EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2023
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	

CIVICS GROUP	2	2	–			INDEX NUMBER		

CHEMISTRY

9729/02

Paper 2 Structured Questions

13 September 2023
2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, civics group, index number in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 2	
1	**/ 12**
2	**/ 16**
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4	**/ 16**
5	**/ 15**
Total	**/ 75**

This document consists of **27** printed pages and **1** blank page.

1 **(a)** In the past two decades, scientists have observed a steady decrease in the pH of the oceans. This phenomenon is known as ocean acidification.

(i) Ocean acidification occurs when carbon dioxide dissolves and reacts with water in the ocean to form carbonic acid, H_2CO_3.

Write equations to illustrate how carbon dioxide decreases the pH of seawater.

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....[2]

(ii) In the past two centuries, the average pH of seawater has dropped from 8.2 to 8.1. Calculate the percentage increase in the concentration of H^+(aq) ions in sea water.

[1]

(iii) The significant change in pH of seawater is unexpected as the oceans have a natural buffering system involving CO_3^{2-}(aq) and HCO_3^-(aq).

Write an equation to show how the CO_3^{2-}(aq)/HCO_3^-(aq) buffer system helps resist the decrease in the pH of seawater when carbon dioxide dissolves.

....[1]

(b) The main cause of ocean acidification is the rising carbon dioxide levels in the atmosphere, which is a result of the increase in the use of fossil fuels. To combat this, alternative fuels such as methanol are being explored.

(i) Define the term *standard enthalpy change of combustion*, $\Delta H_c^\ominus$.

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....[1]

(ii) When 1.86 g of methanol, CH_3OH, was combusted in a bomb calorimeter, a temperature rise of 5.1 K was measured.

In a separate experiment, 1.00 g of benzoic acid, $C_6H_5CO_2H$, produced a temperature rise of 3.2 K when combusted in the same bomb calorimeter under identical conditions.

Given that the enthalpy change of combustion of benzoic acid is -3226 kJ mol^{-1}, calculate the enthalpy change of combustion of methanol.

[3]

(c) Methanol can be synthesised through the reaction between carbon dioxide and hydrogen, as shown in equilibrium 1 below.

equilibrium 1 $CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(l) + H_2O(g)$ $\Delta H_1^{\ominus} = -49.5\ kJ\ mol^{-1}$

At the same time, a side reaction, as shown in equilibrium 2, can occur.

equilibrium 2 $CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$ $\Delta H_2^{\ominus} = +41.2\ kJ\ mol^{-1}$

(i) Explain why the synthesis of methanol is usually conducted at low temperature and high pressure.

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....[2]

(ii) CO(g) is sometimes added to the reaction mixture at constant volume after synthesis has occurred to a certain extent. Suggest one advantage of doing so.

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....[2]

[Total: 12]

Question 2 starts on the next page

2 Copper is a key metal needed in the production of electrical wirings that powers the modern world.

(a) Copper is first extracted from mineral ores such as cuprite (Cu_2O) and tenorite (CuO).

(i) State the oxidation number and the electronic configuration of copper in Cu and CuO in Table 2.1.

Table 2.1

copper species	oxidation number	electronic configuration
Cu		
CuO		

[2]

(ii) Explain why copper exists in different oxidation states such as in Cu_2O and CuO.

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.... [1]

(b) Samples of tenorite (CuO) was analysed for its isotopic composition of copper by means of mass spectrometry. The results of the analysis are given in the table below.

Table 2.2

mass number	16	63	65
% abundance	49	15	36

Using Table 2.2, calculate the A_r value for copper.

[1]

(c) After extraction from one of its mineral ores, the crude copper metal containing iron and silver metal impurities is further purified via electrolysis.

(i) Draw a labelled diagram of the electrolytic cell used to purify a piece of crude copper metal. Include details of the cathode, anode and electrolyte.

[1]

(ii) Using relevant data from the *Data Booklet*, explain what happens at the anode and the cathode during the purification process.

Anode: ....

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Cathode: ....

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[3]

(iii) In a test run for the process, a current of 7.5 A was passed through the electrolytic cell. After some time, it was found that 250 g of pure copper was formed.

