Candidate Full Name	Class	Candidate Number
	6.	

Anglo-Chinese School (Independent)

THE BEST IS YET TO BE

Year 6 Preliminary Examination 2022
INTERNATIONAL BACCALAUREATE DIPLOMA PROGRAMME
CHEMISTRY HIGHER LEVEL

PAPER 2

Monday **12th September 2022** **2 hours 15 minutes**

For examiner's use	
Qn 1	/7
Qn 2	/13
Qn 3	/19
Qn 4	/12
Qn 5	/9
Qn 6	/12
Qn 7	/18
Wrong s.f. /units	
Total	/90

INSTRUCTIONS TO CANDIDATES

- Write your **candidate number in the box above**.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- A calculator is required for this paper.
- A copy of the Chemistry Data Booklet is required for this paper.
- Write your answers in the boxes provided.
- The maximum marks for this examination paper is **90 marks**.

This question paper consists of 23 printed pages, including the cover page.

Answer **all** questions. Write your answers in the boxes provided.

1. Copper is one of the most commonly used metal and exists in two oxidation states, +1 and +2.

Mass spectroscopic analysis of a sample of copper gave the following results:

	% abundance
$^{63}Cu^{+}$	69.17
$^{65}Cu^{+}$	30.83

(a) Calculate the relative atomic mass of copper to two decimal places. [2]

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(b) State the number of protons, neutrons and electrons in the $^{65}Cu^{2+}$ ion. [1]

Number of protons: ______________________

Number of neutrons: ______________________

Number of electrons: ______________________

(c) State the full electron configuration of the Cu^{+} ion. [1]

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(d) Explain why, when ligands bond to the copper(II) ion causing the d–orbitals to split, the complex is coloured. [2]

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(e) If it takes 1.24×10^{-18} J of energy to eject an electron from the surface of copper metal, calculate the longest possible wavelength, in nm, of light that can ionize the metal. [1]

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2. (a) Elements show trends in their physical properties across the Periodic Table.

(i) Explain why the first ionization energy of oxygen is lower than the first ionization energy of nitrogen. [2]

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(ii) Explain why the atomic radius decreases across period 3, from sodium to chlorine. [2]

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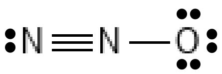
(b) Dinitrogen monoxide, N_2O, causes depletion of ozone in the stratosphere. The Lewis (electron dot) structure of dinitrogen monoxide molecule can be represented as:



Lewis structure **I**

(i) Draw two other possible Lewis (electron dot) structures of dinitrogen monoxide with central atom N. [2]

Lewis structure **II**	Lewis structure **III**

(This question continues on the following page)

(ii) Using formal charge, predict which Lewis structure **I**, **II** or **III** is preferred. Give a reason for your answer. [2]

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(iii) State and explain the shape of the dinitrogen monoxide molecule. [1]

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(c) At the stratosphere, dinitrogen monoxide, N_2O, is converted to nitrogen monoxide, NO, which is a free radical. NO catalyses the depletion of ozone.

(i) Using a Lewis (electron dot) structure, explain why NO is highly reactive. [2]

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(ii) Write two equations to show how NO catalyses the depletion of ozone to form oxygen. [2]

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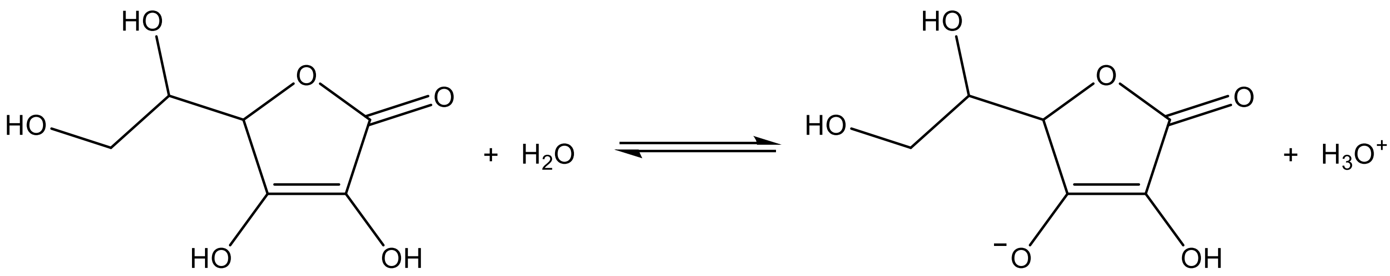
3. Ascorbic acid, $C_6H_8O_6$ is a potent antioxidant and a reducing agent that functions in fighting bacterial infections and is commonly found in fruits such as oranges.

