Examiners' Report
Principal Examiner Feedback

October 2024

Pearson Edexcel International Advanced Level
In Chemistry (WCH14) Paper 01
Rates, Equlibria and Further Organic Chemistry

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General comments

The paper seemed to provide a wide spectrum of assessment of knowledge and skills, and as a result the marks achieved covered the full available range. Questions that required application of mathematical skills proved to be a particular strength, but the application of knowledge to help problem solve or explain a concept, was very dependent on the context. Where the backdrop to a question was demanding yet familiar (e.g. 20(d)(ii)) the question presented only moderate demand to students. However, in an unfamiliar scenario such as 19 (b) many students found it difficult to link together their knowledge of nucleophilic substitution reactions to energy profiles. This suggests that for some students to improve further they will need to broaden their preparation beyond routine examples that are simply memorised. They can then trust the chemistry they have studied to help them solve a problem, rather than relying on the ability to recall an answer.

The mean performance on the paper was around 43 marks.

Multiple Choice Questions

Section A had a mean of 12 marks.

The most accessible questions were 1 (reactants required to form an ester), 2 (comparing boiling temperatures of organic compounds), 4 (interpretation of a titration curve), 8 (pH of water at 313 K), 10(c) (tests to distinguish between aldehydes and ketones) and 14(a) (recall of solvent used with $LiAlH_4$).

The most challenging questions were 7 (interpretation of acidic behaviour of phenolphthalein), 10(b) (recognising that the iodoform test can be used to distinguish between some alcohols) and 15 (formation of a condensation polymer from a single monomer).

Question 16

In (a) students had to break apart the ester to recognise the alcohol used in the synthesis, before they could name the alcohol. As a result, the mark scheme allowed a degree of leniency with the use of non-systematic terminology such as ‘3-methylpenta-3-ol’.

Around 40 % of students could name the alcohol, with those that couldn’t often not recognising the longest carbon chain, suggesting incorrect answers such as ‘diethylethanol’ or similar.

It was clear that many candidates could recognise and label each of the proton environments in (b)(i). The most common misstep was to also label the methyl group attached to the carbonyl carbon as ‘a’, as though it was identical to the group already labelled. Perhaps surprisingly few students used their labels in (b)(i) to help clarify their response in (b)(ii). Whilst many students seemed aware of the use of chemical shifts and splitting patterns in order to help distinguish between groups, a significant number of answers made generic comments rather than discussing these ideas in relation to the methyl groups present in ester **X**. Hence specific shifts and splitting patterns were sometimes absent from responses. Others misread the question, and attempted to just describe how proton environment **‘a’** could be identified. The most significant misunderstanding of NMR spectra related to how one could identify the number of hydrogen atoms in a particular environment. Use of the term ‘height’ of the peak was often used instead of the term (relative) area (under the peak) and was not awarded credit.

Very few candidates drew displayed formulae in (c), perhaps suggesting candidates are becoming more comfortable with skeletal formulae. However, only 20 % of the cohort drew a correct structure. Most proposed answers contained the correct number of carbon atoms, so the challenge for students was producing a structure with five unique carbon environments.

Part (d)(i) was essentially a test of whether students understood what a curly arrow represents. Nearly 50% did, so were awarded both marks. However, it was still common to see curly arrows moving towards, for example, lone pairs of electrons. This suggests that a significant number of the cohort are still learning mechanisms by rote without considering each step in the process. Recognising the role of aspirin in the reaction provided challenging in (d)(ii) with most considering just the positive nature of the hydrogen ion, without the realisation that the conversion of the product of Step 2 would release a hydrogen ion, emphasizing its catalytic role.

Question 17

Over 20% of students scored full marks in (a), with clear, often concise and accurate working. The most common mistakes where

- omission of the subtraction of the amount of hydrogen ions, hence using the initial amount of hydroxide ions to find the pH of the mixture
- subtracting the amount of sulfuric acid from the initial amount of hydroxide ions

Even those who were unsure how to find the pH of an alkali, often scored two marks for calculating the initial amounts of base and acid respectively.

The definition of weak in (b)(i) allowed over 70% of students to score a mark. Most persist in use of the term ‘partially dissociates’, which although given credit, doesn’t quite emphasise how few weak acid molecules dissociate. In a similar vein in (b)(ii), most students understood that a buffer solution resists changes in pH, with a minority believing that the pH does not change at all when small amounts of acid or base are added.

