}^{-3}$

$1.7 \times 10^{-5} = \frac{(0.4)[H^+]}{0.7}$

$[H^+] = \frac{1.7 \times 10^{-5} \times 0.7}{0.4}$

$-\log_{10}[H^+] = \boxed{4.53} = pH$

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Examiner Comments

Here the candidate has successfully used the concentration route to calculate the pH and scores full marks.

(c) A buffer was made by mixing 8.20 g of sodium ethanoate, CH_3COONa, with 250 cm^3 of 0.700 mol dm^{-3} solution of ethanoic acid, CH_3COOH.

Calculate the pH of the buffer.

(4)

$M_r = 2(12) + 3 + 2(16) + 23$

$= 82$

$n = \frac{8.2}{82}$

$= 0.1$

$C = \frac{0.1}{250 \times 10^{-3}}$

$= 0.4$

$pKa = -\log(1.7 \times 10^{-5})$

$= 4.7695511$

$pH = 4.7695511 + \log\left(\frac{0.4}{0.7}\right)$

$= 4.52651 = 4.52$

ResultsPlus
Examiner Comments

Here the candidate has successfully used the Henderson-Hasselbalch equation to calculate the pH and scores full marks.

(c) A buffer was made by mixing 8.20 g of sodium ethanoate, CH_3COONa, with 250 cm^3 of 0.700 mol dm^{-3} solution of ethanoic acid, CH_3COOH.

Calculate the pH of the buffer. (4)

mol of $CH_3COONa = \frac{8.20}{82} = 0.1$

mol of $CH_3COOH = 0.700 \times \frac{250}{1000} = 0.175$

ratio

1 : 1.75

$1.30 \times 10^{-3} = \frac{[H^+]}{[0.700]}$ pH of

$\frac{1.754 \times 1.70 \times 10^{-5}}{1 \times 1.30 \times 10^{-3}}$

ResultsPlus
Examiner Comments

This candidate has used the moles route and scores a mark for calculating the moles of acid and salt. Whilst attempting to rearrange the equation to find the concentration of hydrogen ions, they have wrongly used the Ka of chloroethanoic acid so no further marks are scored.

Question 17(d)

This question was found to be challenging to the majority of candidates. Most were able to score the first mark for the initial colour of the indicator in the acidic conditions found in the bubble bath. However, very few candidates understood the chemistry involved when the bubble bath was diluted with water. Many thought that adding the water caused a neutralisation reaction and some even suggested it made the bath water alkaline. There were some very good answers seen that covered all the scoring points and a few excellent responses that explained the significance of pKin and how the ratio of the two coloured forms altered to produce the bath water colour changes.

(d) A type of bubble bath contains a weak acid and the indicator bromocresol green. The bubble bath is initially yellow but when diluted with bath water, its colour changes from yellow to green to blue.

Use the information on page 9 of the Data Booklet to deduce why the bubble bath changes colour.

(3)

The pK_{In} of bromocresol green is 4.7, and the colour change range is 3.8 ~ 5.4. When pH < 3.8, it is yellow. pH > 5.4 it's blue.

At the beginning, the pH value of bubble bath is smaller than 3.8, when the bath is diluted with bath water, the pH begins to increase, to pH = 4.7, the mix of yellow and blue is green, so the colour change to green. As the pH increase, the pH > 5.4, the colour turn to blue.

ResultsPlus
Examiner Comments

This is an excellent answer. The candidate understands that when water is added dilution takes place and the pH rises. They then relate the change in colour to the change in pH.

(d) A type of bubble bath contains a weak acid and the indicator bromocresol green. The bubble bath is initially yellow but when diluted with bath water, its colour changes from yellow to green to blue.

Use the information on page 9 of the Data Booklet to deduce why the bubble bath changes colour.

(3)

Initially, the bubble bath is acidic so it is yellow in colour. ~~(to the)~~ Bath water ~~(has a pH 7 so it)~~ is alkaline and once it started getting diluted, the solution became neutral ~~(so with pH 7)~~ showing green in the indicator. Upon diluting it further, the solution became alkaline so the indicator turned blue.

ResultsPlus
Examiner Comments

This candidate has scored a mark for the initial colour of the bubble bath. However, they then suggest that adding water causes neutralisation and no further marks are awarded. This was a very common error.

Question 18(a)i

Rather surprisingly, this question was found to be challenging to many candidates.

Although a number made the correct deduction that the catalyst was no longer present in the extracted sample, many incorrect responses such as quenching were seen. A number of candidates also got the reaction confused and thought autocatalysis was taking place or misidentified the catalyst as manganese(II) ions or manganate(VII).

18 This question is about the kinetics of the catalytic decomposition of hydrogen peroxide, H_2O_2, using manganese(IV) oxide as a catalyst.

The equation for the decomposition is shown. MnO_2

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

In an experiment, 10 cm^3 of hydrogen peroxide solution was added to 150 cm^3 of distilled water. A small amount of manganese(IV) oxide granules was added and the clock started.

Every 5 minutes, 10 cm^3 samples of the reaction mixture were withdrawn using a pipette and transferred to a conical flask.

The samples were then acidified with dilute sulfuric acid and titrated with potassium manganate(VII) solution. The equation for the titration is shown.

$$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$$

The results of the experiment are given in the table.

Time / min	0	5	10	15	20	25	30
Volume of manganate(VII) / cm^3	32.5	24.8	18.9	13.9	10.5	8.1	6.5

(a) (i) The reaction in the sample stops immediately on removal from the reaction mixture.

Suggest why this occurs.

(1)

There is no catalyst in the sample to lower the activation energy of decomposition.

ResultsPlus
Examiner Comments

A correct answer.

18 This question is about the kinetics of the catalytic decomposition of hydrogen peroxide, H_2O_2, using manganese(IV) oxide as a catalyst.

The equation for the decomposition is shown.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

In an experiment, 10 cm^3 of hydrogen peroxide solution was added to 150 cm^3 of distilled water. A small amount of manganese(IV) oxide granules was added and the clock started.