Ascorbic acid is assumed to be a monobasic acid. The following equation illustrates the dissociation of ascorbic acid:



ascorbic acid
$C_6H_8O_6$

conjugate base of ascorbic acid
$C_6H_7O_6^-$

The acid dissociation constant, K_a, for ascorbic acid is 6.82×10^{-5} mol dm^{-3}.

(a) A 25.0 cm^3 of 0.500 mol dm^{-3} of the salt of the conjugate base of ascorbic acid, $NaC_6H_7O_6$ was pipetted into a conical flask for titration with hydrochloric acid, HCl.

(i) A pH meter was inserted into the conical flask containing $NaC_6H_7O_6$. It gave a pH reading of more than 7. Explain, using a relevant equation, why a pH reading of more than 7 was obtained. [2]

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(ii) Calculate the pH of the 25.0 cm^3 of 0.500 mol dm^{-3} of $NaC_6H_7O_6$ solution. [2]

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(iii) It was found that 13.30 cm^3 of HCl was required to reach the end–point of the titration. Calculate the concentration of HCl used. [1]

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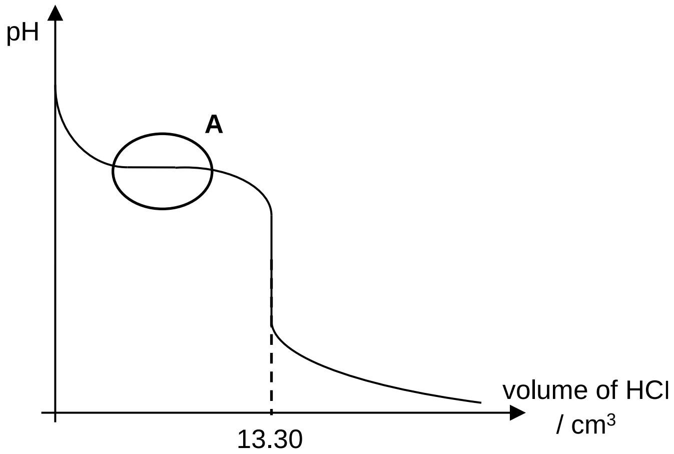
(b) A titration curve for the neutralization reaction between $NaC_6H_7O_6$ and HCl is shown below:



(i) Identify the chemical formula of the species present at the end–point of the titration. [1]

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(ii) State if the pH of the solution present at the end–point of the titration is

- lesser than 7,
- greater than 7, or
- equal to 7 [1]

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(iii) With the aid of a suitable equation, explain how the solution present in region **A** can resist pH change upon addition of small amounts of acid. [2]

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(This question continues on the following page)

(c) In another neutralization reaction, HCl of an identical concentration used in **(a)(iii)** was completely neutralized with 0.500 mol dm^{-3} of NaOH. The highest temperature reached was found to be higher compared to the neutralization of $NaC_6H_7O_6$ with HCl.

Explain the difference in the highest temperature reached. [2]

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(d) The standard enthalpy of formation of the NaCl formed from the neutralization between HCl and NaOH is −411 kJ mol^{-1}. It was also found that the enthalpy change of atomization of sodium metal is +108 kJ mol^{-1}.

(i) With reference to the salt formed, define, with the aid of an equation, the term *lattice enthalpy*. [2]

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(ii) Using a Born Haber cycle, determine the lattice enthalpy of this salt, in kJ mol^{-1}, using sections 8 and 11 of the data booklet and the data given. [3]

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(iii) The experimental and theoretical lattice enthalpy of LiCl and NaCl are stated in the table below.

