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Examiners' report

CHEMISTRY B (SALTERS)

H433

For first teaching in 2015

H433/02 Summer 2022 series

Version 1

Contents

Introduction 4
Paper 2 series overview 5
Question 1 (a), (b) (i) and (b) (ii) 6
Question 1 (c) (i) and (c) (ii) 7
Question 1 (c) (iii) 7
Question 1 (d) (i), (d) (ii) and (d) (iii) 8
Question 1 (e) 9
Question 1 (f) (i) 9
Question 1 (f) (ii) 11
Question 1 (f) (iii) 11
Question 1 (g), (h) (i) and (h) (ii) 12
Question 2 (a) 13
Question 2 (b) 13
Question 2 (c) (i) and (c) (ii) 14
Question 2 (d) 15
Question 2 (f) 15
Question 2 (g) 16
Question 2 (h) (i) and (h) (ii) 16
Question 3 (a) (i) 17
Question 3 (a) (ii) 18
Question 3 (a) (iii) 18
Question 3 (b) (i) and (b) (ii) 19
Question 3 (c)* 20
Question 3 (d) 22
Question 4 (a) (i) and (a) (ii) 23
Question 4 (b) (i) and (b) (ii) 24
Question 4 (c) (i) and (c) (ii) 25
Question 4 (d) 26
Question 4 (e) (i) 27
Question 4 (e) (ii) 27
Question 4 (e) (iii) 28
Question 5 (a) (i) and (a) (ii) 29
Question 5 (b) 30
Question 5 (c) 30

Question 5 (d) 31
Question 5 (e) (i) 31
Question 5 (e) (ii) 32
Question 5 (f) 32
Question 5 (g)* 33

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers are also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Advance Information for Summer 2022 assessments

To support student revision, advance information was published about the focus of exams for Summer 2022 assessments. Advance information was available for most GCSE, AS and A Level subjects, Core Maths, FSMQ, and Cambridge Nationals Information Technologies. You can find more information on our website.

Paper 2 series overview

H433/02 is one of the three examination components for GCE A Level Chemistry B. This component, entitled 'Scientific literacy in chemistry', links together different areas of chemistry within different contexts, some practical, some familiar and some novel. The paper also includes questions based on a pre-released Advance Notice Article, included as an insert with the exam paper. To do well on this paper, candidates need to have studied the pre-release material and to have researched some of the unfamiliar contexts included in this document. They also need to be comfortable applying their knowledge and understanding to unfamiliar contexts and be familiar with a range of practical techniques that they should recognise from completing the practical elements of the course.

The most successful candidates used their time to the full extent and completed the paper in full. They had taken advantage of the advance information notice sent to centres in March to structure their revision, which was evident from their responses to certain questions.

Candidates engaged well with both Level of Response questions. Very few candidates did not achieve below Level 2 on Question 3 (c), and they had obviously prepared well for Question 5, which is based on the Advance Notice Article, "Fluoride compounds in Dental Hygiene", and often answered all parts of the question, even though some of them were from areas of the specification that they may not have gone into in depth previously.

Candidates who did well on this paper generally did the following:	Candidates who did less well on this paper generally did the following:
• Performed standard calculations showing clear working and, where appropriate, conversion to the required number of significant figures. • Demonstrated a sound knowledge of organic structures and reaction mechanisms. • Produced clear and well-constructed answers to the Level of Response Questions.	• Did not link the key steps in a logical manner in Question 1 (f) (i). • Did not interpret data provided in a graphical context, often mis-reading scales.

Question 1 (a), (b) (i) and (b) (ii)

1 Portland cement is a powder that 'sets' to a strong solid when water is added. The cement is usually mixed with gravel so that it sets to make concrete.

The typical ingredients of Portland cement are shown in the table.

Ingredients (solids)	% by mass
CaO	61 – 67
SiO_2	19 – 23
Al_2O_3	2.5 – 6
Fe_2O_3	0 – 6
SO_3	1.5 – 4.5

(a) Give the systematic name for Fe_2O_3.

..... **[1]**

(b) **(i)** A hazard warning for Portland cement states that it is alkaline.

One of the ingredients in the table reacts with water to form an alkaline solution.

Write an equation for the reaction of this ingredient with water including any ions that are formed.

[2]

(ii) When Portland cement sets, the calcium oxide absorbs carbon dioxide from the air.

Suggest an equation for the reaction that occurs.

[1]

Many candidates were successful in answering this question, often scoring full marks. The commonly seen errors were in Question 1 (a) identifying the oxidation state of the iron ion as (II) rather than (III), or to write an equation in (b) (i), that gave $Ca(OH)_2$ as a product rather than its constituent ions as required by the Question. In (b) (ii) most candidates correctly identified the product of the reaction as calcium carbonate and gave the correct formula in their equation.

Question 1 (c) (i) and (c) (ii)

(c) One way of testing for the presence of calcium in the cement would be a flame test, though any iron present would interfere.

(i) What is the flame colour of calcium?

..... **[1]**

(ii) The flame colour is caused by bright lines in the atomic emission spectrum of calcium.

Explain how these lines are formed.

.....

.....

.....

..... **[2]**

Question (c) (i) was very well answered, nearly all candidates gave an answer that was a correct shade of red, and there were very few instances of any other colour being given. This then led into part (ii) where candidates were being tested on their knowledge of emission spectra. The more successful candidates correctly stated that the first step in this process involved the process of energy being absorbed and promoting an electron into a higher energy level, followed by the electron dropping back to its ground state energy level with the release of a photon of a specific frequency. The only commonly seen error was where candidates identified the source of the energy being absorbed as being from light rather than from the thermal energy present in the flame. Less successful candidates often lost the first mark, but they did score the second mark.

Question 1 (c) (iii)

(iii) Calculate the frequency of a line of wavelength 6.16×10^{-7} m.

frequency = ... Hz **[2]**

Most candidates answered this question well gaining 2 marks. Less successful responses often chose the wrong equation to use, E =hv, and so arrived at an incorrect value for the frequency of the emission line.