Every 5 minutes, 10 cm^3 samples of the reaction mixture were withdrawn using a pipette and transferred to a conical flask.

The samples were then acidified with dilute sulfuric acid and titrated with potassium manganate(VII) solution. The equation for the titration is shown.

$$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$$

The results of the experiment are given in the table.

Time / min	0	5	10	15	20	25	30
Volume of manganate(VII) / cm^3	32.5	24.8	18.9	13.9	10.5	8.1	6.5

(a) (i) The reaction in the sample stops immediately on removal from the reaction mixture.

Suggest why this occurs.

(1)

Because reaction is quenched, not enough particles to react, cannot reach activation energy.

ResultsPlus
Examiner Comments

This was a common wrong answer.

18 This question is about the kinetics of the catalytic decomposition of hydrogen peroxide, H_2O_2, using manganese(IV) oxide as a catalyst.

The equation for the decomposition is shown.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

In an experiment, 10 cm^3 of hydrogen peroxide solution was added to 150 cm^3 of distilled water. A small amount of manganese(IV) oxide granules was added and the clock started.

Every 5 minutes, 10 cm^3 samples of the reaction mixture were withdrawn using a pipette and transferred to a conical flask.

The samples were then acidified with dilute sulfuric acid and titrated with potassium manganate(VII) solution. The equation for the titration is shown.

$$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$$

The results of the experiment are given in the table.

Time / min	0	5	10	15	20	25	30
Volume of manganate(VII) / cm^3	32.5	24.8	18.9	13.9	10.5	8.1	6.5

(a) (i) The reaction in the sample stops immediately on removal from the reaction mixture.

Suggest why this occurs.

(1)

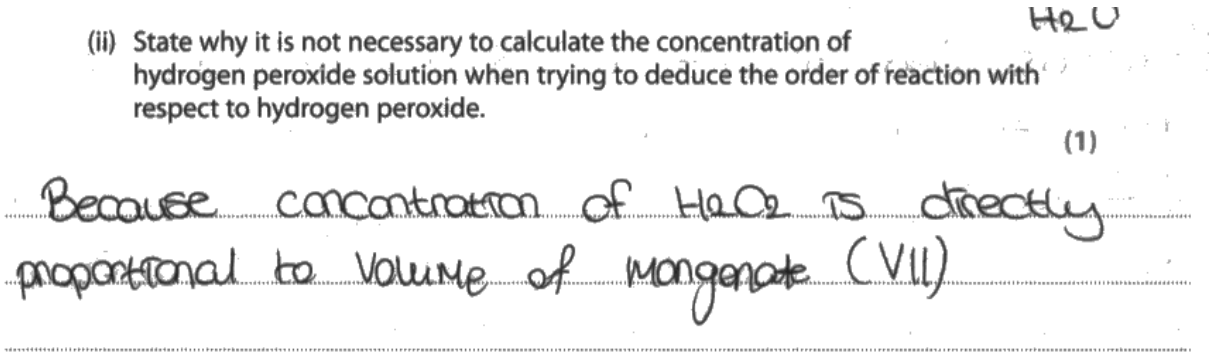
Because Mn^{2+} is an auto-catalyst, ~~removal from the~~ remove MnO_4^- means that no Mn^{2+} will continue to produce.

ResultsPlus
Examiner Comments

This was quite a common incorrect response. The candidate has confused this reaction with autocatalysis.

Question 18(a)ii

Most candidates deduced that there was a connection between the hydrogen peroxide solution and the potassium manganate(VII) solution but very few were able to state the relationship precisely enough to score the mark.



(ii) State why it is not necessary to calculate the concentration of hydrogen peroxide solution when trying to deduce the order of reaction with respect to hydrogen peroxide.

H_2O

(1)

Because concentration of H_2O_2 is directly proportional to volume of manganate (VII)

ResultsPlus
Examiner Comments

A correct answer.

(ii) State why it is not necessary to calculate the concentration of hydrogen peroxide solution when trying to deduce the order of reaction with respect to hydrogen peroxide.

(1)

Because the concentration of hydrogen peroxide remains almost unchanged as it is in excess. Volume of manganate (VII) added is equal to concentration of hydrogen peroxide

ResultsPlus
Examiner Comments

This candidate knows there is some relationship between volume and concentration but they are not equal to each other.

(ii) State why it is not necessary to calculate the concentration of hydrogen peroxide solution when trying to deduce the order of reaction with respect to hydrogen peroxide.

(1)

Because the concentration is proportional to the volume

ResultsPlus
Examiner Comments

This candidate knows there is a relationship between concentration and volume but has not stated what the compounds are so the mark is not scored.

ResultsPlus
Examiner Tip

Make sure answers are not missing essential detail.

(ii) State why it is not necessary to calculate the concentration of hydrogen peroxide solution when trying to deduce the order of reaction with respect to hydrogen peroxide.

(1)

H_2O_2 is both present in slow step of reaction. Order of reaction with respect to H_2O_2 is same with order of reaction with respect to MnO_4^-