Calculate the time required for the reaction in minutes.

[1]

(iv) The theoretical mass of copper formed should be 260 g. In addition, some bubbling was observed at the pure copper electrode.

Identify the gas evolved at the pure copper electrode and suggest a reason for the difference in mass of copper formed.

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.... [2]

(d) A complex ion in the electrolyte is responsible for the light blue colour of the solution.

(i) Define the term “complex ion”.

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.... [1]

(ii) Identify the complex ion responsible for the light blue colour.

.... [1]

A concentrated solution of HCl was accidently added into the electrolyte, which resulted in the formation of a new complex ion. This caused the electrolyte solution to turn from pale blue to yellow-green.

(iii) State the type of reaction that led to the change in colour.

.... [1]

(iv) Suggest, with the aid of an ionic equation, an explanation for the observation.

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.... [2]

[Total: 16]

3 Hydrochloric acid, HC*l* is a strong acid, while chloric(I) acid, HC*l*O is a weak acid.

(a) HC*l* and HC*l*O can react with each other in a Bronsted-Lowry acid-base reaction.

(i) Write an equation for the reaction of HC*l* with HC*l*O.

.... [1]

(ii) Identify the two different conjugate acid-base pairs in the reaction occurring in **(a)(i)**.

acid ……………………………… conjugate base …………………………..

base …………………………….. conjugate acid …………………………..

[1]

(b) Two different solutions are prepared using HC*l* and HC*l*O.

Solution X is made by mixing 50 cm^3 of 2.00×10^{-3} mol dm^{-3} HC*l*(aq) with 50 cm^3 of 2.00×10^{-3} mol dm^{-3} NaC*l*(aq). The resultant solution has a pH of 3.0.

Solution Y is made by mixing 50 cm^3 of 0.100 mol dm^{-3} HC*l*O(aq) with 50 cm^3 of 0.100 mol dm^{-3} NaC*l*O(aq). The resultant solution has a pH of 7.5.

(i) Use the information about Solution X to prove that HC*l*(aq) is a strong acid. Show your working.

[2]

(ii) Write the expression for the acid dissociation constant, K_a, for chloric(I) acid, HC*l*O(aq).

.... [1]

(iii) Use the information about Solution Y to calculate the K_a value for HC*l*O(aq).

[1]

(c) Chloric(III) acid, $HClO_2$, is much more acidic than chloric(I) acid, HC*l*O.
This can be explained by the greater stability of the conjugate base of $HClO_2$ due to the delocalisation of electrons over both oxygen and chlorine atoms.

chloric(I) acid　　chloric(III) acid

With the aid of a suitable diagram, suggest how delocalisation of electrons occurs in the conjugate base of $HClO_2$.

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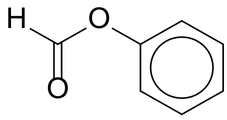
[2]

(d) Esters can undergo hydrolysis in the presence of strong aqueous acids such as HC*l*(aq).

The aromatic ester **E** is an example of one such compound.



E

(i) Name the ester **E**.

.... [1]

(ii) To synthesise ester **E**, CH_3OH must first be converted to HCO_2H.
State the reagents and conditions for the conversion of CH_3OH to HCO_2H.

.... [1]

(iii) Outline how ester **E** may be formed from HCO_2H.

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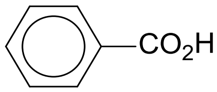
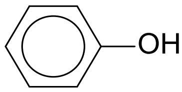
.... [1]

Question 3 continues on the next page

(e) The K_a value for some weak acids are given in Table 3.1.

Table 3.1

acid	formula	K_a / mol dm^{-3}
benzoic acid		6.3×10^{-5}
carbonic acid	H_2CO_3	4.5×10^{-7}
ethanol	CH_3CH_2OH	1.0×10^{-16}
ethanoic acid	CH_3CO_2H	1.8×10^{-5}
phenol		1.3×10^{-10}

(i) Explain the difference in K_a values between phenol and ethanol.

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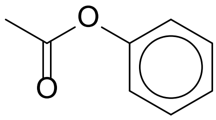
.... [2]

(ii) Give the structural formula of the organic products that would be formed from each step in Table 3.2.