Question 1 (d) (i), (d) (ii) and (d) (iii)

(d) Fe_2O_3 and CaO are present in Portland cement.

(i) In which 'blocks' of the periodic table are these elements found?

Ca .....

Fe ..... **[1]**

(ii) The electron configuration of a calcium **ion** is $1s^2 2s^2 2p^6 3s^2 3p^6$.

How does the electron configuration of the **cation** in Fe_2O_3 differ from this?

.....

..... **[1]**

(iii) Explain why iron can form two stable cations.

.....

..... **[1]**

This set of three questions was designed to assess candidates' knowledge and understanding of the key differences between transition metals and other metals. Question (d)(i) was generally well answered and the correct blocks within the periodic table were identified. The only common error was the use of capital letters which is not the convention used in chemistry for these blocks of elements.

Question 1 (d) (ii) produced a range of responses. The most successful candidates correctly identified that the 4s electrons present in an iron atom are lost and that the outermost occupied sub-shell is the 3d sub-shell and that in Fe^{3+} this contains 5 electrons. The more commonly seen incorrect responses included an outermost configuration of $3d^6$ – consistent with Fe^{2+}, or $4d^5$ where the incorrect primary quantum level is identified.

Question 1 (d) (iii) was challenging for candidates of all abilities. Responses tended to focus on the loss of the outer s-shell electrons rather than stating that more than one d configuration was possible, where candidates did score here was in recognising that more than one oxidation state was possible for iron.

Question 1 (e)

(e) Fe_2O_3 is soluble in concentrated hydrochloric acid.

Excess sodium hydroxide is added to this solution.

Name the precipitate formed and describe its colour.

name: .....

colour: ..... **[1]**

Most candidates recognised that when the reaction was completed that the product would be a precipitate of iron hydroxide. Successful candidates correctly recognised that it would be the iron(III) precipitate and that it is an orange/brown colour, but less successful candidates either suggested that it would be the iron(II) precipitate, or gave an incorrect colour for the precipitate.

Question 1 (f) (i)

(f) **(i)** A student has a solution containing $Fe^{3+}(aq)$ and reads that it will react with iodide ions to form iodine. The iodine can then be titrated with sodium thiosulfate.

Describe a method to measure the volume of sodium thiosulfate solution required to react with the iodine from 25 cm^3 of $Fe^{3+}(aq)$.

.....

.....

.....

.....

.....

..... **[5]**

This question produced a wide variety of responses. The more successful candidates gained 3 or 4 marks here, while many other candidates gained 1 or 2 marks on this question. Very few candidates did not gain any marks here and even fewer left the question blank. All candidates recognised from the stem of the question that the reaction involved a titration and therefore chose apparatus that was appropriate to this technique.

What separated more successful candidates was their ability to sequence the steps in their suggested method. High achieving candidates often scored at least 3 marks, while the majority of candidates usually gained marks for recognising that the sodium thiosulfate solution needed to be in the burette and that they needed to repeat their titration to achieve consistent/concordant results.

Exemplar 1

In a rinsed conical flask place 25 cm^3 of Fe^{3+} solution using a rinsed volumetric pipette. Add 2 drops of starch for an indicator and sulfuric acid. fill a rinsed burette with Sodium Thiosulfate titrate dropwise do a rough titration to Then repeat titrate dropwise to the end point where there is a colour change to form yellow to blue black Record volume of Sodium Thiosulfate used repeat until 3 concordant results are achieved and calculate the mean [5]

Exemplar 1 shows a typical response gaining 3 of the 5 available marks. The candidate has used a volumetric pipette to measure their Fe^{3+} solution but has not added any iodide solution, and although they have added their starch indicator, suggesting that iodine would be present. They added it too early in their procedure and so did not score this mark.

Question 1 (f) (ii)

(ii) The student finds that 25.0 cm^3 of $Fe^{3+}(aq)$ requires 3.2 cm^3 of 0.510 $mol\,dm^{-3}$ sodium thiosulfate.

Calculate the concentration of the $Fe^{3+}(aq)$.

$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$

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

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

$[Fe^{3+}]$ = ... $mol\,dm^{-3}$ **[3]**

This calculation was well answered by many candidates. They set out their working, in a clear and logical manner which made it easy to see where to award marks if the final answer was incorrect. However, more successful candidates did score all 3 marks, and the only commonly seen incorrect answer was in quoting the final value to more than 2 significant figures.

Question 1 (f) (iii)

(iii) The student decides to repeat the experiment using 0.0510 $mol\,dm^{-3}$ sodium thiosulfate.

Suggest why the student does this.

.....

.....

.....

..... **[2]**

More successful candidates realised that the error in the reading from the burette does not change, it is always 0.05cm^3, and that by using a more dilute solution they would produce a larger titre which in turn would give a lower percentage error in the titre. Other responses that gained some marks usually recognised that a larger titre would be produced, marking point 1, but they then went on to say that this would make their results more precise/accurate, which was not deemed worthy for marking point 2.

Question 1 (g), (h) (i) and (h) (ii)

(g) Iron is formed in stars by fusion reactions.

Complete the nuclear equation for one such reaction.

$$^{48}_{24}\text{.....} + {}^{\text{.....}}_{\text{.....}}\text{He} \longrightarrow {}^{\text{.....}}_{\text{.....}}\text{Fe}$$

[2]

(h) The table shows the stable isotopes of iron and their abundances.

Mass number	Abundance / %
54	5.85
56	91.75
57	2.12
58	0.28

(i) What is meant by the term **mass number**?

.....

..... **[1]**

(ii) Explain, without doing a calculation, how this data shows that the relative atomic mass of iron is below 56.

.....

.....