ResultsPlus
Examiner Comments

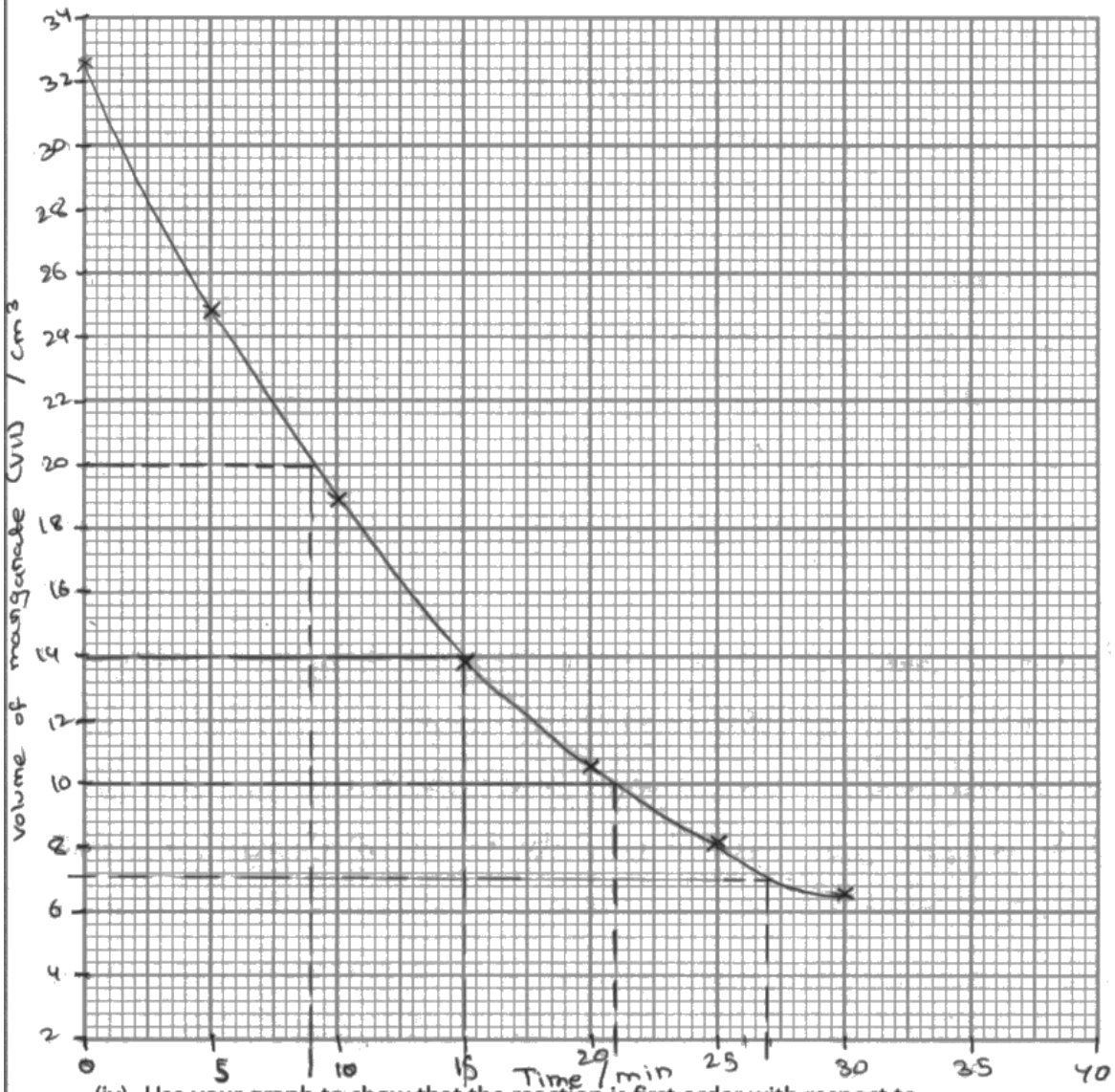
Only about 10% of candidates scored this mark and this is an example of the range of wrong responses that were seen.

Question 18(a)iii-iv

Although some candidates used an awkward scale that made it more challenging to plot, the graph in (a)(iii) was generally well plotted and a neat smooth curved line drawn. If a mark was lost it was usually for missing or incorrect units on the axes. The constant half-lives of a first order reaction were nearly universally recalled in (a)(vi) but fewer candidates managed to show them on the graph or state their values.

(iii) Plot a graph of the volume of potassium manganate(VII) solution against time.

(3)



(iv) Use your graph to show that the reaction is first order with respect to hydrogen peroxide. You must show your working on the graph.

(3)

$20\ cm^3 \rightarrow 10\ cm^3 \quad t_{1/2} = 21 - 9 = 12$ minutes.

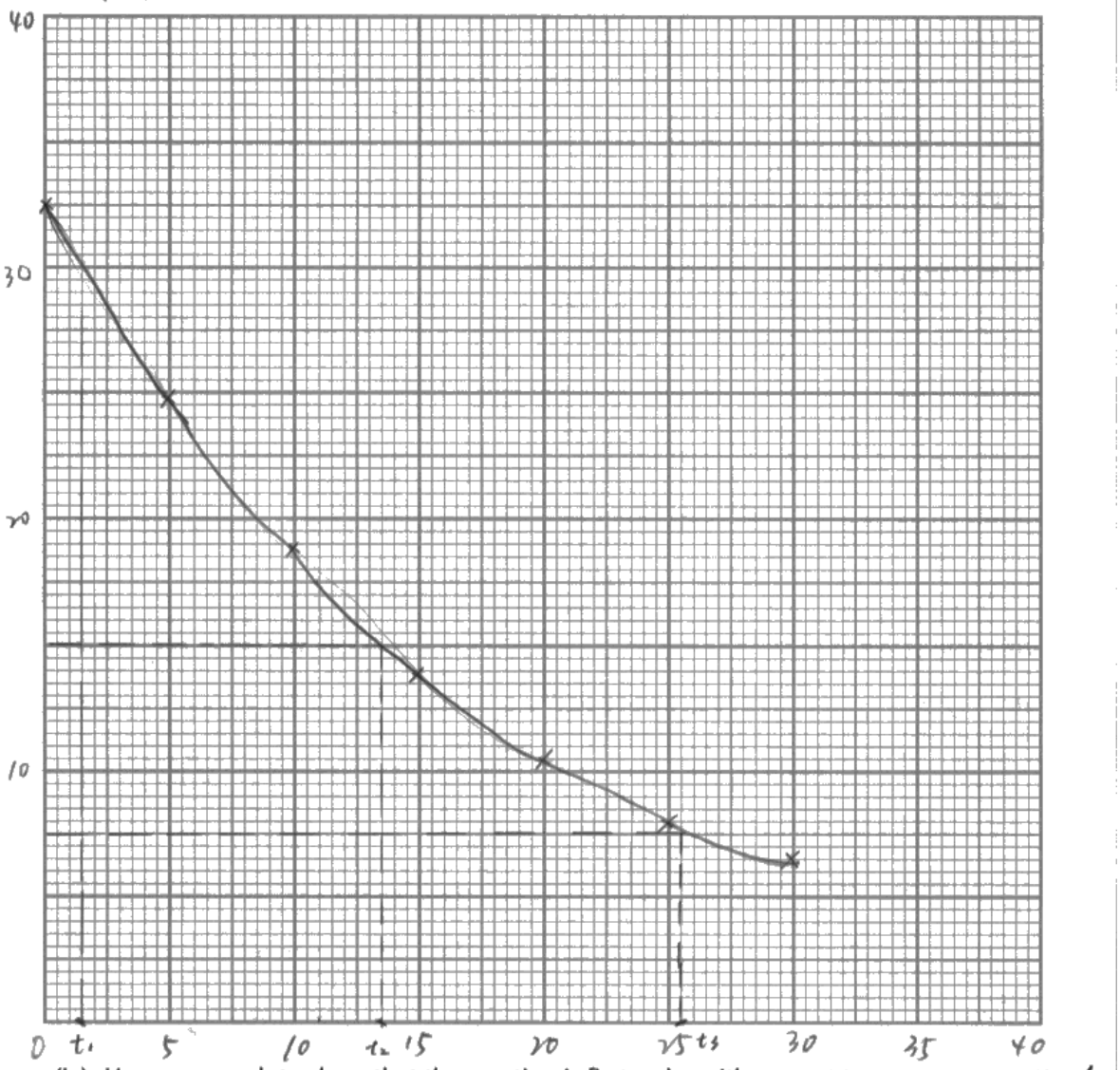
$14\ cm^3 \rightarrow 7\ cm^3 \quad t_{1/2} = 27 - 15 = 12$ minutes.