Table 3.2

step	reaction	organic products formed
1	heating ester **F** under reflux with an excess of NaOH(aq)  **F**	
2	bubbling CO_2 through the resultant mixture in step 1	

[2]

(iii) Using information from Table 3.1, explain the organic products formed in step 2.

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.... [1]

[Total: 16]

4 This question is mainly about the chemistry of unsaturated hydrocarbons.

(a) Alkynes are compounds containing a carbon-carbon triple bond and they undergo reactions similar to those of alkenes.

When gaseous but-2-yne, $CH_3C{\equiv}CCH_3$, is reduced with hydrogen gas using a modified palladium metal catalyst, it is possible to control the reduction such that only one of the stereoisomers of but-2-ene is formed.

(i) Draw the structural formula of *cis*-but-2-ene and *trans*-but-2-ene, indicating clearly which is the *cis*-isomer and the *trans*-isomer.

[1]

(ii) Explain why *trans*-but-2-ene is thermodynamically more stable than *cis*-but-2-ene.

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.... [1]

(iii) State the type of catalysis occurring in the reduction of but-2-yne and explain its mode of action.

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.... [3]

(iv) Hence, suggest, with explanation, whether the *cis*- or the *trans*-isomer of but-2-ene is formed by reducing but-2-yne using the modified palladium metal catalyst.

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.... [1]

(b) Benzene is an unsaturated hydrocarbon that can undergo reduction to cyclohexane. However, its reduction requires higher temperatures and pressures, and longer reaction times than the reduction of alkenes or alkynes. Explain why this is so.

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.... [1]

(c) Pent-2-yne, $CH_3C{\equiv}CCH_2CH_3$, can be oxidised by $KMnO_4$ under certain conditions to form an organic product, $C_5H_8O_2$, which gives a yellow precipitate with aqueous alkaline iodine.

Suggest the structural formula of the organic product formed.

[1]

(d) In some circumstances, organic compounds with halogen atoms will undergo an elimination reaction as shown in Fig. 4.1.

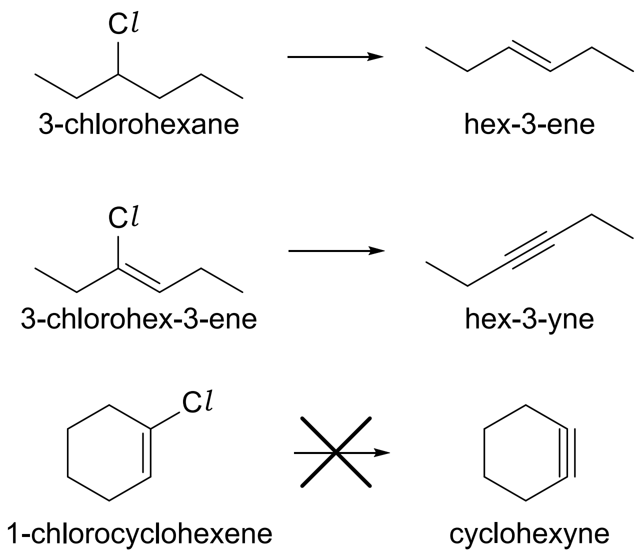

Fig. 4.1

(i) Suggest why it is much harder for 3-chlorohex-3-ene to undergo elimination compared to 3-chlorohexane.

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.... [1]

(ii) Given that the C atoms in a C≡C bond are sp hybridised, suggest why cyclohexyne is **not** formed.

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.... [1]

(e) (i) With the aid of a labelled diagram, explain how the orbitals overlap to form the C≡C bond in ethyne, H–C≡C–H.

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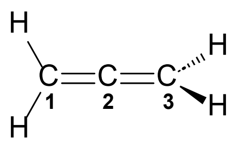
.... [3]

(ii) Propadiene is the simplest example of an allene, which are organic compounds with two adjacent carbon-carbon double bonds.



propadiene

By considering the orientation of orbitals on C2, explain why propadiene is not a planar molecule.

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.... [1]

(f) Buta-1,3-diene can undergo electrophilic addition with liquid bromine in a 1 : 1 ratio to give two products as shown in Fig. 4.2.