	Experimental Lattice Enthalpy / kJ mol^{-1}	Theoretical Lattice Enthalpy / kJ mol^{-1}
LiCl	+864	+810
NaCl	Calculated in **(d)(ii)**	+771

Explain the relative discrepancy between the experimental and theoretical lattice enthalpy observed in LiCl compared to NaCl.
(If you did not obtain an answer to **(d)(ii)**, use +790 kJ mol^{-1}, but this is not the correct value.) [3]

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4. Nitrogen monoxide, NO (g), reacts with hydrogen, H_2 (g), in an enclosed vessel as shown in the equation below.

$$2NO\ (g) + 2H_2\ (g) \rightarrow N_2\ (g) + 2H_2O\ (g)$$

(a) Identify a method to monitor the rate of reaction. [1]

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(b) The rate equation for this reaction is given as Rate = $k\ [NO]^2\ [H_2]$
The result of an experiment in which NO reacted with H_2 is shown in the table below.

Initial [NO] / mol dm^{-3}	Initial [H_2] / mol dm^{-3}	Initial rate of reaction / mol dm^{-3} s^{-1}
2.50×10^{-3}	2.50×10^{-3}	1.27×10^{-3}

(i) Use the data and the rate equation to calculate a value for the rate constant *k*. [2]

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(ii) State the units for the rate constant, *k*. [1]

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(This question continues on the following page)

(iii) Calculate the initial rate of the reaction if the volume of the reaction vessel was suddenly halved under constant temperature. Explain your answer. [2]

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(c) The reaction mechanism is proposed to proceed in three steps.

Step 1: $2NO \rightleftharpoons N_2O_2$
Step 2: $N_2O_2 + H_2 \rightarrow N_2O + H_2O$
Step 3: $N_2O + H_2 \rightarrow N_2 + H_2O$

(i) Deduce which of the three steps is the rate determining step. [1]

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(ii) Explain your answer to **(c)(i)**. [1]

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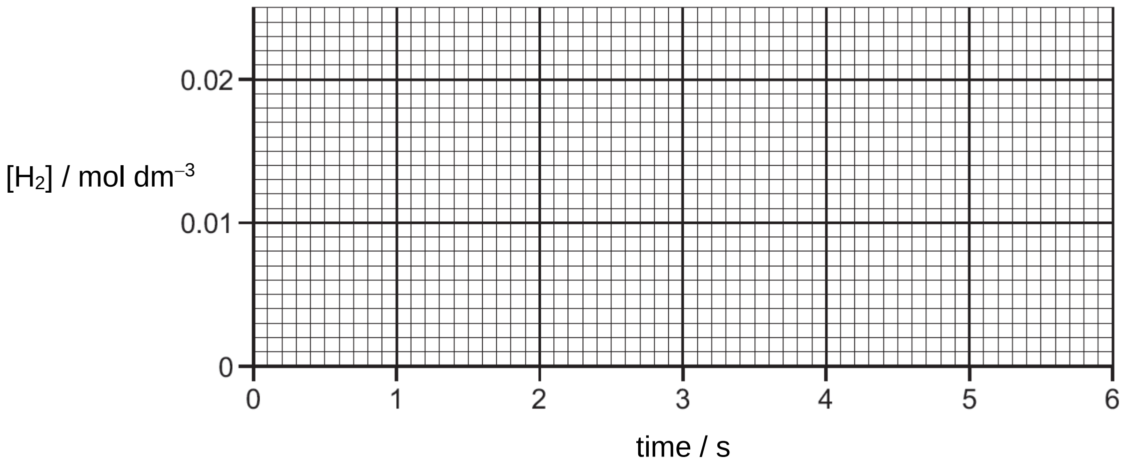
(d) A third experiment is performed under different conditions. A small amount of H_2 (g) of concentration 0.0200 mol dm^{-3} is mixed with a large excess of NO (g). The concentration of H_2 (g) is found to have a constant half-life of 2.00 seconds under the conditions used.

Use the axes below to construct a graph of the variation in the concentration of H_2 (g) during the first 6 seconds under the conditions used. [2]



(e) In a separate experiment, dinitrogen pentoxide, N_2O_5, undergoes thermal decomposition to produce nitrogen dioxide:

$$N_2O_5\ (g) \rightarrow 2NO_2\ (g) + \frac{1}{2}O_2\ (g)$$

Variation of the rate constant with temperature for the decomposition reaction is given in the following table.