half-life constant, so first order.

The candidate has plotted the graph correctly and used non successive half-lives to score full marks.

(iii) Plot a graph of the volume of potassium manganate(VII) solution against time.

(3)



(iv) Use your graph to show that the reaction is first order with respect to hydrogen peroxide. You must show your working on the graph.

(3)

- The graph can be used to determine the half-life of the hydrogen peroxide
- the every half-life have same length of time.
- So the ~~rear~~ first order with respect to hydrogen peroxide

ResultsPlus
Examiner Comments

The candidate has lost a mark for the graph as they have not included the units for the volume of potassium manganate(VII). This was a common error. Although they have correctly drawn two successive half-lives at 15 and 7.5 cm^3, they have not stated their values so a mark is lost here too.

Question 18(b)

Responses to this question were very varied. Only a minority of candidates made the link between the number of H_2O_2 molecules in the slow or rate determining step and the order of reaction to score both marks.

A much larger number of candidates could state the order for each reaction with respect to H_2O_2 or write the rate equation for each reaction to score one mark. Unfortunately, a significant number of candidates did not understand the significance of the number of H_2O_2 molecules in the slow or rate determining step to the order of reaction and were unable to score.

(b) Two possible mechanisms have been suggested by students carrying out this reaction.

Mechanism 1

Step 1 $2H_2O_2(aq) \rightarrow [H_4O_4](aq)$ (transition state) slow

Step 2 $[H_4O_4](aq) \rightarrow 2H_2O(l) + O_2(g)$ fast

Mechanism 2

Step 1 $H_2O_2 \rightarrow 2OH$ slow

Step 2 $H_2O_2 + OH \rightarrow H_2O + HO_2$ fast

Step 3 $HO_2 + OH \rightarrow H_2O + O_2$ fast

Explain whether or not these mechanisms are consistent with the reaction being first order.

(2)

• mechanism 1 is not consistent with reaction being first order as the slow step has 2 moles of H_2O_2 present which would make the reaction 2nd order. • mechanism 2 is consistent with reaction being first order as the slow step has only 1 mole of H_2O_2. **(Total for Question 18 = 10 marks)**

ResultsPlus
Examiner Comments

The candidate has related the order to the number of molecules in the slow step and scores both marks.

(b) Two possible mechanisms have been suggested by students carrying out this reaction.

Mechanism 1

Step 1 $2H_2O_2(aq) \rightarrow [H_4O_4](aq)$ (transition state) slow

Step 2 $[H_4O_4](aq) \rightarrow 2H_2O(l) + O_2(g)$ fast

Mechanism 2

Step 1 $H_2O_2 \rightarrow 2OH$ slow

Step 2 $H_2O_2 + OH \rightarrow H_2O + HO_2$ fast

Step 3 $HO_2 + OH \rightarrow H_2O + O_2$ fast

Explain whether or not these mechanisms are consistent with the reaction being first order.

(2)

1. rate = $k[H_2O_2]^2$ this is second order

2. rate = $k[H_2O_2]$ this is ~~1st~~ first order

therefore mechanism 2 is consistent with the reaction being first order.

(Total for Question 18 = 10 marks)

ResultsPlus
Examiner Comments

The candidate has worked out the order of reaction for both mechanisms but has not mentioned the number of molecules in the rate determining steps, so only one mark is scored. This was a common response and only scored one mark.

Question 19(a)

Most candidates found these calculations quite straightforward with many scoring full marks. In (a)(i) and (a)(ii) the most common error was to miss off the factor of five for the number of water molecules.

Any mistakes did allow transfer error marks in (a)(iii). The final calculation in (a)(iii) proved the most challenging with many candidates missing out multiplying by 1000 and it was surprising the number of candidates who gave a negative Kelvin value, despite this being impossible.

19 This question is about some copper compounds.

(a) Crystals of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, lose water when heated, forming anhydrous copper(II) sulfate, $CuSO_4$.

$$CuSO_4 \cdot 5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

Substance	$CuSO_4 \cdot 5H_2O(s)$	$CuSO_4(s)$	$H_2O(l)$
Standard enthalpy of formation, $\Delta_f H^\ominus$ / $kJ\,mol^{-1}$	−2279.6	−771.4	−285.8
Standard molar entropy, $S^\ominus$ / $J\,K^{-1}\,mol^{-1}$	300.4	109.0	69.9

(i) Using the data in the table, calculate the standard enthalpy change, $\Delta_r H^\ominus$, for this reaction.