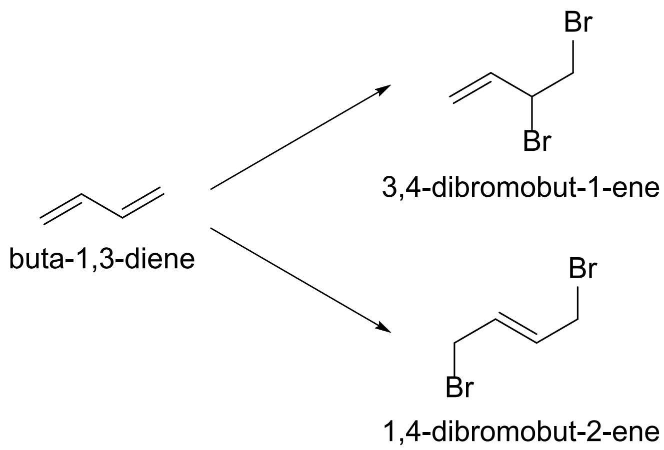


Fig. 4.2

The formation of 1,4-dibromobut-2-ene is unexpected but can be rationalised due to the delocalisation of electrons to form an alternative carbocation.

Suggest the mechanism for the formation of 1,4-dibromobut-2-ene. Show relevant lone pairs and dipoles, and use curly arrows to indicate the movement of electron pairs.

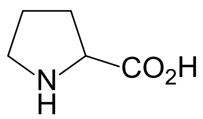
[2]

[Total: 16]

Question 5 starts on the next page

5 Glycinin is a water-soluble globular protein found in soy beans. Some amino acids found in glycinin are listed in Table 5.1.

Table 5.1

$H_2N-C(R)(H)-CO_2H$		
amino acid	Side-chain, R	pK_a of side-chain
arginine	$-(CH_2)_3N(H)-C(=NH)-NH_2$	12.5
aspartic acid	$-CH_2-C(=O)OH$	3.9
glutamic acid	$-CH_2CH_2-C(=O)OH$	4.3
glycine	$-H$	–
leucine	$-CH_2CH(CH_3)_2$	–
lysine	$-CH_2CH_2CH_2CH_2NH_2$	10.5
*proline		–
valine	$-CH(CH_3)_2$	–

* The full structure of proline is shown as it is the only amino acid that possesses a secondary amine for its amino group.

Fig. 5.1 shows a polypeptide chain folding into a globular shape, due to side-chain interactions.

