Oxford Cambridge and RSA

Monday 20 June 2022 – Morning

A Level Chemistry B (Salters)

H433/02 Scientific literacy in chemistry

Time allowed: 2 hours 15 minutes

You must have:
- a clean copy of the Advance Notice Article (inside this document)
- the Data Sheet for Chemistry B

You can use:
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

ADVICE
- Read each question carefully before you start your answer.

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Answer **all** the questions.

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]

(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]**

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

Explain how these lines are formed.

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

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

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

(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?

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

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

.....

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

(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]**

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(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 $Fe^{3+}(aq)$.

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

(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]**

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

Suggest why the student does this.

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

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

Complete the nuclear equation for one such reaction.

$$^{48}_{24}\ldots\ldots + {}^{\ldots}_{\ldots}He \longrightarrow {}^{\ldots}_{\ldots}Fe$$ **[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.

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

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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]**

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

π bonds ..... σ bonds ..... **[1]**

(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]**

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

[1]

(e) The presence of the three isomers as monomers in 'polybutene' means that different side-chains are present that do not allow the polymer chains to get close together. This causes the polymer to be a liquid suitable for lip gloss.

Name the intermolecular bonds that hold the chains together in polybutene.

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

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(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]

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

Name a catalyst and the corresponding conditions for this reaction.

catalyst: .....

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

(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]**

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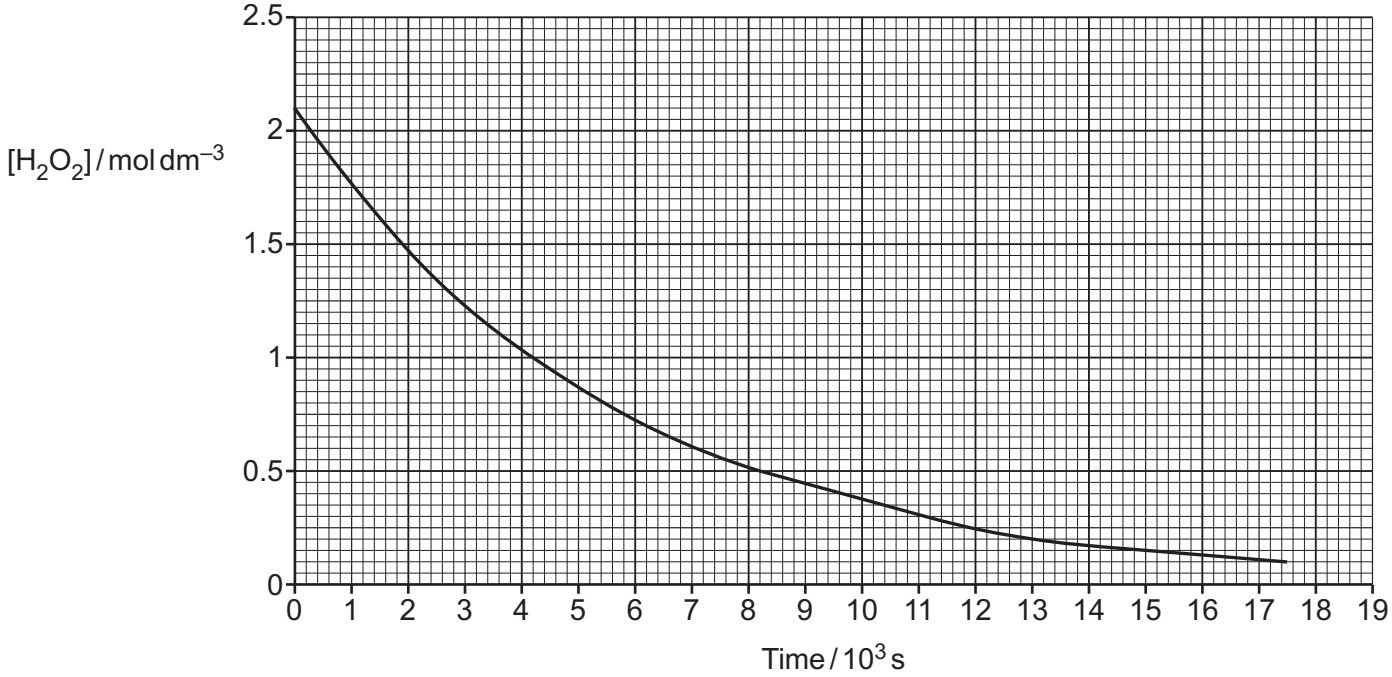
3 Some students read about the reaction between hydrogen peroxide and iodide ions as shown in **equation 3.1**.

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

(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]**

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(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.

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

(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.