(2)

$\Delta_r H^\ominus = -771.4 - 285.8 \times 5 - (-2279.6)$

$= 79.2\ kJ\ mol^{-1}$

(ii) Using the data in the table, calculate the standard molar entropy change, $\Delta S^\ominus_{system}$, for this reaction.

(2)

$\Delta S^\ominus_{system} = 109 + 5 \times 69.9 - 300.4$

$= 158.1$

(iii) Using your answers from (a)(i) and (a)(ii), calculate the **lowest** temperature at which hydrated copper(II) sulfate will decompose.

(3)

$\Delta S_{system} = \Delta S_{system} + \Delta S_{surroundings}$

$= 158.1 - \frac{\Delta H}{T}$

when $\Delta S_{system} = 0$, T is the lowest

so $T = \frac{\Delta H}{158.1}$

$= \frac{79200}{158.1} = 501\ K$

$t = 501 - 273$

$= 228^\circ C$

A fully correct answer.

19 This question is about some copper compounds.

(a) Crystals of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, lose water when heated, forming anhydrous copper(II) sulfate, $CuSO_4$.

$$CuSO_4 \cdot 5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

Substance	$CuSO_4 \cdot 5H_2O(s)$	$CuSO_4(s)$	$H_2O(l)$
Standard enthalpy of formation, $\Delta_f H^\ominus$ / $kJ\,mol^{-1}$	−2279.6	−771.4	−285.8
Standard molar entropy, $S^\ominus$ / $JK^{-1}\,mol^{-1}$	300.4	109.0	69.9

(i) Using the data in the table, calculate the standard enthalpy change, $\Delta_r H^\ominus$, for this reaction.

(2)

$-771.4 + 5(-285.8) - (-2279.6)$

$= \boxed{79.2\ kJ\,mol^{-1}}$

(ii) Using the data in the table, calculate the standard molar entropy change, $\Delta S^\ominus_{system}$, for this reaction.

(2)

$109.0 + 5(69.9) - 300.4 = \boxed{158.1\ JK^{-1}mol^{-1}}$

(iii) Using your answers from (a)(i) and (a)(ii), calculate the **lowest** temperature at which hydrated copper(II) sulfate will decompose.

(3)

$\frac{-79.2}{T} + 158.1 = 0$

$\frac{-79.2}{T} = -158.1$ $\quad \frac{-79.2}{-158.1} = T = \boxed{0.5\ K}$

Parts (a)(i) and (ii) are correct but in part (iii) the candidate has not multiplied by 1000. Despite the fact that this is such a low temperature and cannot be correct, only one mark was lost.

When doing entropy calculations pay particular attention to the units and check the final answer to see if it is possible.

19 This question is about some copper compounds.

(a) Crystals of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, lose water when heated, forming anhydrous copper(II) sulfate, $CuSO_4$.

$$CuSO_4 \cdot 5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

Substance	$CuSO_4 \cdot 5H_2O(s)$	$CuSO_4(s)$	$H_2O(l)$
Standard enthalpy of formation, $\Delta_f H^\ominus$ / kJ mol^{-1}	−2279.6	−771.4	−285.8
Standard molar entropy, $S^\ominus$ / J K^{-1} mol^{-1}	300.4	109.0	69.9

(i) Using the data in the table, calculate the standard enthalpy change, $\Delta_r H^\ominus$, for this reaction.

(2)

Σproducts − Σreactants, $(C-285.8 \times 5) + (-771.4)) - C-2279.6)$

$= -2200.4 + 2279.6 = 79.2$ kJ mol^{-1}

(ii) Using the data in the table, calculate the standard molar entropy change, $\Delta S^\ominus_{system}$, for this reaction.

(2)

Σ products − Σreactants

$= ((69.6 \times 5) + (109)) - 300.4$

$= 156.6$ J K^{-1} mol^{-1}

(iii) Using your answers from (a)(i) and (a)(ii), calculate the **lowest** temperature at which hydrated copper(II) sulfate will decompose.

(3)

$\Delta G_T = \Delta H - T\Delta S_{system}$

$79.2 \times 1000 = T \times 156.6$

$T = 506$ K

Part (a)(i) is correct but in part (ii) the candidate has made a mistake in the calculation so a mark is lost. However, this figure is correctly used in part (iii) and all three marks are scored through transferred error.

19 This question is about some copper compounds.

(a) Crystals of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, lose water when heated, forming anhydrous copper(II) sulfate, $CuSO_4$.

$$CuSO_4 \cdot 5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

Substance	$CuSO_4 \cdot 5H_2O(s)$	$CuSO_4(s)$	$H_2O(l)$
Standard enthalpy of formation, $\Delta_f H^\ominus$ / $kJ\,mol^{-1}$	−2279.6	−771.4	−285.8
Standard molar entropy, $S^\ominus$ / $JK^{-1}\,mol^{-1}$	300.4	109.0	69.9

(i) Using the data in the table, calculate the standard enthalpy change, $\Delta_r H^\ominus$, for this reaction.

(2)

$-771.4 - 5(285.8) - (-2279.6) = 79.2$ kJ/mol

(ii) Using the data in the table, calculate the standard molar entropy change, $\Delta S^\ominus_{system}$, for this reaction.

158.1

(2)

$109. + 5(69.9) - 300.4 = 158.1$ ~~kJ~~ J/K/mol

(iii) Using your answers from (a)(i) and (a)(ii), calculate the **lowest** temperature at which hydrated copper(II) sulfate will decompose.

(3)

$0 = \frac{-\Delta H}{T} + \Delta S_{total}$

$0 = \frac{-79.2 \times 10^3}{T} + \cancel{+35}\ 158.1$

$-158.1 \times T = -79.2 \times 10^3$

$T = \frac{-79.2 \times 10^3}{-158.1}$ $\quad T = \cancel{500}\ 501\ ^\circ C$

Parts (a)(i) and (ii) are correct. In part (iii) the candidate has done the calculation correctly but has given the wrong units so a mark is lost.

