EXAM PAPERS PRACTICE

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Detailed mark scheme

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Level: CIE AS and A Level (9701)
Subject: Chemistry
Topic: CIE Chemistry
Type: Topic Question

Chemistry CIE AS & A Level
To be used for all exam preparation for 2025+

CHEMISTRY AS and A

This to be used by all students studying CIE AS and A level Chemistry (9701) But students of other boards may find it useful

Question 1.

(a) When 1-chloropropane is heated under reflux with ethanolic potassium cyanide, KCN, the following reaction occurs.

$$CH_3CH_2CH_2Cl + KCN \rightarrow CH_3CH_2CH_2CN + KCl$$

i) Draw the displayed formula of the organic product formed in this reaction.

[1]

ii) State the IUPAC name of this organic product.

[1]

_____

_____

(2 marks)

(b) Suggest why this reaction is useful to chemists during the synthesis of other organic compounds.

_____

(1 mark)

(c) The $CH_3CH_2CH_2CN$ can undergo hydrolysis.

i) Write the equation for the acid hydrolysis of $CH_3CH_2CH_2CN$.

[2]

ii) Draw the displayed formula of the intermediate formed when $CH_3CH_2CH_2CN$ is hydrolysed by sodium hydroxide.

[1]

_____

_____

(3 marks)

Question 2.

(a) This question is about hydroxynitriles.

The hydroxynitrile shown in Fig. 2.1 can be prepared from the reaction between propanal and hydrogen cyanide.

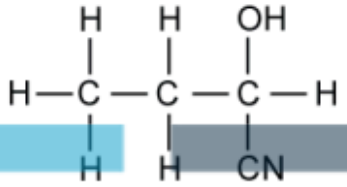


Fig. 2.1

Give the IUPAC name of this hydroxynitrile.

_____

(1 mark)

(b) Using 'curly arrows', complete the reaction mechanism shown in Fig. 2.2 for the reaction between propanal and the cyanide ion, CN^-.

Include any lone pairs of electrons and partial or whole charges.

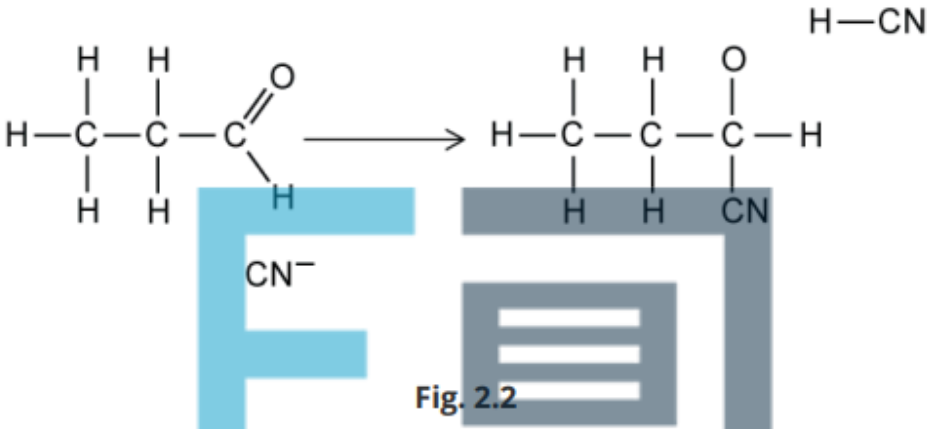


Fig. 2.2

(4 marks)

(c) Name the type of reaction mechanism shown in Fig. 2.2.

(1 mark)

Question 3.

(a) Propanal undergoes nucleophilic addition with a mixture of HCN and NaCN to make 2-hydroxybutanenitrile, $CH_3CH_2CH(OH)CN$.

The mechanism for this reaction occurs in two main steps. The first step involves a nucleophile attacking the carbonyl carbon of propanal.

Explain which species acts as the nucleophile during this reaction.

_____

_____

(2 marks)

(b) The second step in the mechanism involves an intermediate species, $CH_3CH_2C(O)HCN^-$, reacting with HCN to form 2-hydroxybutanenitrile.

Draw the mechanism for this step.

- Identify the intermediate species that reacts with HCN.
- Include all charges, partial charges, lone pairs and curly arrows.

_____

_____

_____

(3 marks)

(c) The structure of the 2-hydroxybutanenitrile product is shown in **Fig. 1.1.**

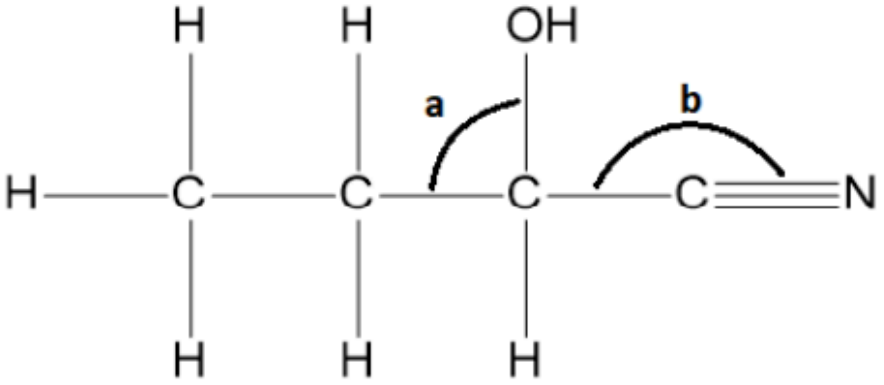


Fig. 1.1

Predict the values for the bond angles **a** and **b** shown in the diagram.

