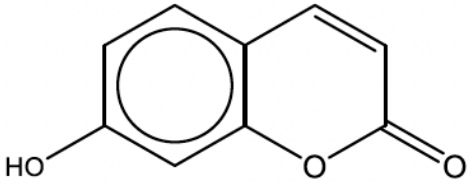
H2 Chemistry

Organic Chemistry Synthesis and Reaction Scheme Practice Questions

H2 Chemistry Reaction Scheme

1. 2022 ACJC P2 Q4

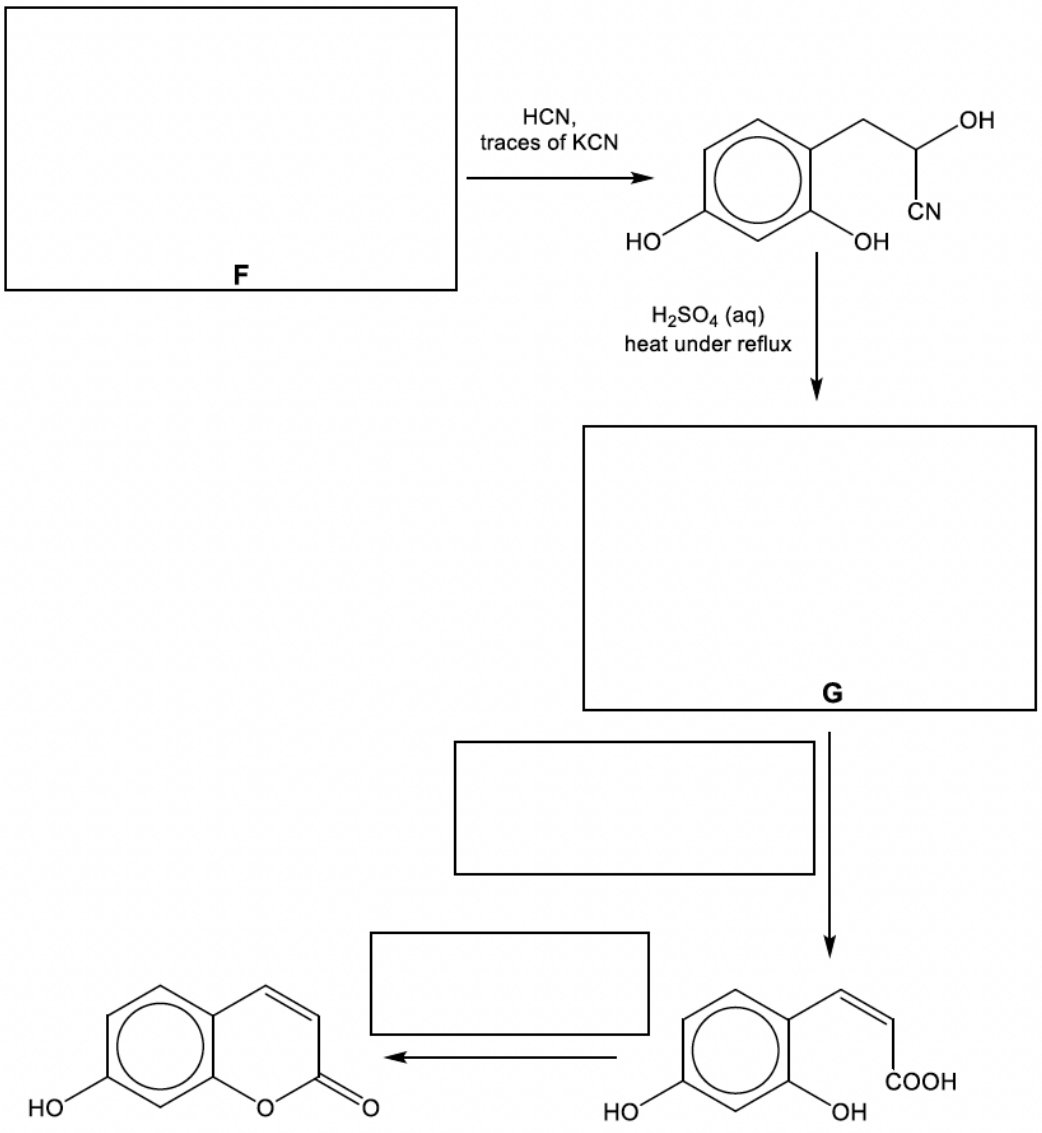
(a) Umbelliferone is a yellowish-white crystalline solid occurring naturally in carrots and is used as a sunscreen agent. It has the structure shown below:



The following reaction scheme shows how umbelliferone may be synthesised from compound **F**, which has a molecular formula of $C_8H_8O_3$.