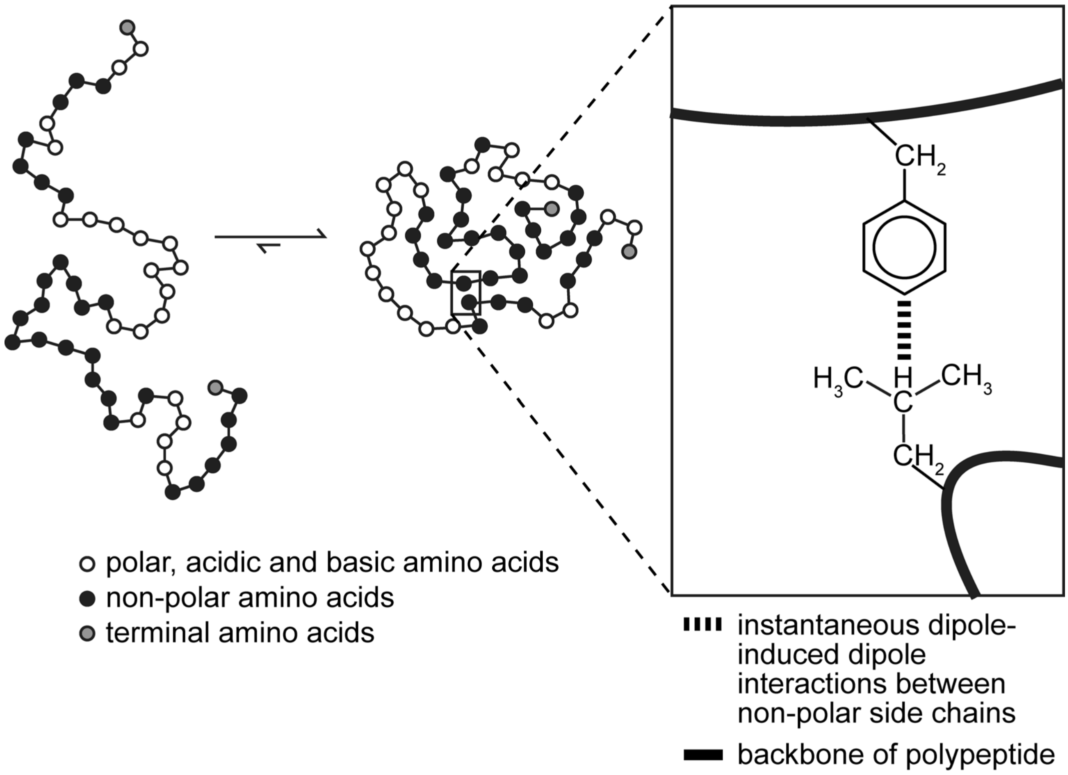


Fig. 5.1

(a) With reference to Fig. 5.1 and Table 5.1, suggest another type of side-chain interaction found in a polypeptide chain of glycinin at pH 7.

Illustrate your answer with the side-chains of suitable pairs of amino acids on Fig. 5.2.

type of side-chain interaction: ....

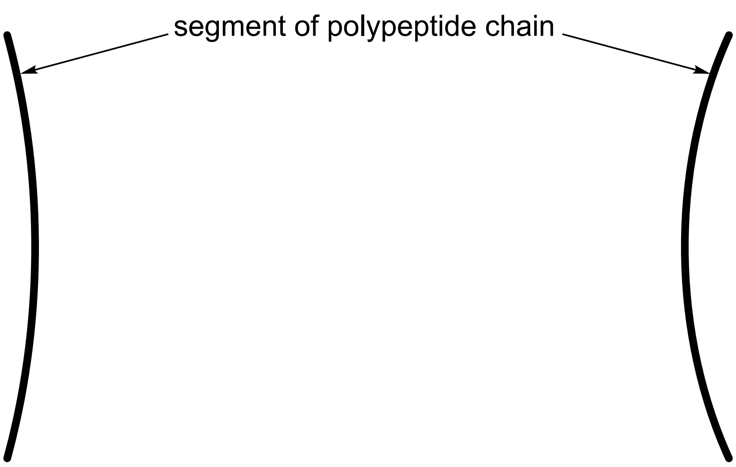


Fig. 5.2

[2]

(b) Papain is an enzyme that breaks down proteins into smaller peptides and amino acids. It exhibits broad specificity, cleaving peptide bonds on the carboxyl side of glycine, leucine and basic amino acids.

A short segment of six amino acid sequence in glycinin is shown in Fig. 5.3.

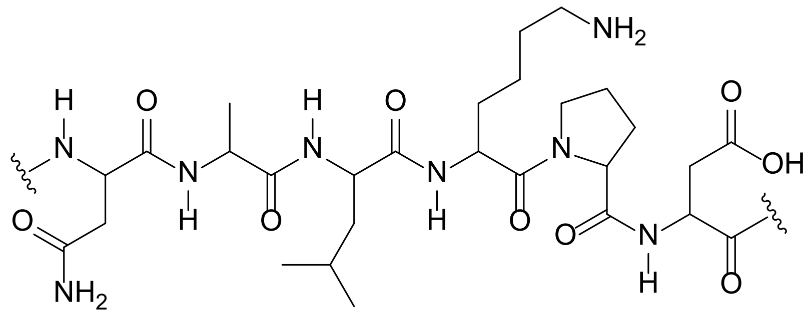


Fig. 5.3

(i) With reference to Table 5.1 and your knowledge of the basicity of organic compounds, circle on Fig. 5.3 the peptide bonds that are cleaved by Papain. [2]

(ii) Suggest the reagent and condition needed to fully hydrolyse glycinin.

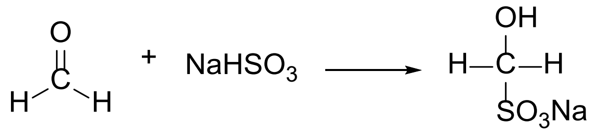
.... [1]

(c) Formaldehyde, HCHO, is a toxic chemical which was reported to be abused as a food preservative for food with short shelf life such as soy bean curds.