_____

_____

(2 marks)

(d) The product 2-hydroxybutanenitrile exists as a pair of stereoisomers.

i) Name the type of stereoisomerism shown by 2-hydroxybutanenitrile.

[1]

ii) Draw three-dimensional diagrams of this pair of stereoisomers. Indicate with an asterisk (*) the chiral centre on one of the structures drawn.

[3]

_____

_____

_____

_____

(4 marks)

Question 4.

(a) Two students try to prepare butanoic acid from a halogenoalkane in the laboratory.

Both students perform a nucleophilic substitution reaction to form **P** in reaction 1 of **Fig. 2.1**.

They both form butanoic acid from **P** but student **A** uses a single reaction, while student **B** uses two reactions.

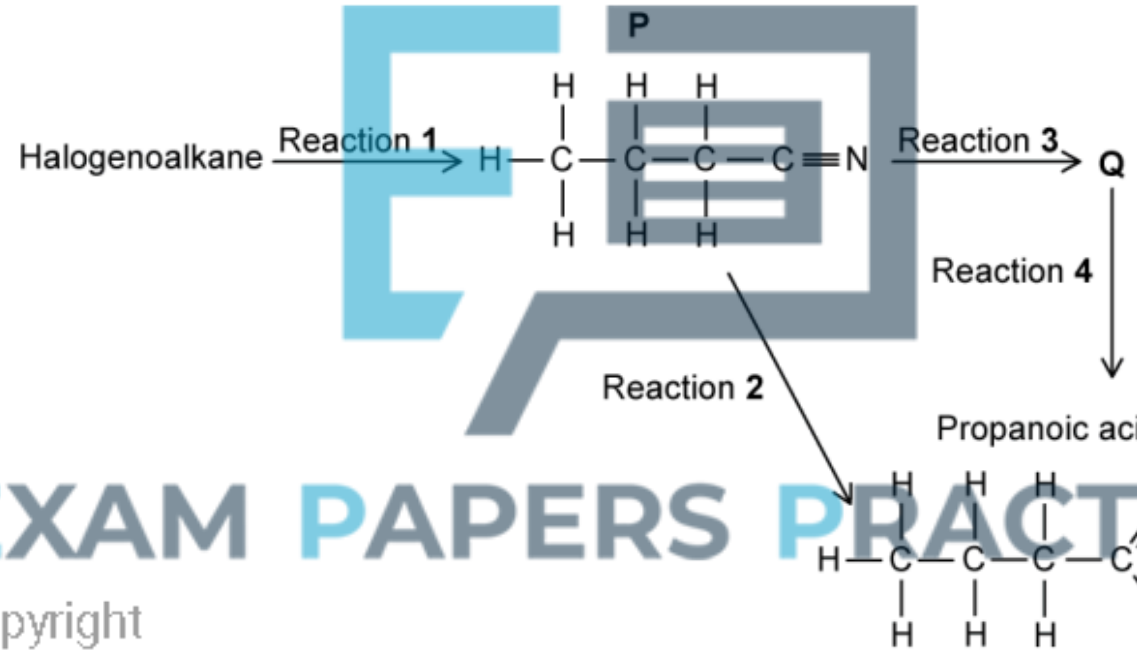


Fig. 2.1

i) State the reagents and conditions required for reaction 1.

[2]

ii) Student **A** uses 1-bromopropane to form **P**.

Student **B** uses a different halogenoalkane which forms **P** at a slower rate.

Suggest the identity of the halogenoalkane that student **B** uses. Explain your answer.

[2]

(4 marks)

(b) Student **A** converts **P** into butanoic acid in a single step, reaction 2.

i) Name the type of reaction occurring in reaction 2.

[1]

ii) State an appropriate reagent for reaction 2 and name the other product of the reaction.

[1]

(2 marks)

(c) Student **B** converts **P** into **Q** using dilute sodium hydroxide in reaction 3. This is followed by acidification of the product in reaction 4 to form butanoic acid.

Draw the structural formula of **Q**.

(1 mark)

(d) Explain why it is likely that student **A** will have a higher overall yield of butanoic acid from their halogenoalkane than student **B**.

(2 marks)

Question 5.

(a) Halogenoalkanes are often used as intermediates in organic reactions.