..... **[1]**

Question 1 (g) was well answered by most candidates. They used the data sheet to find the correct symbol for the element with atomic number 24. By using the mass number and atomic number for the helium nucleus, they then determined the correct values for the mass number and atomic number of the iron isotope.

Question 1 (h) (i) was well answered by most candidates. The only common error seen with this was in quoting the definition for relative atomic mass. This often resulted in candidates losing this mark as this was deemed to be a contradiction rather than simply giving the expected statement from the mark scheme.

More successful responses were usually given the mark for Question 1 (h) (ii) by comparing the abundances of the isotope below A_r 56 with the total abundances of the isotopes above A_r 56. However less successful responses did not score here as they often simply focused on the isotope at 56 and did not take into consideration the effect that the other isotopes would have on the overall relative atomic mass value for iron.

Question 2 (a)

2 'Polybutene' is used in lip gloss.

The monomers for polybutene are the three isomers of butene, which are 2-methylpropene, but-2-ene and isomer **A**.

(a) Draw the **skeletal** formula of isomer **A** and name it.

skeletal formula:

name: ..... **[1]**

This was a well answered question. Candidates produced an appropriate skeletal structure and correctly named the isomer.

Question 2 (b)

(b) Give the number of π bonds and σ bonds in but-2-ene, $CH_3CH=CHCH_3$.

π bonds ..... σ bonds ..... **[1]**

This question proved challenging for many candidates. The most commonly seen incorrect responses include the number of pi bonds as being 2. More able candidates however did score this mark.

Question 2 (c) (i) and (c) (ii)

(c) But-2-ene, $CH_3CH=CHCH_3$, exists as *E* and *Z* isomers.

(i) Draw the structure of the *E* isomer of but-2-ene.

[1]

(ii) Does 2-methylpropene, $(CH_3)_2C=CH_2$, have *E* and *Z* isomers?

Explain your answer.

.....

..... **[1]**

Question 2 (c) (i) provided a range of diagrams to represent the structure of the E isomer. Where candidates used a skeletal representation, as in 2a, they usually scored the mark. However, if they used other representations, it was not uncommon to see incorrect diagrams drawn where they displayed structures consistent with the Z-isomer.

In Question 2 (c) (ii) the mark was for the explanation and candidates had to evidence that they were discussing the groups attached to the carbon atoms making up the double bond. Statements that included the phrase 'either side of the double bond' lacked the clarity required to differentiate between the bonding arrangements for the carbon atoms and responses that might have referred to the arrangements of groups above and below the plane of the double bond.

Misconception

It is important when discussing E/Z isomerism that candidates recognise that for this to occur the carbon atoms that make up the double bond have to contain 2 different groups if they contain two of the same groups they can only form the Z-isomer.

Question 2 (d)

(d) Draw the repeating unit of the polymer of 2-methylpropene, $(CH_3)_2C=CH_2$.

[1]

The vast majority of candidates were given this mark, and subsequently recognised the type of intermolecular forces present between chains of the polymer in Question 2 (e) to score a second mark.

Question 2 (f)

(f) But-2-ene, $CH_3CH=CHCH_3$, reacts with hydrogen bromide.

Draw the mechanism for this reaction.

Show curly arrows, full charges and the product.

[3]

The more successful responses were usually given all 3 marks, and less successful responses were given at least 1 mark. There were very few candidates who were not given any marks on this question. Most candidates were given their mark here by drawing the correct structure for the final product. Where candidates were not given marks, this was often because they did not make it clear in step two that the origin of the electrons attacking the carbocation was from either the negative charge, or from a lone pair of electrons, on the bromide ion.

Question 2 (g)

(g) But-2-ene reacts with hydrogen to form butane.

Name a catalyst and the corresponding conditions for this reaction.

catalyst: .....

conditions: ..... **[1]**

Where a correct catalyst was named occasionally, incorrect conditions were given, e.g. Nickel catalyst with a temperature more than the value stated in the mark scheme, or a platinum catalyst with a high temperature and pressure. The only other common incorrect catalysts named were iron or another transition metal.

Assessment for learning

Revision resources for students that look at different reaction types and the conditions required for these reactions to take place would aid candidates.

Question 2 (h) (i) and (h) (ii)

(h) But-2-ene is formed industrially by cracking alkanes from crude oil.

(i) Complete the equation for a cracking reaction.

$$\longrightarrow 2C_4H_8 + C_4H_{10}$$ **[1]**

(ii) Cracking is an example of heterogeneous catalysis.

Name the **first** step in the mechanism of heterogeneous catalysis.

..... **[1]**

Both parts of this question were well answered by many candidates, with very few candidates failing to achieve at least 1 mark. Where a mark was not achieved in (i) it was often a result of not using the '2' in front of the formula of but-2-ene correctly when working back to obtain the formula of the larger molecule. This produced molecules with insufficient hydrogen atoms, e.g. $C_{12}H_{18}$.

In Question 2 (h) (ii) minor misspellings of the word adsorption were allowed, e.g. adsorption, provided that it was not implying absorption, as these are two different processes that can occur. Alternatively, a correct description of the adsorption process at the surface of the catalyst was acceptable.