Temperature, T / K	Rate constant, k / s^{-1}
298	1.74×10^{-5}
328	7.59×10^{-4}

By referring to sections 1 and 2 of the data booklet, calculate the activation energy for the decomposition reaction. [2]

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5. Arsenic pentafluoride (AsF_5) is a toxic and colourless substance which can be decomposed into arsenic trifluoride gas (AsF_3) and fluorine gas (F_2) at 105 ^oC in a close system as shown below:

$$AsF_5\ (g) \rightleftharpoons AsF_3\ (g) + F_2\ (g)$$

(a) Outline two characteristics of the reaction when it reaches dynamic equilibrium. [2]

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(b) Deduce the equilibrium constant expression, K_c, for the decomposition of AsF_5 (g). [1]

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(c) 0.328 mol of AsF_5 (g) was introduced into a 10.5 dm^3 closed container and at equilibrium it was found that 27.7% of the original number of moles of AsF_5 (g) has decomposed.

(i) Calculate the concentration of the reactant and products at equilibrium. [3]

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(This question continues on the following page)

(ii) Hence, calculate the value of K_c at 105 $^{\circ}$C [1]

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(iii) Predict what would happen to the position of equilibrium and the value of K_c if the pressure is increased from 1 atm to 2 atm. [2]

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6. Potassium iodide, KI, is a reducing agent commonly used in iodometric titration with sodium thiosulfate, $Na_2S_2O_3$.

(a) A 0.642 ± 0.001 g sample of potassium iodate, KIO_3, was dissolved in water and the solution was made up to 250.00 ± 0.01 cm^3 in a volumetric flask. 25.00 ± 0.02 cm^3 of this solution was pipetted into a conical flask and excess acidified potassium iodide solution, KI was added. The iodine formed from the reaction required 22.50 ± 0.10 cm^3 of sodium thiosulfate for titration.

(i) The following shows the half-equation for the reduction of IO_3^- (aq).

$$2IO_3^- (aq) + 12H^+ (aq) + 10e^- \rightarrow I_2 (aq) + 6H_2O (l)$$

Deduce the overall redox equation for the reaction of IO_3^- (aq) with I^- (aq). [1]

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(ii) Determine the percentage uncertainty for the concentration of sodium thiosulfate. [1]

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(b) (i) Using section 24 of the data booklet, explain why acidified aqueous potassium iodide turns brown when exposed to air for a period time. [3]

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(ii) A potassium iodide solution that turned brown was used as a standard solution in a titration with sodium thiosulfate. State if this will affect the precision or accuracy of the titration. [1]

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(c) Suggest, giving a reason, the relative reducing strength of the group 17 halide ions. Use section 24 of the data booklet. [2]

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(d) An aqueous solution of potassium iodide is electrolyzed using graphite electrodes.

(i) Write balanced half-equations for the reactions occurring at the anode (positive electrode) and cathode (negative electrode). [2]

Anode (positive electrode):

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Cathode (negative electrode):

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(ii) Explain how the pH of the solution changes as the electrolysis proceeds. [2]

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7. Propene is the second most important starting product in the petrochemical industry after ethylene. It is the raw material for a wide variety of products. Propene production has been increasing in East Asia, most notably Singapore and China.

(a) Draw a section, showing **three** repeating units of the polymer that can be formed from propene. [1]

(b) When propene is bubbled through iodine monochloride, ICl, dissolved in a suitable solvent, the reddish–brown liquid decolourised.

(i) State the type of reaction occurring. [1]

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(ii) Draw the **full** structural formula of the major product. [1]

(This question continues on the following page)

(iii) Explain why the organic product that you have drawn in **(b)(ii)** is the major product. [2]

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(c) Propene was first reacted with concentrated H_2SO_4, followed by heating the resulting intermediates with water. Two isomeric organic products, **X** and **Y**, were obtained and separated.

(i) Explain if infrared (IR) spectroscopy can be used to distinguish the two isomers. [1]