Pay attention to units as marks can be lost so easily.

Question 19(b)

This novel calculation proved to be quite challenging. Whilst a large number of candidates knew exactly what to do and arrived at the correct answer, there were numerous and varied errors seen in the majority of responses. The masses of solid and solution were frequently confused and often moles were not included in the calculation at all. However, transfer error marks were awarded and so the mean mark was just above two.

(b) Hydrated copper(II) sulfate is soluble in water. A student carried out an experiment to determine its enthalpy change of solution.

100 g of distilled water was placed in a polystyrene cup and the temperature recorded.

21.36 g of hydrated copper sulfate was added to the distilled water, the mixture stirred, and the minimum temperature recorded.

Using this data, the student's calculated enthalpy change of solution was +12.3 kJ mol^{-1}.

Calculate the temperature change in this experiment.

[specific heat capacity of the solution is 3.7 J g^{-1} °C
total mass of solution = 121.36 g
molar mass of $CuSO_4 \cdot 5H_2O$ = 249.6 g mol^{-1}]

(4)

$Q = mc\Delta T$

$= (121.36)(3.7)\Delta T$

$1052.596 = 121.36(3.7)\Delta T$

$\Delta T = 2.34\ ^\circ C$

$\Delta H = \frac{\theta}{mol}$

$+12.3 = \frac{\theta}{0.086}$

$n = \frac{m}{RFM}$

$n = \frac{21.36}{249.6} = 0.0855769$

$\theta = 1.0526\ kJ$

$\times 1000$

$= 1052.596\ J$

2.34°C

ResultsPlus
Examiner Comments

A fully correct answer.

(b) Hydrated copper(II) sulfate is soluble in water. A student carried out an experiment to determine its enthalpy change of solution.

100 g of distilled water was placed in a polystyrene cup and the temperature recorded.

21.36 g of hydrated copper sulfate was added to the distilled water, the mixture stirred, and the minimum temperature recorded.

Using this data, the student's calculated enthalpy change of solution was +12.3 kJ mol^{-1}. ΔH.

Calculate the temperature change in this experiment.

[specific heat capacity of the solution is 3.7 J g^{-1} °C
total mass of solution = 121.36 g
molar mass of $CuSO_4 \cdot 5H_2O$ = 249.6 g mol^{-1}]

(4)

$q = n \times \Delta H$

$q = n \times \Delta H$

Temp $= \frac{q}{mc}$.

$q = n \times \Delta H$

$\text{mol} = \frac{121.36}{249.6} = 0.49 \text{ mol}$

$q = 0.49 \times 12.3$

$q = 5.98$

Tem change $= \frac{q}{n \times c}$ $5.98 \times 1000 = 5980.5$

$\frac{5980.5}{(3.7) \times 121.36} = 13.3^{\circ}c$

ResultsPlus
Examiner Comments

This candidate used the wrong mass of copper sulfate to calculate the moles (121.36 g instead of 21.36 g) but achieved transfer error marks. This was a common error.

(b) Hydrated copper(II) sulfate is soluble in water. A student carried out an experiment to determine its enthalpy change of solution.

100 g of distilled water was placed in a polystyrene cup and the temperature recorded.

21.36 g of hydrated copper sulfate was added to the distilled water, the mixture stirred, and the minimum temperature recorded.

Using this data, the student's calculated enthalpy change of solution was +12.3 kJ mol^{-1}.

Calculate the temperature change in this experiment.

[specific heat capacity of the solution is 3.7 J g^{-1} °C
total mass of solution = 121.36 g
molar mass of $CuSO_4 \cdot 5H_2O$ = 249.6 g mol^{-1}]

(4)

$m = 100 cm^3$ $\quad Q = 100 \times 3.7 \times x$

$Q = 370x$

$\frac{}{1000}$

$Q = 0.37x$

$+12.3 = \frac{0.37x}{0.0855769}$

$moles = \frac{21.36}{249.6} = 0.0855769$

$\frac{1.052596}{0.37} = \frac{0.37x}{0.37}$

$x = 2.84$

$\Delta T = 2.84\ ^{\circ}C$

ResultsPlus
Examiner Comments

This candidate used the wrong mass of solution (100 g instead of 121.36 g) but achieved transfer error marks. This was a very common error.

(b) Hydrated copper(II) sulfate is soluble in water. A student carried out an experiment to determine its enthalpy change of solution.

100 g of distilled water was placed in a polystyrene cup and the temperature recorded.

21.36 g of hydrated copper sulfate was added to the distilled water, the mixture stirred, and the minimum temperature recorded.

Using this data, the student's calculated enthalpy change of solution was $+12.3\ kJ\ mol^{-1}$.

Calculate the temperature change in this experiment.

[specific heat capacity of the solution is $3.7\ J\ g^{-1}\ °C$
total mass of solution = 121.36 g
molar mass of $CuSO_4 \cdot 5H_2O = 249.6\ g\ mol^{-1}$]

(4)

moles of $CuSO_4\ 5H_2O = \frac{21.36}{249.6} = 0.085576$ moles

ResultsPlus
Examiner Comments

This candidate correctly calculated the number of moles so scored one mark.

Question 19(c)i

Very few candidates managed to recall correctly and in sufficient detail both parts of this definition. Although a significant number of candidates scored one mark for mentioning enthalpy change and one mole of gaseous ions, many missed this by stating that energy was needed or required. The second marking point was more challenging and few candidates could explain the process clearly and in sufficient detail to score.

(c) Copper(II) chloride, $CuCl_2$, is another copper compound that is soluble in water. It is possible to calculate the enthalpy change of solution, $\Delta_{sol}H$, using a Hess cycle and the lattice energy and enthalpy changes of hydration, $\Delta_{hyd}H$.