Question 3 (a) (i)

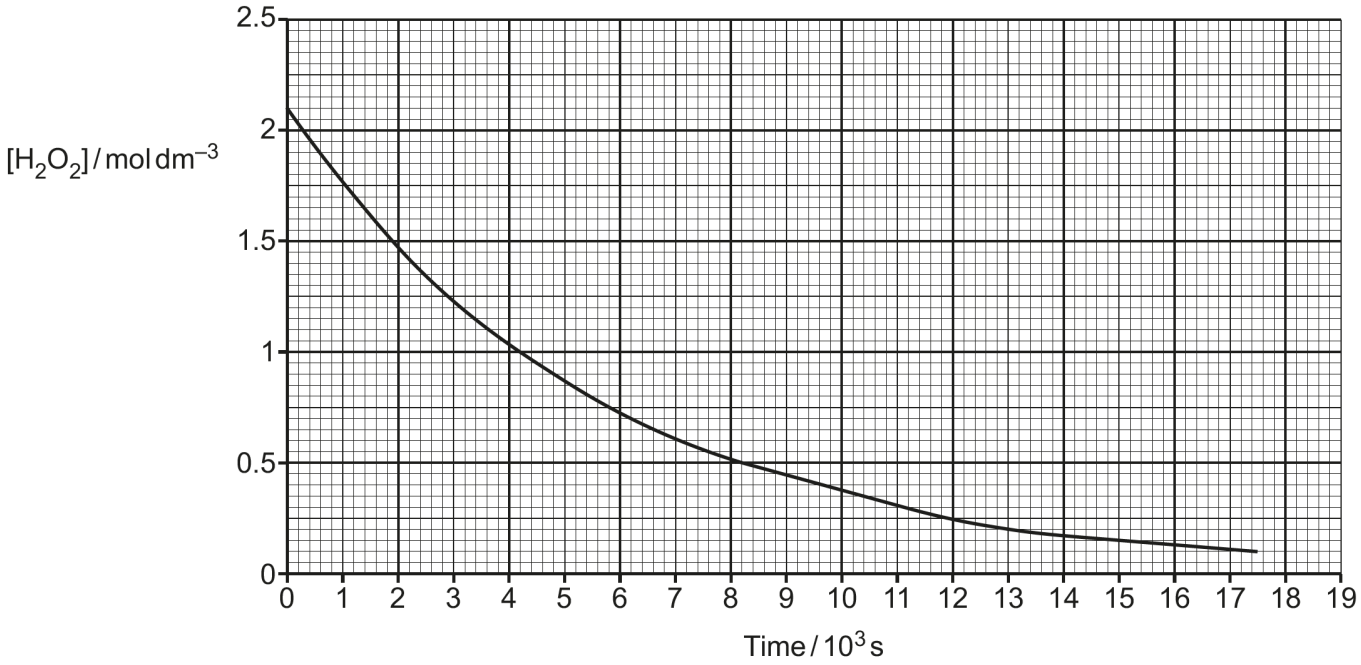
3 Some students read about the reaction between hydrogen peroxide and iodide ions as shown in **equation 3.1**.

$2H^+ + H_2O_2 + 2I^- \rightarrow I_2 + 2H_2O$ **Equation 3.1**

(a) The students find the results of an experiment which measures the concentration of hydrogen peroxide at various times.

Large excesses of acid and iodide ions are present.

The students plot a graph of these results as shown below.



(i) Use the graph to measure two half-lives to show that the kinetics are first order.

Show your working on the graph.

first half-life = ...

second half-life = ... **[3]**

Candidates who drew in the appropriate construction lines on their graph often used the concentrations of 1mol dm^{-3} and 0.5mol dm^{-3} but did not recognise that where the curve meets to y-axis is at 2.1mol dm^{-3} and so arrived at a value for the first half-life that was longer than it should have been. Alternatively, if they did choose suitable values for the concentrations, they then either did not include any units for their half-life values, or just quoted the values read directly from the x-axis, e.g. 4000s and 8000s/ $4x10^3$ and $8x10^3$.

Question 3 (a) (ii)

(ii) Use the graph to measure the initial rate of the reaction in $mol\,dm^{-3}\,s^{-1}$.

initial rate = ... $mol\,dm^{-3}\,s^{-1}$ **[1]**

It was decided that the value quoted here should be treated as an independent marking point, so that candidates who made an error in (a) (i) could still score this mark if they had calculated it correctly. However, if candidates had mis-read the scale on the x-axis in a(i) then they would provide values here, that would be a factor of 10^3 lower here also. Therefore, this as an error carried forward was allowed which subsequently meant that many candidates who would have lost marks in both parts of this question, did at least gain marks for correctly processing their tangent in a manner that was consistent across both parts of the question.

Question 3 (a) (iii)

(iii) The graph shows that the reaction in **equation 3.1** is first order with respect to hydrogen peroxide.

Explain why the orders with respect to the other reagents cannot be determined from this experiment.

.....

.....

.....

..... **[2]**

Very few candidates were given more than 1 mark on this question. Usually candidates recognised that only the peroxide concentration had been changed, and measured, but did not state that the concentrations of the other reagents were in excess.

Question 3 (b) (i) and (b) (ii)

(b) The students then set up some experiments to find the orders of reaction with respect to iodide and hydrogen ions.

At the starting time they mix the hydrogen peroxide, acid and iodide ions together with a fixed volume of sodium thiosulfate and starch solutions.

They measure the time for the colourless solutions suddenly to go dark blue as iodine is formed.

(i) Suggest why the tubes go dark blue after a period of time rather than gradually from the start.

.....

.....

.....

.....

.....

..... **[2]**

(ii) How can the relative rates of reaction be found from the students' results?

.....

..... **[1]**

Although many candidates recognised that this was an example of a 'clock' reaction, they sometimes did not explain why the tubes changed colour at different times.

In Question 3 (b) (i) some responses were vague and made no reference to the fact that initially the iodine formed reacts with the fixed amount of thiosulfate solution, they tended to state that 'the solution changes colour once the iodine is formed/in excess' which would not score any marks. For marking point 1 candidates needed to evidence that no colour change can take place until all of the thiosulfate has reacted. Then to score marking point 2 they had to indicate that once this has happened, the iodine produced then reacts with the starch to bring about the colour change.

In Question 3 (b) (ii), although mention was made to comparing the times for the reactions, candidates had to demonstrate that they knew that when dealing with rates, the units are often of the form 'x'/sec and so they needed to use the idea of 1/time in their answers.

Question 3 (c)*

$2H^+ + H_2O_2 + 2I^- \rightarrow I_2 + 2H_2O$ **Equation 3.1**

(c)* The students' results are shown below.

Use these results and information from earlier in the question to work out the rate equation for the reaction, explaining your reasoning.