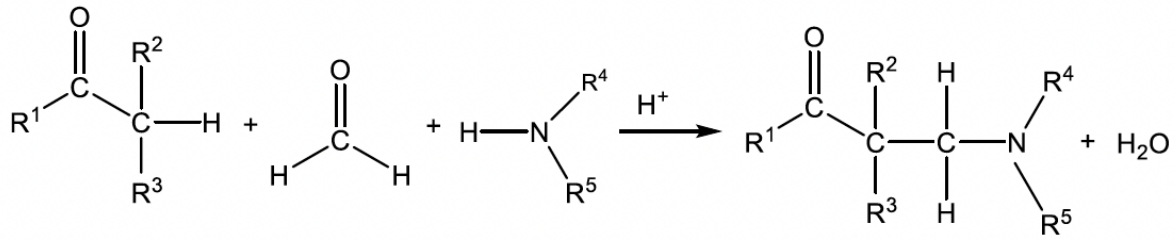
In the boxes provided, fill in the missing

- reagents and conditions,
- structures of compounds **F** and **G**.

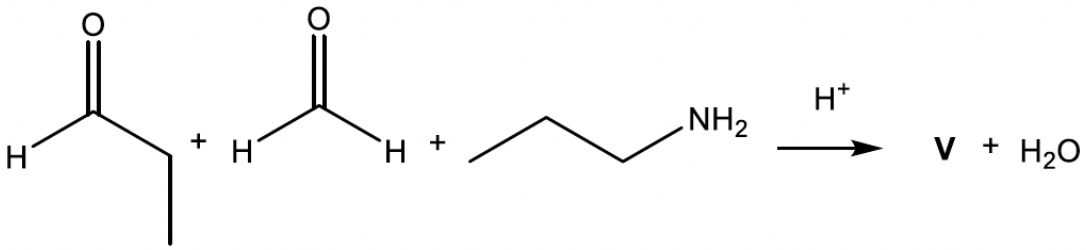


[4]

(b) The Mannich reaction is an organic reaction which consists of an amino alkylation of the hydrogen atom adjacent to a carbonyl functional group, by methanal and a primary amine, secondary amine or ammonia, in the presence of acid.