Over a quarter of students were familiar with the type of calculation in (b)(iii), and hence scored full marks. However, a significant number found this problem very challenging. Many attempted to use the Henderson-Hasselbalch equation but lacked the mathematical skills to process and re-arrange logarithmic data with sufficient care. Others who attempted to use the K_a expression, assumed that $[H^+] = [HSO_3^-]$ even though the stem makes it clear this is a buffer solution. Some students did appreciate that the final step of the problem must be to multiply a value by the relative formula mass of $NaHSO_3$, but it was often difficult to tell whether the final value calculated was based was a genuine attempt to use the amount of salt calculated.

Question 18

The mechanism in (a)(i) showed that most students are aware of the reaction. The level of detail required provided a degree of discrimination with 30% of the cohort managing to score full marks. Unlike 16(d)(i) very few arrows pointed in the wrong direction and those whom scored 3 marks had often made only a single error across marking points 2 to 7. The most significant chemical error was the assumption by some students that the lone pair on the cyanide ion is on the nitrogen atom. Oddly, even when this incorrect assumption was made, the bond in the intermediate was invariably to the carbon on the cyanide group. The explanation in (a)(ii) proved to be far more challenging and only a small minority of students appreciated the presence of NaOH would trigger the HCN dissociation to move to the right, to produce cyanide ions, even though the CN^- symbol in the slow step of the reaction was a helpful clue.

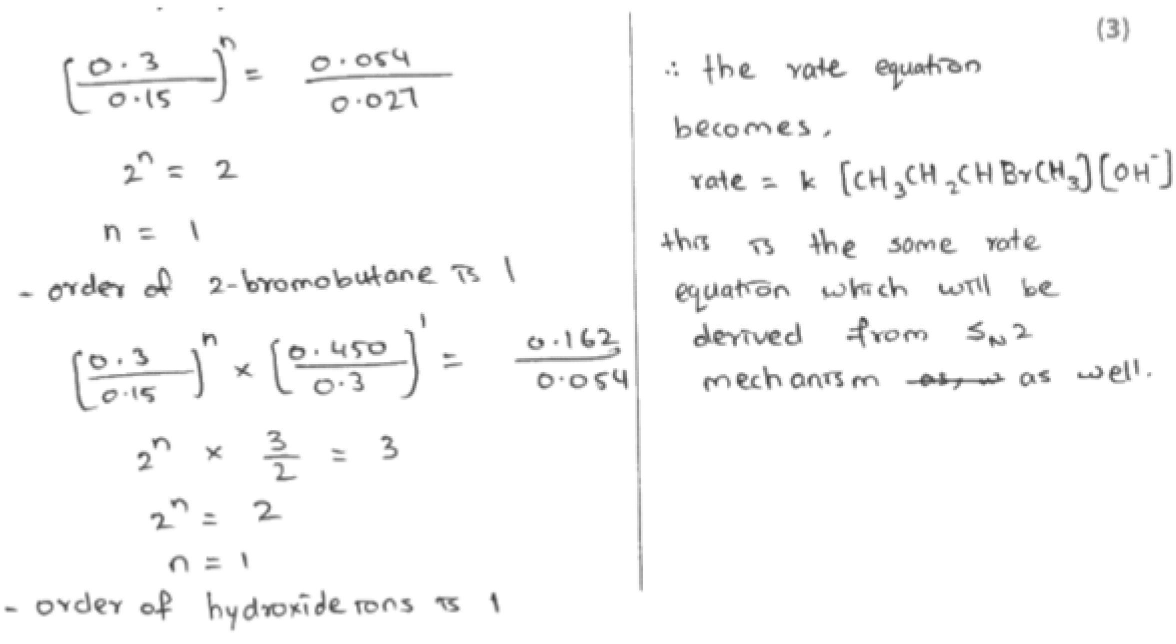
Despite the presence of both ethanal and the cyanide ions in the slow step of the mechanism, inclusion of HCN in the rate equation was a common error in (b). The sketch graph in (c) proved less demanding with most students showing a suitable first order graph. A few confused a rate against time graph with a concentration against time graph. Hence they drew a curve, occasionally with half-lives. In (d) most students understood what processes where required and could provide some detail worth credit. Recognition of the formation of the orange precipitate was the most common creditworthy comment, closely followed by the need to filter off the solid. Many also appreciated the need to take the melting temperature and compare with a known source. Although discussing the need to recrystallise was also customary, only the more able students broke down the process into meaningful steps, with even fewer attempting to give the purpose of each step. This was despite the guidance in the question stem.

Question 19

Most students found it difficult to differentiate between structural and stereoisomers in (a)(ii), and many answers gave adequate but not relevant descriptions of the former. Others either described geometric or optical isomers, not appreciating that both are types of stereoisomers. Only a small number did recognise that the arrangement of the **atoms** in space was key, and statements such as ‘different 3D arrangement’, without a reference to atoms were considered insufficient to score.