Calculate the rate constant, *k*, and suggest a possible mechanism for the reaction.

Experiment	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	Initial rate of formation of I_2 / mol dm^{-3} s^{-1}
1	0.030	0.010	0.10	5.25×10^{-6}
2	0.030	0.020	0.10	1.05×10^{-5}
3	0.030	0.020	0.20	1.05×10^{-5}

.....

.....

.....

.....

.....

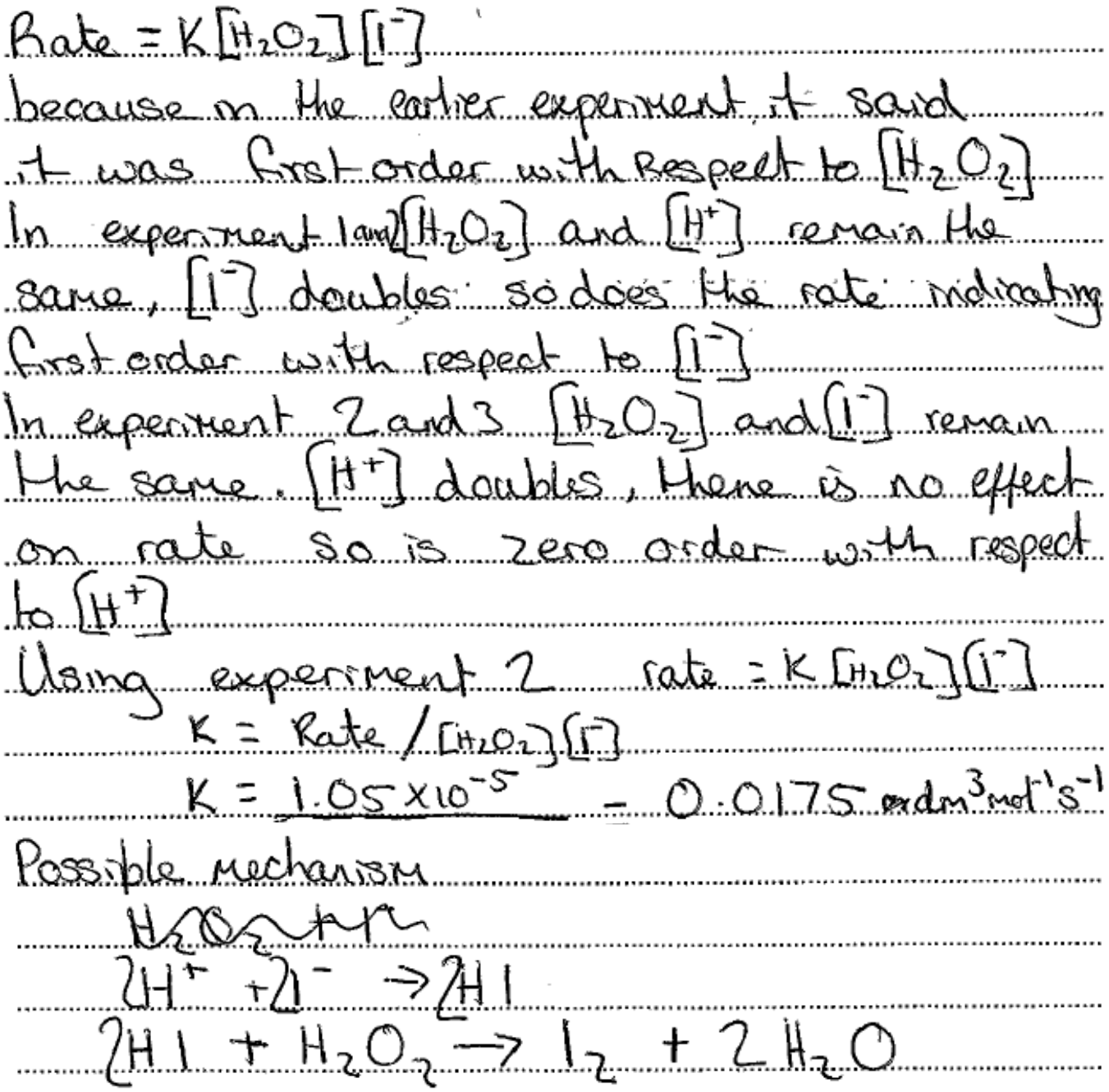
..... **[6]**

Question 3 (c) was the first of the Level of Response questions on this paper. The vast majority of candidates achieved a mark at Level 2 or above on this question.

Candidates knew how to determine the orders of reaction with respect to both the hydrogen ions and the iodide ions and demonstrated this in their working out. They also recognised that the reaction was first order with respect to the peroxide molecules from 3(a), and so many candidates successfully constructed a rate equation that was consistent with their calculated orders.

From this they then used reaction mix 1 to calculate a value for the rate constant and more successful candidates also determined appropriate units for *k*.