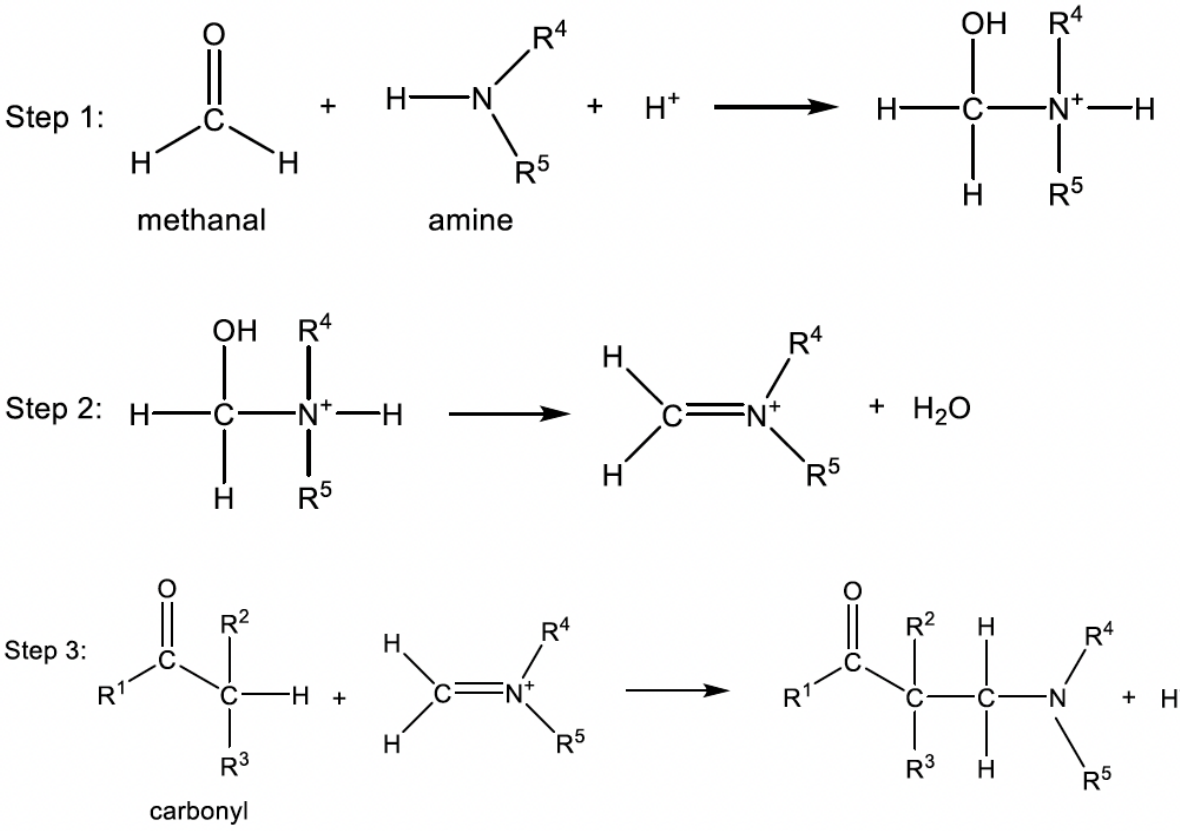
(i) Predict the structure of **V,** $C_7H_{15}NO$, when the following compounds undergo the Mannich reaction.



V

[1]

(ii) The proposed mechanism for the Mannich reaction is as follows:



Suggest the type of reaction that occurred in step 1 and 2.

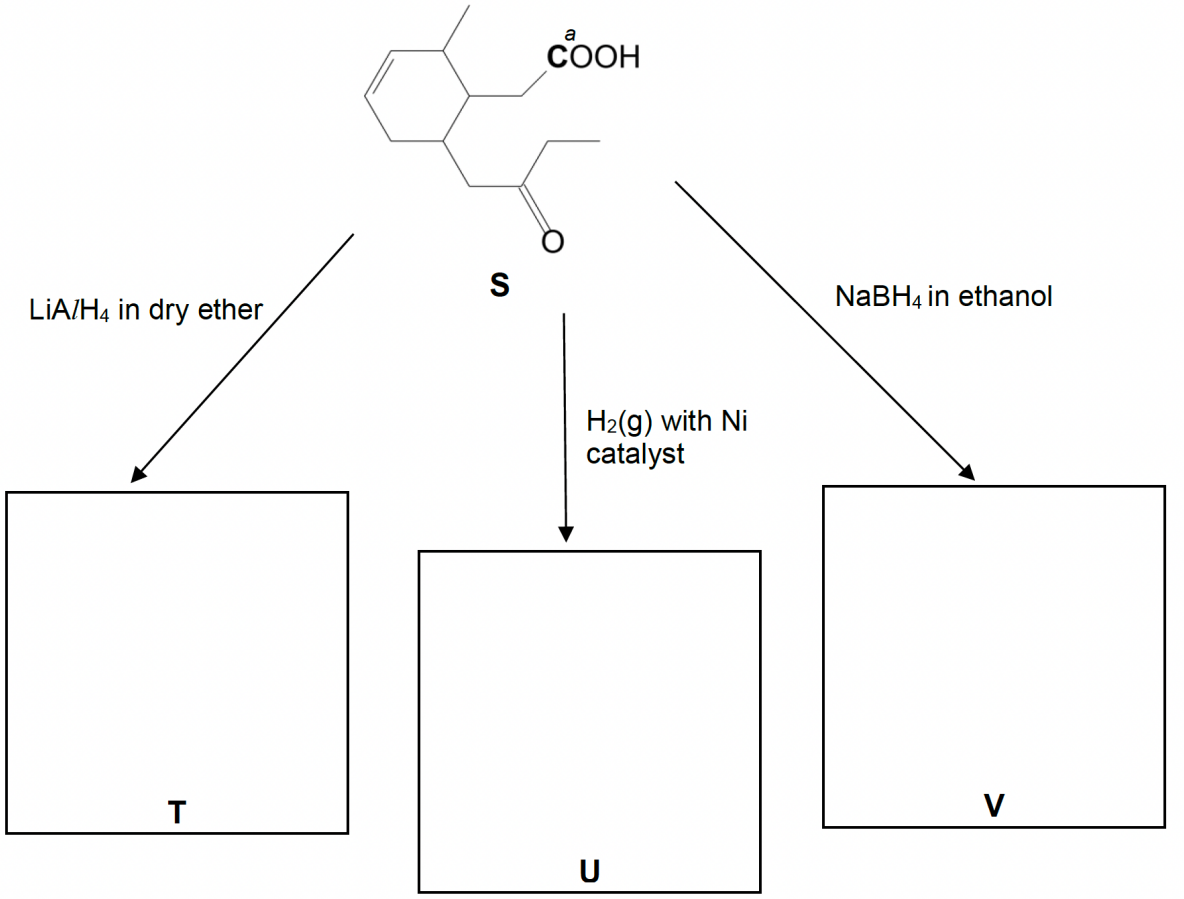
step 1 .....