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

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

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

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

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

Additional answer space if required

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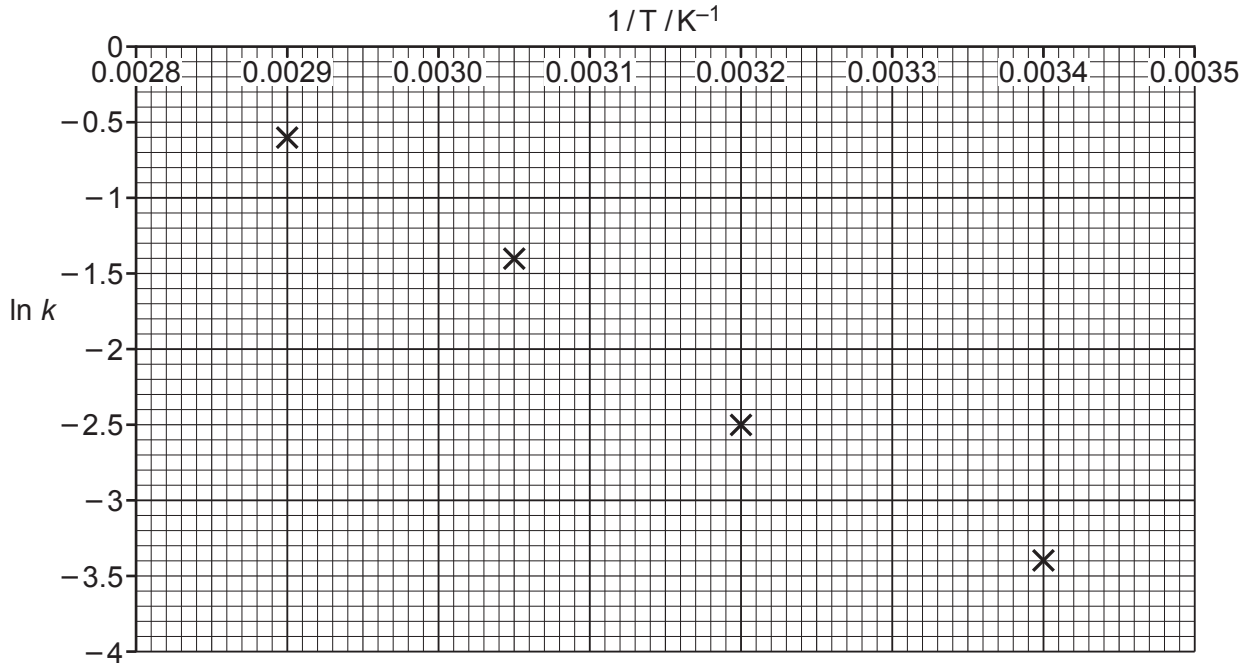
(d) The students find data for the variation of the rate constant, *k*, with temperature.
From their data they plot the graph below.



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

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

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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]

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

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

[2]

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

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

(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?

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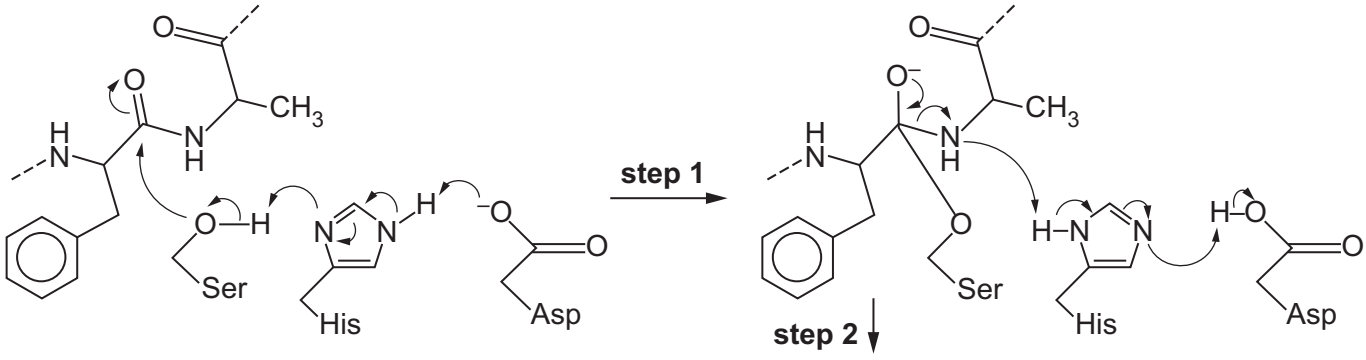
..... **[2]**

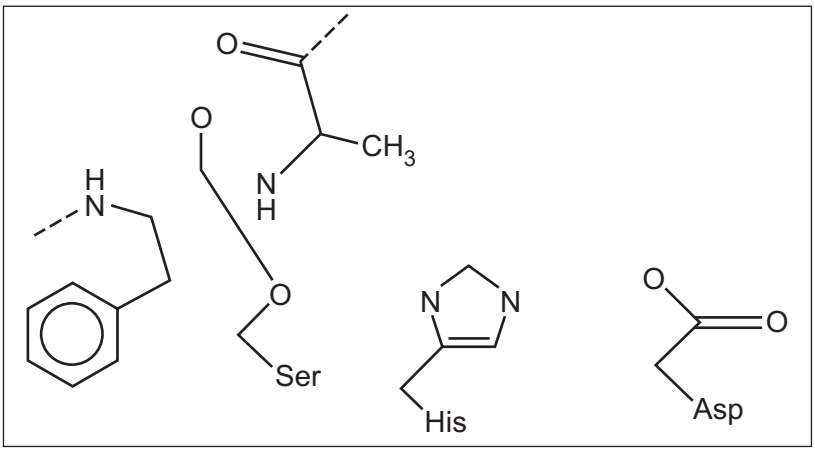
(d) Chymotrypsin catalyses the hydrolysis of proteins in the small intestine.

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.





[3]

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

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

(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.

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

(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.

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

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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]**

(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.

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

(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]

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

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

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

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

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

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

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

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

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

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(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.

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Additional answer space if required

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END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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