(i) Explain what is meant by the term **enthalpy change of hydration**.

(2)

enthalpy change to change 1 mol of gaseous ions to aqueous ions by excess dilution by water such that no heat change occurs in further dilution

ResultsPlus
Examiner Comments

A fully correct answer.

(c) Copper(II) chloride, $CuCl_2$, is another copper compound that is soluble in water. It is possible to calculate the enthalpy change of solution, $\Delta_{sol}H$, using a Hess cycle and the lattice energy and enthalpy changes of hydration, $\Delta_{hyd}H$.

(i) Explain what is meant by the term **enthalpy change of hydration**.

(2)

The energy required turn one mole of gaseous ions to one mole of aqueous ions in an infinitely diluted solution under standard conditions

ResultsPlus
Examiner Comments

Any mention of energy required was a 'do not award' for the first mark. However, the candidate scores the second mark for 'infinitely dilute solution'.

ResultsPlus
Examiner Tip

When asked to give an enthalpy change definition, use the phrase 'enthalpy change' in the answer to avoid the risk of losing a mark.

(c) Copper(II) chloride, $CuCl_2$, is another copper compound that is soluble in water. It is possible to calculate the enthalpy change of solution, $\Delta_{sol}H$, using a Hess cycle and the lattice energy and enthalpy changes of hydration, $\Delta_{hyd}H$.

(i) Explain what is meant by the term **enthalpy change of hydration.**

(2)

the energy released when 1 mole of a substances gaseous ions dissolve in water to become soluble

ResultsPlus
Examiner Comments

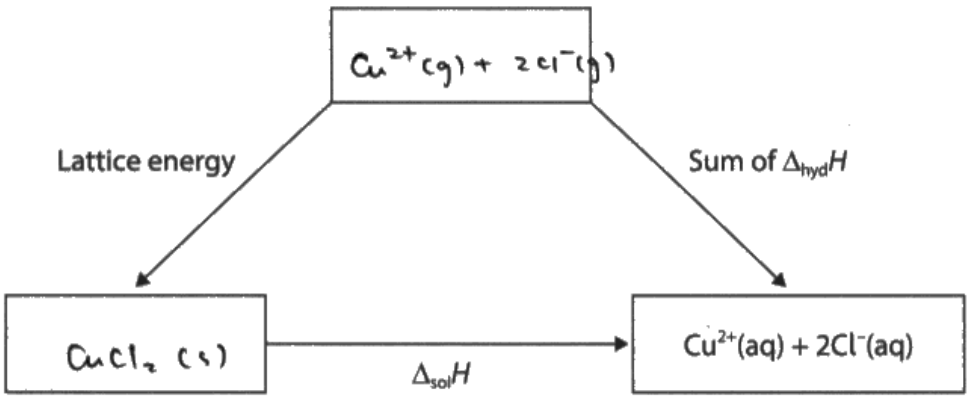
The candidate scores one mark for mentioning the energy released when one mole of gaseous ions dissolve in water. The second mark is not scored as they do not say completely dissolved.

Question 19(c)ii-iv

The majority of candidates found parts (c)(ii), (c)(iii) and (c)(vi) very accessible and full marks were scored by about half the candidates. However, mistakes on the cycle in (c)(ii) were quite common. Missing or incorrect state symbols and species appearing in the wrong box were often seen. However, errors in (c)(iii) and (c)(vi) were very rare and transfer error marks were often awarded too.

(ii) Complete the Hess cycle by filling in the empty boxes.

(1)



(iii) Complete the expression for the enthalpy change of solution using the enthalpy changes of hydration and lattice energy.

(1)

$\Delta_{sol}H =$ − lattice energy + Sum of $\Delta_{hyd}H$

(iv) The lattice energy of copper(II) chloride is −2811 kJ mol^{-1}.
Use this value, the data in the table, and your expression in (c)(iii) to calculate the enthalpy change of solution.

(2)

Ion	Enthalpy change of hydration / kJ mol^{-1}
Cu^{2+}	−2100
Cl^-	−378

$\Delta_{sol}H = -(-2811) + (-2100) + 2\times(-378)$

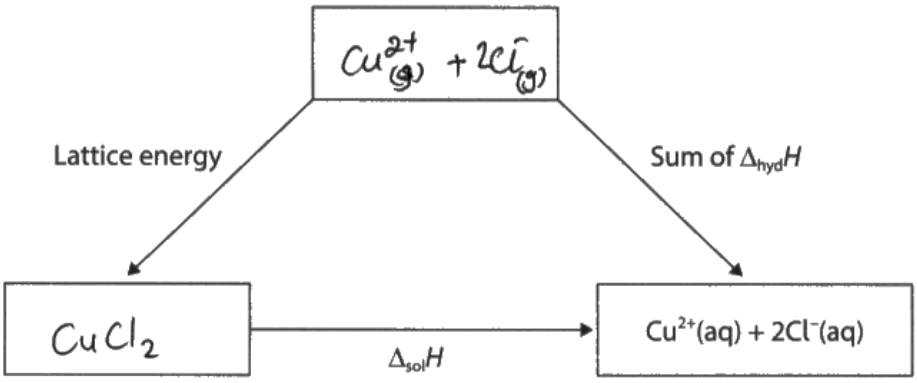
$\Delta_{sol}H = -45$ kJ. mol^{-1}

ResultsPlus
Examiner Comments

A fully correct answer.

(ii) Complete the Hess cycle by filling in the empty boxes.