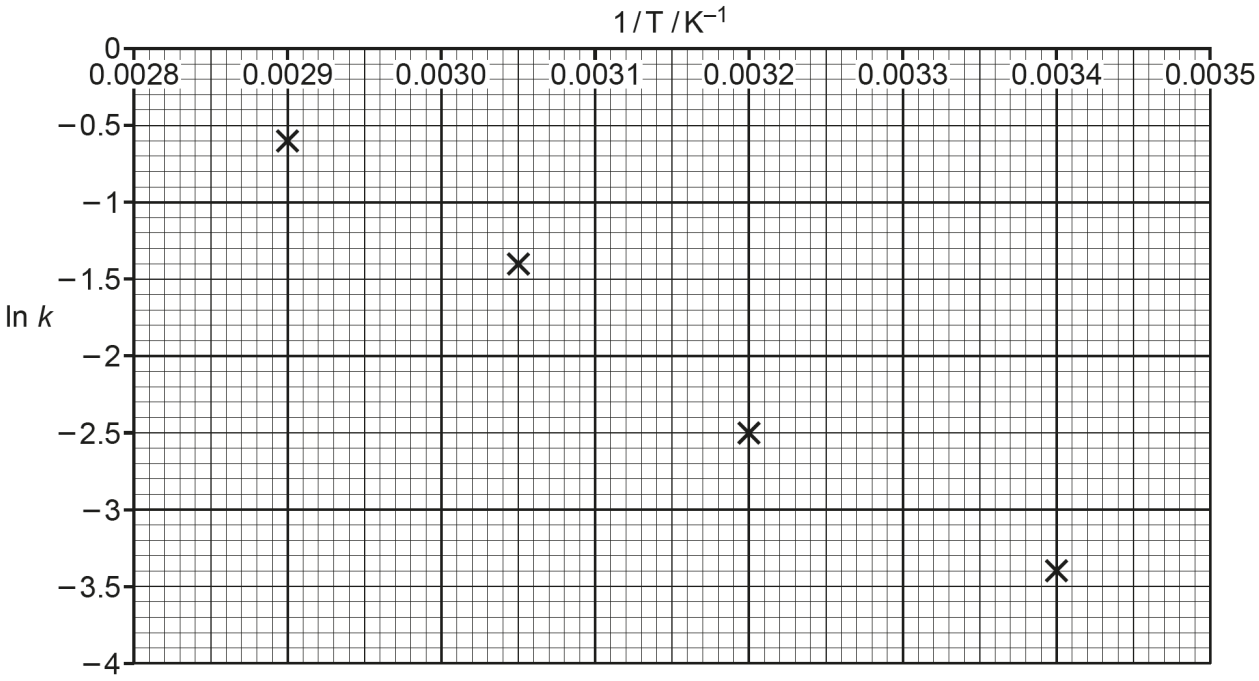
Exemplar 2



Exemplar 2 was placed at Level 2 and was gvien 4 marks. For this candidate to progress to Level 3 they needed to produce a mechanism that was consistent with the rate equation, i.e. the rate determining step should have included iodide ions reacting with hydrogen peroxide molecules, this could have been shown as being a slow step or clearly labelled as the rate determining step. Further steps could have been included that would have eventually led to the overall equation for the reaction, but again although there were a pair of equations provided, neither was consistent with their rate equation.

Question 3 (d)

(d) The students find data for the variation of the rate constant, *k*, with temperature. From their data they plot the graph below.



Use the graph to calculate E_a in kJ mol^{-1} for the reaction in **equation 3.1**.

E_a = ... kJ mol^{-1} **[4]**

This question provided a variety of responses and was a good discriminator between candidates.

The more successful candidates drew an appropriate line of best fit for the plotted points and used this to calculate a gradient that they then were able to manipulate within the Arrhenius Equation to calculate a value for the activation energy.

Candidates who were given 2 marks often did so for drawing an appropriate line of best fit, and after attempting a calculation, arrived at a value in J mol^{-1} that they converted to kJ mol^{-1}.

A commonly seen incorrect answer saw candidates attempting to take a single point from the grid and using this to calculate a value. This often resulted in them scoring at most 1 mark, for marking point 4, or more usually 0 marks.

Question 4 (a) (i) and (a) (ii)

4 Chymotrypsin is an enzyme present in the small intestine.

One of the amino acids in chymotrypsin is serine, which can be represented as $HOOCCHRNH_2$.

(a) (i) A molecule of serine has a chiral centre and two enantiomers.

Draw and label **two** serine molecules below to illustrate the meaning of the terms **chiral centre** and **enantiomer**.

[3]

(ii) Glycine $HOOCCH_2NH_2$ is another amino acid.

In solution, glycine exists as a zwitterion.
Draw the structure of this zwitterion.

[1]

This question was the start of a sequence of questions dealing with the chemistry of enzymes.

Question 4 (a) saw many candidates gaining at least 2 marks.

In Question (a) (i) structures were drawn using the appropriate convention for bonds going into and out of the plane of the paper, and very few candidates lost a mark for producing structures with a pair of bonds that were in the plane of the paper but at 180° to one another.

Many candidates either labelled the central carbon atom as being chiral, or they wrote a definition of a chiral centre adjacent to their diagram. Where marks were usually lost was in failing to indicate, or explain what an enantiomer was. The simplest way of doing this was dependent on scoring marking point one, and would have been to label their structures as enantiomers with an arrow pointing to each side of the mirror.

In Question 4 (a) (ii) most candidates scored this mark. They knew what a zwitterion was and were able to draw a structure that clearly showed the movement of a hydrogen ion from the acid end of the molecule across to the amine end of the molecule which produced the correct ionic species at either end of the amino acid.

Question 4 (b) (i) and (b) (ii)

(b) Serine reacts with glycine to form two dipeptides.

(i) In the boxes below, draw the structural formulae for the two dipeptides.

[2]

(ii) Explain, with a reason, whether the reaction to form the dipeptides is condensation or addition.

.....

..... **[1]**

Most candidates scored at least 1 mark on this pair of questions as they correctly drew a structure containing a peptide bond.

In order to score the second mark in Question 4 (b) (i) candidates were required to produce both structures with a correctly drawn peptide link, and for one structure the R group in the serine molecule was adjacent to the terminal NH_2 group of the dipeptide, and for the other structure that the R group was adjacent to the NH part of the peptide link. This was essential in order to demonstrate that candidates knew that the link could be ser-gly, or gly-ser depending on which group from each amino acid was involved in the peptide formation reaction.

Question 4 (b) (ii) was well answered and most candidates gained this mark.

Question 4 (c) (i) and (c) (ii)

(c) Chymotrypsin is a protein with a definite amino acid sequence and parts that have an α-helical structure.

(i) What name is given to the amino acid sequence of a protein?

..... **[1]**

(ii) What name is given to the α-helical structure and how is it held together?

.....

.....