step 2 ..... [2]

2. 2022 ASRJC P2 Q4

(i) The following reagents are added to separate samples of compound **S**.

Draw the structure of each of the organic products, **T**, **U** and **V**.



[3]

3. 2022 ASRJC P3 Q3

The reaction scheme in Fig. 3.1 outlines the synthesis of *Articaine*, a local anaesthetic used in dentistry. Step 1 of the synthesis involves the use of a dichloro-compound, $CH_3CHClCOCl$.

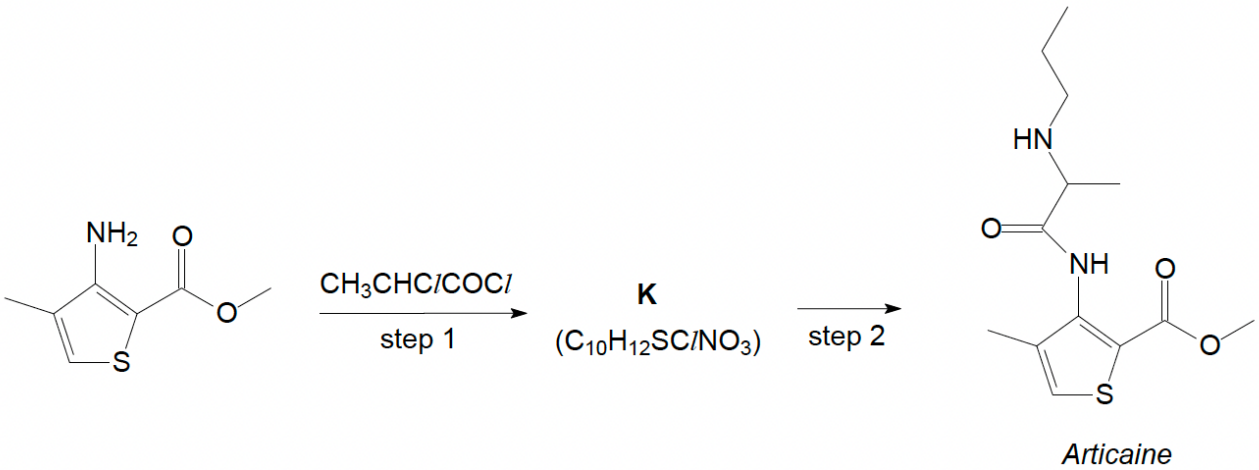
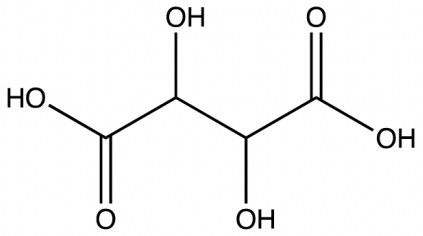


Fig. 3.1

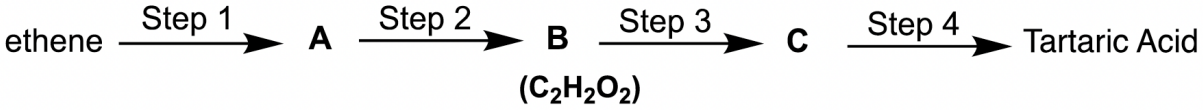
(i) Deduce the structure for the organic compound **K** and state the reagent required for step 2. [2]

4. 2022 CJC P3 Q2

(a) Tartaric acid is a white crystalline diprotic organic acid. It can be synthesised from ethene in four steps.