Three reactions of bromoethane, CH_3CH_2Br, are shown if **Fig. 3.1**.

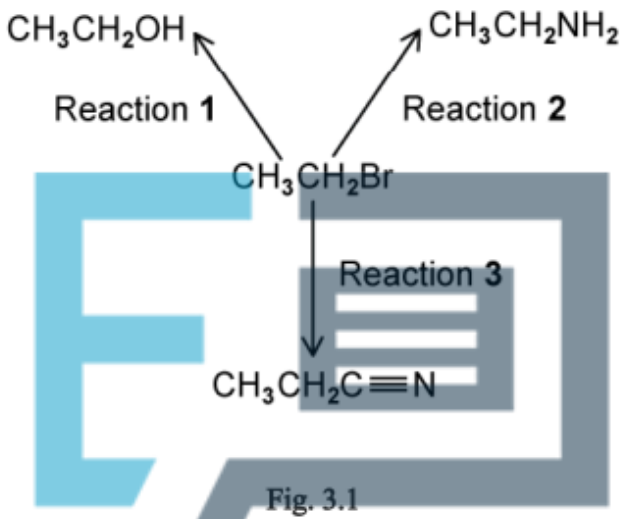


Fig. 3.1

For each reaction, state the reagent and solvent used.

reaction 1

reagent .....

solvent .....

reaction 2

reagent .....

solvent .....

reaction 3

reagent .....

solvent .....

(6 marks)

(b) Reactions 1 and 3 require specific reaction conditions to occur as shown in **Fig. 3.1**.

For each reaction, give another solvent and the alternative product that will be formed.

reaction 1

alternative solvent .....

alternative product .....

reaction 3

alternative solvent .....

alternative product .....

(4 marks)

(c) The product of reaction 2 can be converted into CH_3CN.

i) Name the compound CH_3CN.

[1]

ii) Name the type of reaction used to form CH_3CN.

[1]

(2 marks)

(d) The product of reaction 3 can be used to produce propanoic acid by two different hydrolysis reactions.

Compare the two types of hydrolysis reaction in the production of propanoic acid from the product of reaction 3.

(5 marks)

Question 6.

(a) 2-hydroxy-2-phenylpropanenitrile is shown in Fig. 1.1.

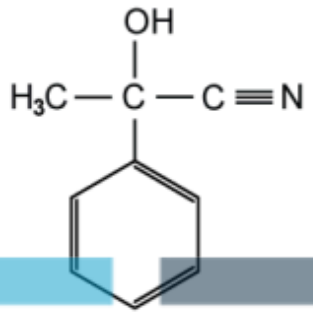


Fig. 1.1

Deduce the number of sigma (σ) and pi (π) bonds in 2-hydroxy-2-phenylpropanenitrile.

sigma .....

pi .....

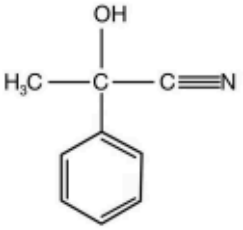
(2 marks)

(b) A molecule of 2-hydroxy-2-phenylpropanenitrile contains sp, sp^2 and sp^3 hybridised carbon atoms.

State the number of sp, sp^2 and sp^3 hybridised carbon atoms in a molecule of 2-hydroxy-2-phenylpropanenitrile.

(3 marks)

(c) 2-hydroxy-2-phenylpropanenitrile can be produced from compound **X**, a secondary alcohol, in a two-step synthesis.

compound **X** $\xrightarrow{\text{step 1}}$ compound **Y** $\xrightarrow{\text{step 2}}$ 

State the reagents and conditions required for step 1 and step 2.

reagents for step 1 .....

conditions for step 1 .....

reagents for step 2 .....

conditions for step 2 .....

(4 marks)

(d) i) Draw the mechanism for the second step in the synthesis of 2-hydroxy-2-phenylpropanenitrile.

You should clearly show the structure of compound **Y** and any intermediate formed and include all relevant charges, partial charges, curly arrows and lone pairs.

[6]

ii) Draw the structure of compound **X**.

[1]

(7 marks)

Question 7.

(a) 2,2-dimethylpentanenitrile is useful in the synthesis of a variety of medicines and pharmaceuticals.

Draw the skeletal formula of 2,2-dimethylpentanenitrile.

(1 mark)

(b) 2,2-dimethylpentanenitrile undergoes hydrolysis when heated with dilute hydrochloric acid.

Write an equation for the hydrolysis of 2,2-dimethylpentanenitrile.

(2 marks)

(c) 2,2-dimethylpentanoic acid can also be produced by the hydrolysis of 2,2-dimethylpentanenitrile using sodium hydroxide but this occurs in two steps.

i) Draw the fully displayed formula of the intermediate organic product.

[1]

ii) State the other product formed with this intermediate organic product.

[1]

iii) State the type of reaction that is required to produce 2,2-dimethylpentanoic acid from this intermediate organic product.

[1]

(3 marks)