..... **[2]**

Candidates demonstrated a sound knowledge and understanding in this pair of questions and were often given all 3 of the available marks. The only commonly seen error was in Question 4 (c) (i) where candidates referred to this as a polypeptide structure rather than the expected primary structure.

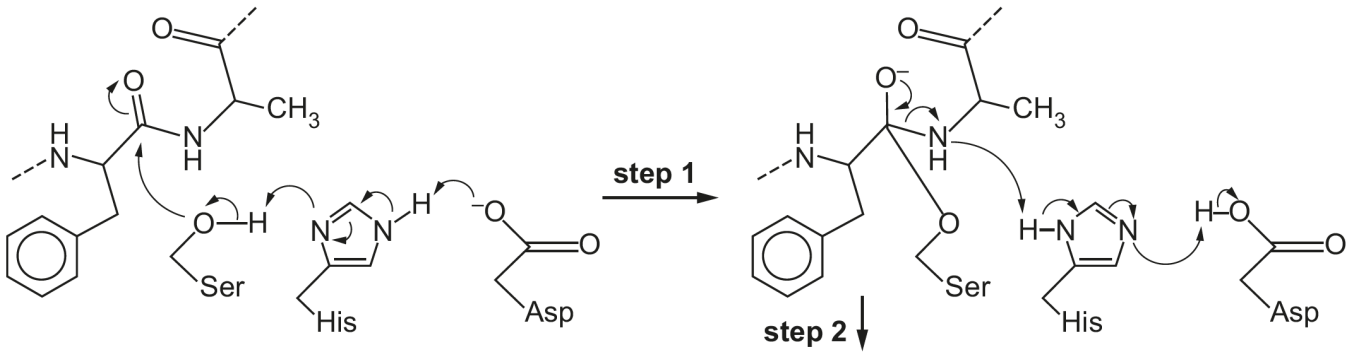
Question 4 (d)

(d) Chymotrypsin catalyses the hydrolysis of proteins in the small intestine.

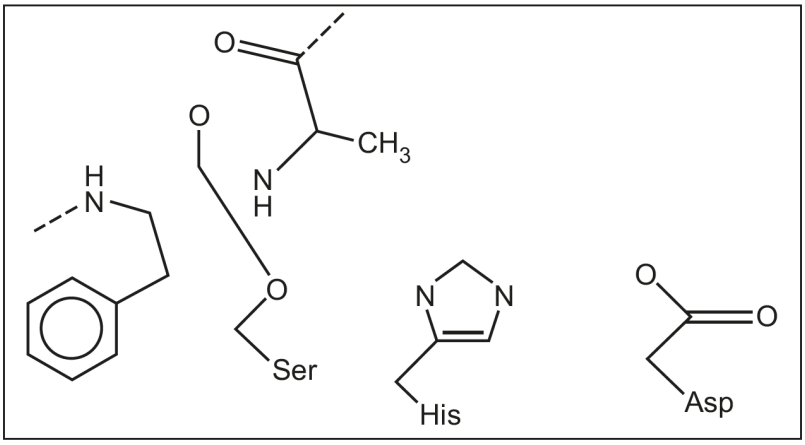
The active site of chymotrypsin consists of the amino acids serine, histidine and aspartic acid. These occur on different parts of the chain that are brought together by the folding of the structure.

The start of the hydrolysis mechanism is shown below. The protein being hydrolysed is at the top left.

Complete the diagram in the box below to show the results of the electron movements in step 2.



step 2



[3]

This question was more difficult for candidates with some leaving it blank. The most commonly seen correct fragment was the upper fragment from the protein chain containing an NH_2 group, the other fragments were often incomplete or contained extra bonds that were incorrect.

Question 4 (e) (i)

(e) (i) Explain why warming a solution of chymotrypsin will destroy its activity as an enzyme.

.....

.....

.....

..... **[2]**

Candidates understood that warming the enzyme caused bonds to break within the enzyme that rendered it inactive. However, they were often unclear about the nature of the bonds being broken and identified them as ionic bonds or disulphide bridges which would be unlikely to happen and so could not score marking point 1.

Alternatively, candidates stated that the enzyme would be destroyed or change shape which was too imprecise as the correct response was to state that the active site would lose its shape. The enzyme molecule is not destroyed in this process, but its tertiary structure is altered to render the enzyme inactive.

Question 4 (e) (ii)

(ii) Chymotrypsin has an optimum pH = 8.

Draw a sketch to suggest the shape of the graph of chymotrypsin activity against pH.

Explain the shape of your graph.

.....

..... **[3]**

Most candidates scored 2 marks here, as they correctly drew a 'bell shaped' curve with the axes correctly labelled and gave a clear indication that the peak was above pH8 (or labelled as pH8) to score the second mark.

Some candidates struggled with their explanation of the shape and stated that the extremes of pH would denature/destroy the enzyme rather than being clear that the presence of H^+/OH^- ions would interact with ionic groups in the active site causing this to lose its shape.

Question 4 (e) (iii)

(iii) A student says that the rate of an enzyme reaction is proportional to the substrate concentration.

Comment on the student's statement, correcting any errors.

.....

.....

.....

.....

.....

..... **[2]**

This question was about asking for an explanation about how the rate changes with substrate concentration. Many candidates gave a response that was in terms of how the rate changes with enzyme concentration. The mark scheme makes it clear that in order to gain marks here candidates had to discuss how changing the substrate concentration would affect the rate of this reaction. Therefore responses that focused on the enzyme concentration were not incorrect, but were not deemed to be worthy of marks. For example, a response stating that the enzyme became the limiting factor may be true but is not worth a mark as it makes no reference to whether or not this is at high substrate concentration or at low enzyme concentration.

Question 5 (a) (i) and (a) (ii)

5 This question concerns the Advanced Notice Article 'Fluoride compounds in dental hygiene' that is included as an insert with this paper.

(a) Hydrofluoric acid (HF) is described in the article as 'moderately strong' with a pK_a of 3.14.