Tartaric acid

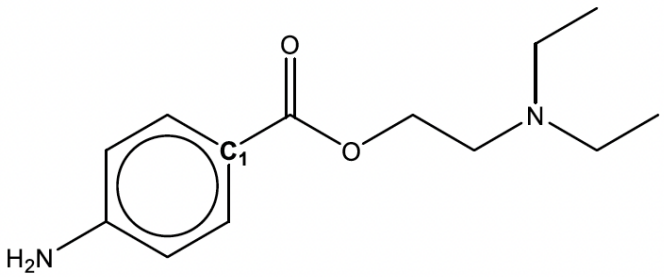


($C_2H_2O_2$)

Draw the structures of the intermediates, **A**, **B** and **C**, and give the required reagents and conditions for each step of the conversion. [7]

5. 2022 CJC P3 Q4

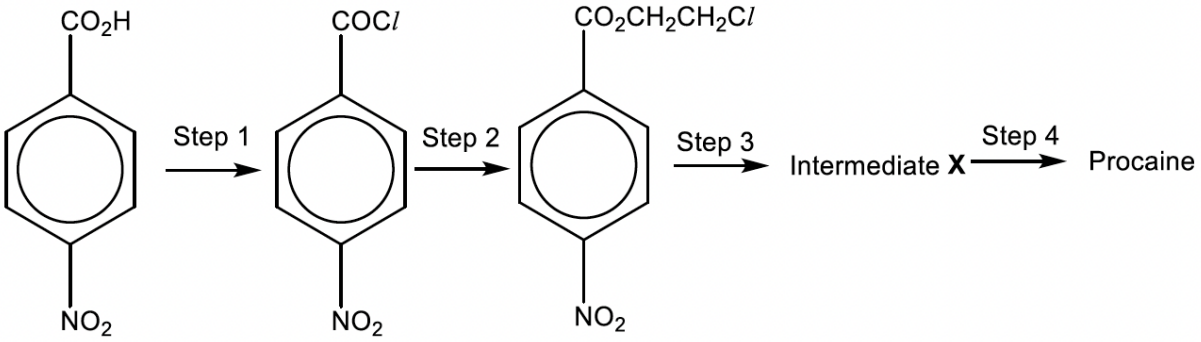
(a) Procaine, one of the first injectable local anaesthetic used during surgery has the following structure:



Procaine

(i) State the oxidation state of C_1 in Procaine. [1]

(ii) Procaine can be made by the following reaction scheme:



State the reagents and conditions used for steps 1, 2, 3 and 4. Draw the structure of intermediate **X**. [5]

6. 2022 DHS P2 Q3

Phenylethene, $C_6H_5CH=CH_2$, can be used to synthesise three different aromatic compounds **R**, **S** and **T** as shown in Fig. 3.1.

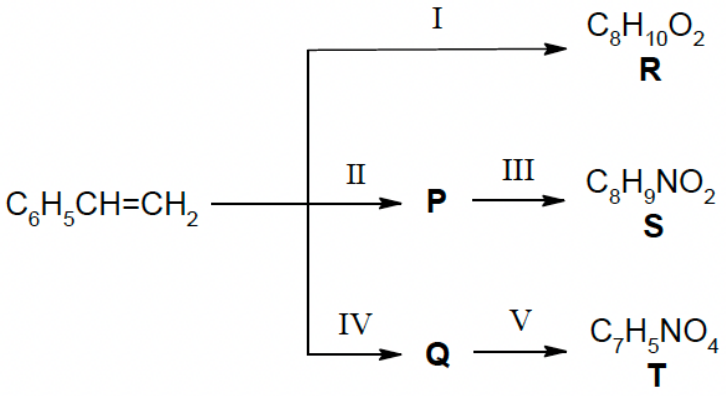


Fig. 3.1

(i) State the reagents and conditions required for reaction I.