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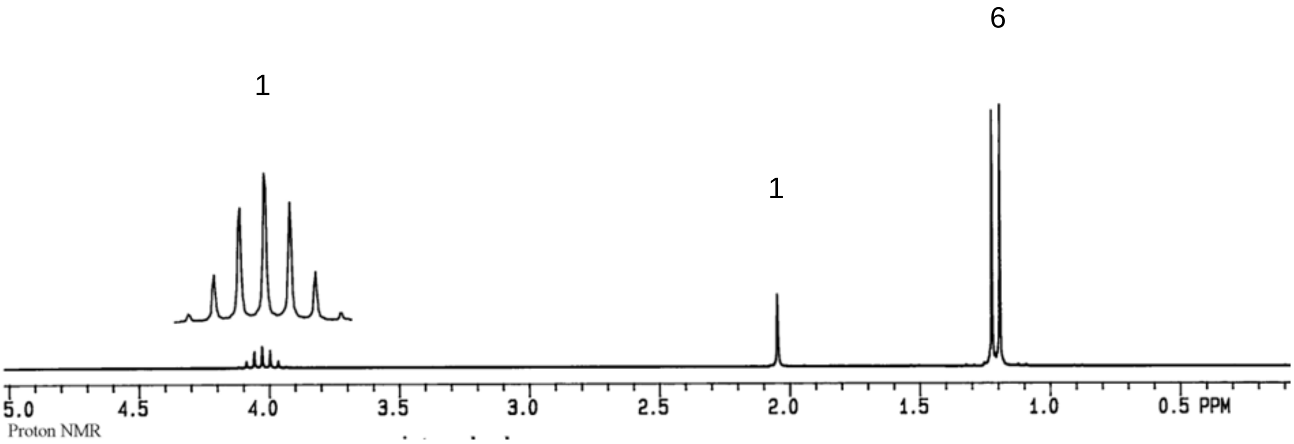
(ii) The diagram shows the ^1H NMR spectrum of **X,** the integral values are listed above the peaks. Using the ^1H NMR and section 27 of the data booklet, deduce with reasons, the structure of **X**. [3]



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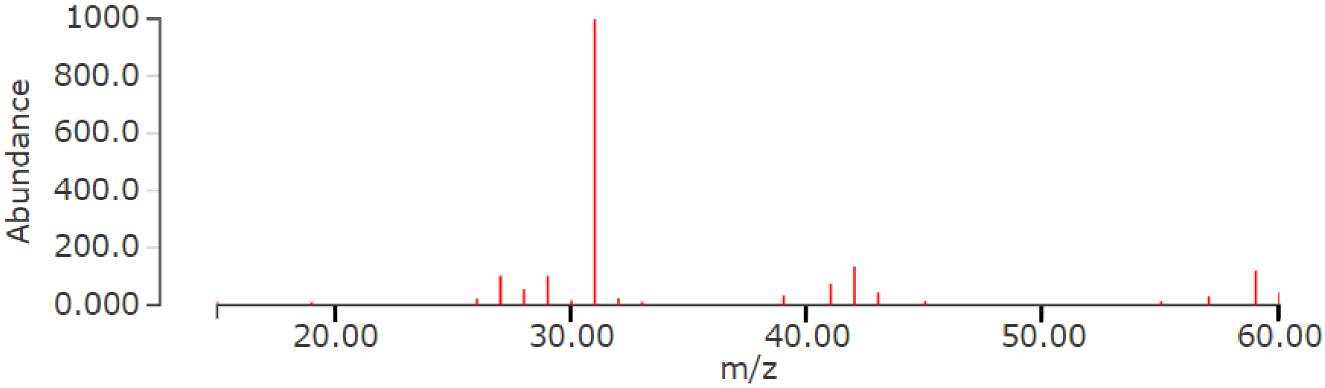
(iii) The diagram shows the mass spectrum of **Y**.



Using section 28 of the data booklet, identify the species responsible for the following m/z values in the mass spectrum of **Y**. [2]

m/z values	**species**
29	
31	
60	

(iv) **X** and **Y** were oxidized with acidified potassium dichromate(VI) solution in separate round bottom flasks. Draw the structures of the organic products formed. [2]

Oxidation product of **X**	Oxidation product of **Y**

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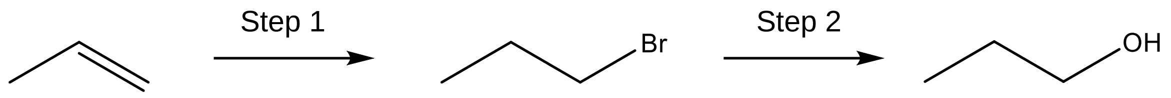
(d) Propene undergoes a series of reactions as shown below:



(i) State the reagents and conditions for step 1 and step 2. [2]

Step 1:

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Step 2:

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(ii) Explain the mechanism of the reaction in step 2, using curly arrows to represent the movement of electron pairs. [3]

End of Paper