(i) Write the expression for K_a for HF and give its units.

K_a =

units ..... **[2]**

(ii) Calculate the $\frac{[F^-]}{[HF]}$ ratio in hydrofluoric acid under the acidic conditions in plaque at pH 5.0.

$\frac{[F^-]}{[HF]}$ = ... **[3]**

This question was well answered by most candidates, with candidates gaining marks in both parts. Question 5 (a) (i) was particularly well answered with candidates gaining at least 1, if not both, of the marks available here. In Question 5 (a) (ii) many candidates scored all 3 marks, however, it was not uncommon to see the equation being inverted and a value of 1.38×10^{-2} being produced which would have gained marking points 1 and 3.

Question 5 (b)

(b) The HPO_4^{2-} ion is mentioned in the article.

Write the formula of the conjugate base of the HPO_4^{2-} ion and explain your answer.

.....

.....

..... **[2]**

Common incorrect responses to this question included the calcium salt, $CaHPO_4$, and the $H_2PO_4^-$ ion being named. However there were many candidates who scored at least 1 mark for correctly identifying the phosphate ion, PO_4^{3-} as the conjugate base but many did not gain the second mark as they did not give an appropriate explanation for why this was behaving as a base. The most successful candidates did score this mark as they were able to state that it either gained a proton from an acid, or that it was formed by the loss of a proton from the original ion given in the stem of the question.

Question 5 (c)

(c) SnF_2 is said in the article to hydrolyse at 'higher pH'.

Suggest an equation for the reaction between SnF_2 and hydroxide ions.

[1]

This question produced a number of incorrect answers. The most common error was in giving F_2 as a product of the reaction. Although this did produce a balance in the number of atoms present on both sides of the equation, there was an imbalance in the charges present. Again however, the more successful candidates across the paper did gain this mark.

Question 5 (d)

(d) Name the shape around the N atom in the $-NH_3^+$ group in dectaflur.

..... **[1]**

There were very few scripts where this question was not attempted. While it was not uncommon for stronger candidates to gain this mark, less successful candidates gave answers such as pyramidal or square planar both of which were incorrect.

Question 5 (e) (i)

(e) (i) Explain the relationship between the ion product, IP, and the solubility product, K_{sp}, for an ionic substance.

.....

.....

.....

.....

..... **[2]**

Less successful responses often left this question blank and even the more successful candidates tended not to gain marks. Some candidates recognised that both expressions had a similar mathematical form, but they did not recognise that K_{sp} represented a relationship for the equilibrium between the ions and the ionic solid when the solution is at saturation. Also, few recognised that IP was valid for all of the ions present in a solution at any other concentration, including when at supersaturation. Although some candidates did state that if IP was greater than K_{sp} that the solution would be supersaturated, this was insufficient to gain any marks.

Question 5 (e) (ii)

(ii) Calculate the supersaturation of calcium fluoride in saliva after brushing.

Give your answer to the **nearest whole number**.

supersaturation = ... **[3]**

This was well attempted by the majority of candidates. Many candidates gained 2 or 3 marks on this question. Where they did not gain full marks was from either not giving their final answer to the nearest whole number, as instructed in the question, or by an incorrect calculation of IP initially.

Question 5 (f)

(f) Calculate the ppm by mass of fluorine in pure fluoroapatite, $Ca_5(PO_4)_3F$.

ppm by mass = ... **[2]**

The final calculation on the paper was well answered by most candidates. Again, very few candidates did not attempt this question, and the majority did gain at least 1 mark with many gaining both of the available marks. Where candidates did calculate the Mr of fluorapatite correctly, and used the Ar value of Fluorine to gain the first mark, the most commonly seen error was to multiply this value by 1000 rather than by $1x10^6$ to arrive at their final answer.

Question 5 (g)*

(g)* Use information from the article to describe the chemistry of how fluoride improves dental health and to explain why this is **not** because of the formation of a protective or a hard layer.

.....

.....

.....

.....

.....

..... **[6]**

The final question produced a range of responses across all Levels. Very few candidates did not score any marks as they addressed at least one aspect of how fluoride improves dental hygiene. Some candidates were gave responses that focused mainly on the anti-bacterial role, or in the formation of plaque and often only accessed Level 1 when they started discussing the danger to dental health caused by the attack of acids on the enamel. But, as they had often spent some time on their initial discussion it appeared that they became conscious of time limitations and so did not include enough detail about remineralisation, or fluorapatite precipitation to go beyond Level 1.

Many candidates gave good discussions on how the inclusion of fluoride in dental products improves dental hygiene and made mention of why it was not responsible for hardening the enamel outer layer and so were able to access Level 2.

Exemplar 3

Fluoride improves dental health [illegible],
hence its inclusion in many dental care products.
It improves remineralization due to improved
nucleation through precipitation of fluorapatite,
helping counteract demineralization that occurs
due to the consumption of acidic foods. It also
has antibacterial effects although this is
mostly due to the counterion, which helps
protect against caries.
However, it's positive effects are not due
to the formation of a protective layer, as
fluoride compounds are acid soluble so this
is not possible in the mouth. It also barely
hardens the enamel, and we can find
evidence for this in the form of shark [6]

Additional answer space if required

tooth enamel comprised of fluorapatite,
as ~~they are~~ it is not significantly harder than
human tooth enamel.

Exemplar 3 shows a typical response at Level 2 that was given 4 of the available marks.

The candidate has picked out evidence to suggest why fluoride both improves dental health and why it does not provide a protective hard layer. This evidence addresses both of the main areas but the only fine detail included in the response was in making a comparison between human teeth and shark's teeth. For this response to move to Level 3 it the candidate would have needed to include some of the fine detail to support how fluoride promotes improvement in dental health, e.g. that acid attacks hydroxylapatite causing demineralisation, but that fluoride ions, F^-, act as a catalyst to encourage remineralisation of the enamel layer.

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