Formaldehyde content can be determined via the process below:

A. **Back titration**

1. A 5 cm^3 sample containing HCHO, is reacted with excess of sodium bisulfite solution, $NaHSO_3$. The mixture is left to stand for 30 minutes.



A

2. 20 cm^3 of 0.080 mol dm^{-3} iodine solution, I_2 is added to the reaction mixture in step 1 until the solution turns brown.

$$NaHSO_3 + I_2 + H_2O \rightarrow NaI + HI + H_2SO_4$$

3. The unreacted I_2 from step 2 is then titrated with 0.100 mol dm^{-3} of sodium thiosulfate solution, $Na_2S_2O_3$.

$$I_2 + 2Na_2S_2O_3 \rightarrow Na_2S_4O_6 + 2NaI$$

The titre volume, V_A is 25.30 cm^3.

B. **Blank titration**

Steps 1 to 3 are repeated using 5 cm^3 of deionised water instead of HCHO. The titre volume, V_B is 22.00 cm^3.

(i) The concentration of HCHO in the sample can be determined by considering the difference between V_A and V_B.
Suggest why V_B is lower than V_A.

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.... [1]

(ii) Determine the concentration of HCHO in the 5 cm^3 sample.

[3]

(iii) Suggest a chemical test to distinguish HCHO and compound **A**.
You may assume $–SO_3Na$ is inert.

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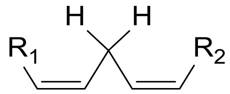
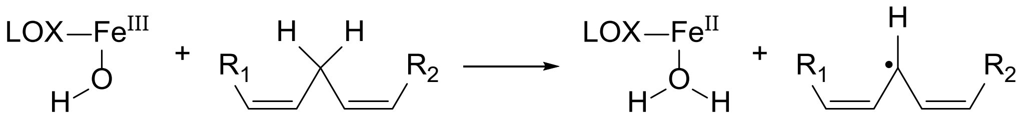
.... [2]

(d) Soy bean lipoxygenase is an iron-containing enzyme that oxidises unsaturated fatty acids in three stages as shown in Fig. 5.4.

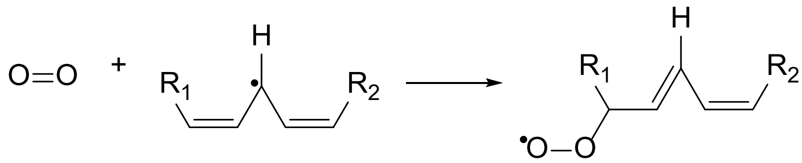
The lipoxygenase is represented as LOX–Fe^{III}–OH. The iron has a +3 oxidation state.

The fatty acid is represented as .

stage 1: Hydrogen abstraction from an allylic carbon to form a radical



stage 2: Addition of O_2 to form a peroxy radical (−OO•)



stage 3: Reduction of the peroxy radical to an organic hydroperoxide (ROOH)

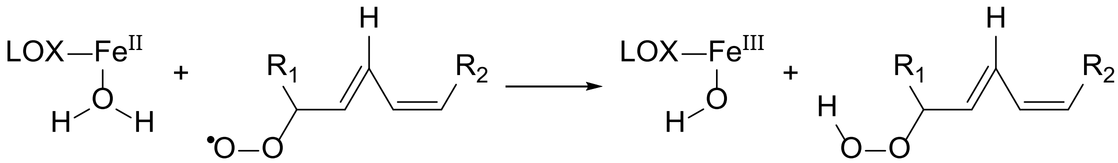


Fig. 5.4

(i) In stage 1, the C−H bond undergoes *homolytic fission*. Explain the term *homolytic fission*.

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....

.... [1]

(ii) Use curly arrow notation to show the movement of electrons for stage 2 in Fig. 5.4. [1]

(iii) Write the overall equation for the oxidation of fatty acid described in Fig. 5.4. Hence, determine the enthalpy change of reaction for the overall reaction.

[2]

[Total: 15]

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