In (a)(ii) most students could use the data to show the reaction was first order with respect to 2-bromobutane by clearly referring to the data from experiments 1 and 2. Others then compared either experiments 2 and 3 or experiments 1 and 3 to successfully deduce the overall effect on the rate due to the change in both the concentration of 2-bromobutane **and** hydroxide ions. However, although it was common to see students then state the reaction was first order with respect to hydroxide ions, only a small number made the explicit link to the data to show how they arrived at this deduction.

The best answers used excellent numeracy skills, and clear statements regarding the orders. This tended to involve students setting up equations using the concentration and rate data to prove the orders are both equal to 1, such as the example below.



$$\left(\frac{0.3}{0.15}\right)^n = \frac{0.054}{0.027}$$

$2^n = 2$

$n = 1$

- order of 2-bromobutane is 1

$$\left(\frac{0.3}{0.15}\right)^n \times \left(\frac{0.450}{0.3}\right)^1 = \frac{0.162}{0.054}$$

$2^n \times \frac{3}{2} = 3$

$2^n = 2$

$n = 1$

- order of hydroxide ions is 1

(3)

∴ the rate equation becomes,

rate = k $[CH_3CH_2CHBrCH_3][OH^-]$

this is the same rate equation which will be derived from S_N2 mechanism ~~as, w~~ as well.

A small but noticeable number of students misread the questions and just drew the S_N2 mechanism.

A key issue for a few students when answering (a)(iii) was the desire to give stock answers regardless of the context of the question. Such responses didn't consider the mechanism was S_N2 and so made statements regarding attack of the hydroxide ion from above and below a planer carbocation resulting in a racemic mixture, a common answer to questions in previous series, based on S_N1. Others did realise that S_N2 would result in a product that shows optical activity, but a much smaller number noted the plane-polarised light would rotate in the opposite direction compared to the reactant, as though students were struggling to visualise the inversion.

Although many candidates appreciated that the S_N1 mechanism had two steps, they could not always link this knowledge to the energy profile, instead tending to discuss the overall energy change of the reaction. The best answers made use of the diagram, annotating it effectively to link the features of the diagram to the mechanism. Such students were then less reliant on the kind of precise language needed when relying solely on prose.

Question 20

Students had clearly prepared for the type of question in (a)(i) and the majority managed to secure both marks. The challenge was more significant in (a)(ii) but even then, over 30% of the cohort managed to score two or three marks, the lost mark nearly always due to not considering significant figures in the final answer.

It was unusual to see full marks awarded in (b), perhaps because some students were caught out by the synoptic nature of the problem. A number of students based their calculation on the mass of magnesium chloride, whilst others added this mass to that of the water or omitted to include the negative sign with their final answer.

Reponses to (c)(i) were surprisingly mixed with a number showing the change the wrong way round and others omitting state symbols. However, the calculation in (c)(ii) was very well answered by many. A number, perhaps releasing their answer from (b) lacked validity, chose to use the data provided.

The use of the term 'theoretical' seemed to be ignored by many students in (d)(i) and as a results answers based on loss of energy to the surroundings were common. Others did appreciate the model assumes the bonding to be 100% ionic, but only a few managed to make a second relevant point.

The partial covalent nature of magnesium chloride was spotted by many in (d)(ii) and this was often linked to the polarisation of the chloride ion. However, students found it challenging to express the difference between the two values using language appropriate to the chemical context. Hence terms such as 'greater' and 'higher' were used to describe the experimental value. As well as being mathematically incorrect in terms of negative values, such language doesn't help emphasise the more exothermic nature of the experimental value.

The calculations in (e) proved to be a strong finish to the paper for many, with over 30% scoring all five available marks. The most common error in (e)(i) was not taking into account the ratio in the equation and so simply stating that 0.06 is greater than 0.025, which is not enough to score the second mark. Students used a variety of methods to solve (e)(ii), the most common approach based on the calculation of the relative formula mass of the hydrated salt.

SUMMARY

Based on their performance on this paper, students are offered the following advice:

- read the information given in the question carefully, noting any instructions given in bold type
- ensure that you appreciate that $[H^+] \neq [salt]$ in a buffer solution, and unless you are confident in your ability to manipulate logarithmic equations, base buffer calculations on K_a expressions rather than the Henderson-Hasselbalch equation
- use the guidance in the stem to help you structure your response to extended questions, to make sure you include all the details required
- ensure you can describe the difference between structural and stereoisomers
- where appropriate, annotate diagrams to help communicate your understanding
- broaden your revision to better enable you to deal with problems of a synoptic nature
- use language such as 'more exothermic' and 'less exothermic' when comparing enthalpy changes, rather than 'greater' or 'smaller'

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