(1)

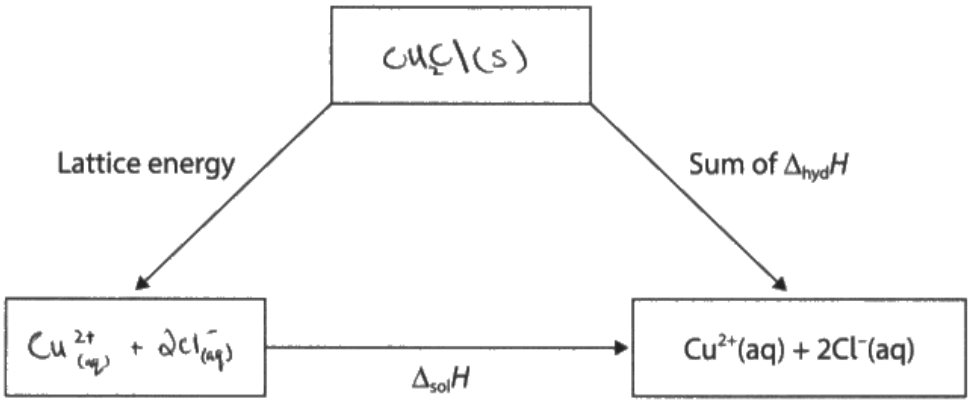


ResultsPlus
Examiner Comments

This candidate has missed out the state symbol for the copper chloride. This was quite a common mistake.

(ii) Complete the Hess cycle by filling in the empty boxes.

(1)



(iii) Complete the expression for the enthalpy change of solution using the enthalpy changes of hydration and lattice energy.

(1)

$\Delta_{sol}H = \Delta H_{LE} + 2\Sigma\Delta H_{hydration}$

(iv) The lattice energy of copper(II) chloride is $-2811\ kJ\ mol^{-1}$.
Use this value, the data in the table, and your expression in (c)(iii) to calculate the enthalpy change of solution.

(2)

Ion	Enthalpy change of hydration / $kJ\ mol^{-1}$
Cu^{2+}	−2100
Cl^-	−378

$\Delta_{sol}H = 2811 + (-378 \times 2) + (-2100)$

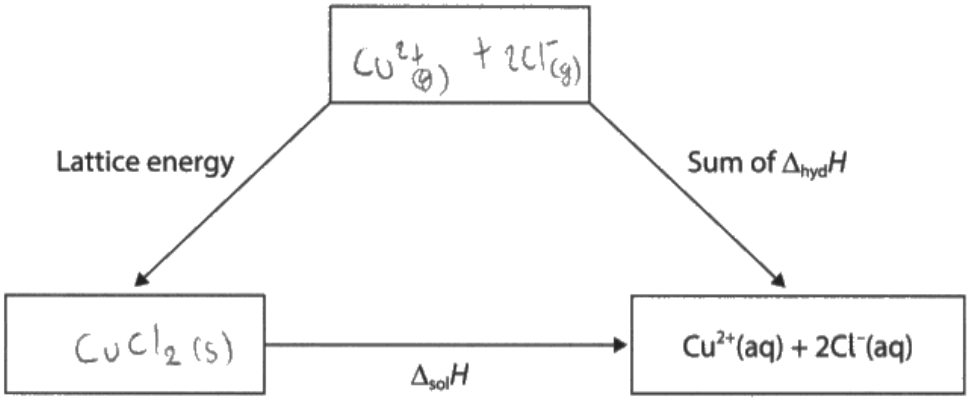
$\Delta_{sol} = -45\ kJ\ mol^{-1}$

ResultsPlus
Examiner Comments

This candidate has got the cycle wrong in (ii) and the expression wrong in (iii), but they still manage to score both marks for the calculation in (vi).

(ii) Complete the Hess cycle by filling in the empty boxes.

(1)



(iii) Complete the expression for the enthalpy change of solution using the enthalpy changes of hydration and lattice energy.

(1)

$\Delta_{sol}H =$ Sum of $\Delta_{hyd}H$ − lattice energy

(iv) The lattice energy of copper(II) chloride is −2811 kJ mol^{-1}.
Use this value, the data in the table, and your expression in (c)(iii) to calculate the enthalpy change of solution.

(2)

Ion	Enthalpy change of hydration / kJ mol^{-1}
Cu^{2+}	−2100
Cl^-	−378

$\Delta_{sol}H = -2100 - 378 + 2811$ kJ mol^{-1}

$= 333$ kJ mol^{-1}

ResultsPlus
Examiner Comments

The candidate has not multiplied 378 by 2, but scores a transfer error mark in (vi).

Question 19(c)v

A few candidates appeared confused by this question, giving answers relating to nuclear attraction, filling of d orbitals or ionisation energies.

Nevertheless, the majority of candidates scored the first mark for Cu+ having a lower charge or larger radius or lower charge density than Cu^{2+}. However, most of these went on to repeat the question that Cu^{+} has a lower hydration enthalpy, rather than complete the explanation in terms of the strength of attraction to water molecules.

(v) The enthalpy change of hydration of Cu^{+} is $-593\ kJ\ mol^{-1}$.
Explain why the hydration enthalpy of Cu^{+} is much less exothermic than Cu^{2+}.

(2)

Cu^{+} have lower charge and larger ~~o~~ ionic radius. than Cu^{2+}
Cu^{+} weaker ionic - dipole attraction to water.
So Cu^{+} is much less exothermic than Cu^{2+}

ResultsPlus
Examiner Comments

A fully correct answer.

(v) The enthalpy change of hydration of Cu^+ is $-593\,kJ\,mol^{-1}$.
Explain why the hydration enthalpy of Cu^+ is much less exothermic than Cu^{2+}.

(2)

The charge of Cu^{2+} is higher and the radius of Cu^{2+} is also smaller which means it has a greater charge density than Cu^+ and so is much more exothermic.

The candidate has scored the first mark but makes no reference to the interaction of the ions with water molecules so does not score the second. This type of response was very common.

Paper Summary

Based on their performance on this paper, candidates should:

- Always read the information in the question carefully, noting any instructions in bold type.
- Practise identifying conjugate acid-base pairs.
- Practise identifying different proton environments in NMR spectroscopy and predict their splitting patterns.
- Show working when carrying out calculations and think carefully about units, significant figures and rounding.
- Practise using indicator data to explain colour changes.
- Remember when drawing graphs to ensure that half of the grid is used, the axes are labelled and the appropriate line of best fit is drawn.
- Practise deducing orders of reaction from reaction mechanisms.

Grade boundaries

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