..... [1]

Compounds **S** and **T** have the following features.

- Each compound contains a disubstituted benzene ring.
- They have an identical substituent on their benzene rings.
- **S** has its substituents at positions 1 and 2 on the benzene ring.
- **T** has its substituents at positions 1 and 3 on the benzene ring.

(ii) Using the information provided and given that the same type of reaction is occurring in III and V, suggest structures for the intermediates **P** and **Q**.

Hence state the reagent and conditions required for reaction II.

P	**Q**

reagent and conditions for reaction II .....

..... [3]

7. 2022 HCI P2 Q2

A chemist proposed to synthesise MSG using the following reaction scheme. Draw intermediates **A** and **B**, and state the reagents and conditions for step 1 and step 2.

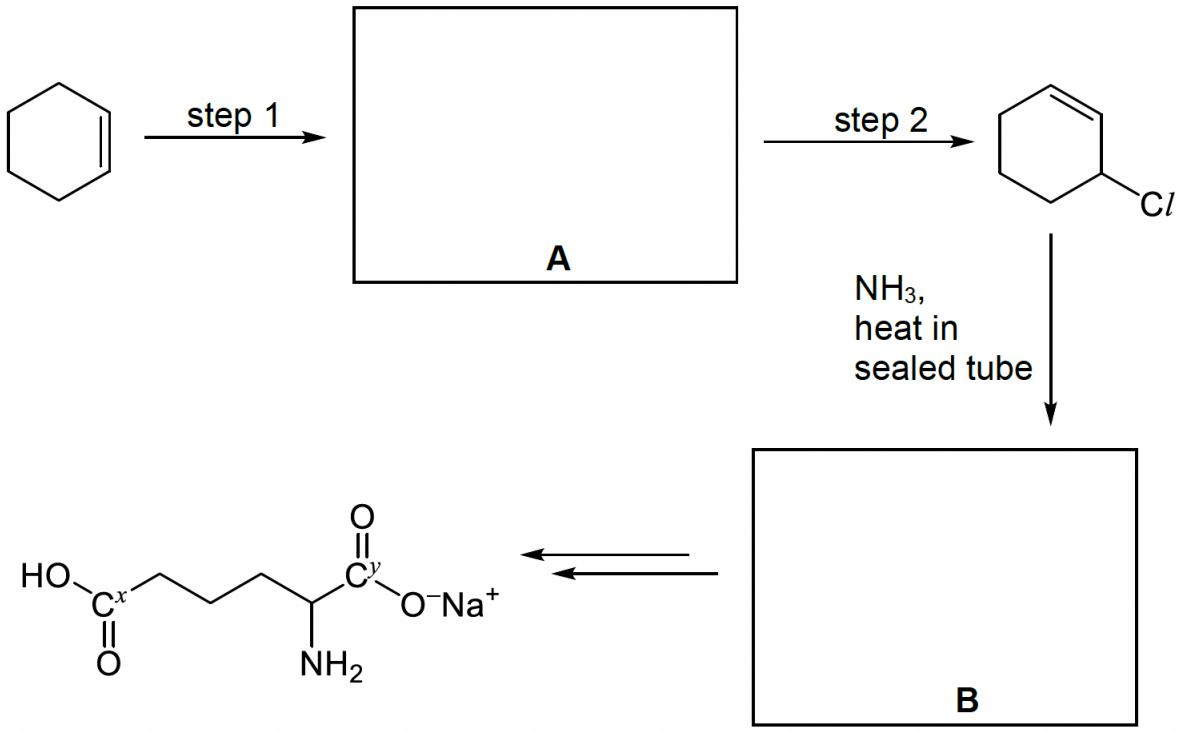


Fig. 2.1

step 1: .....

step 2: .....

[4]

8. 2022 HCI P3 Q1

Epoxyethane is a cyclic ether and the simplest epoxide: a three-membered ring consisting of one oxygen atom and two carbon atoms.

A reaction scheme involving epoxyethane is shown in Fig. 1.1.

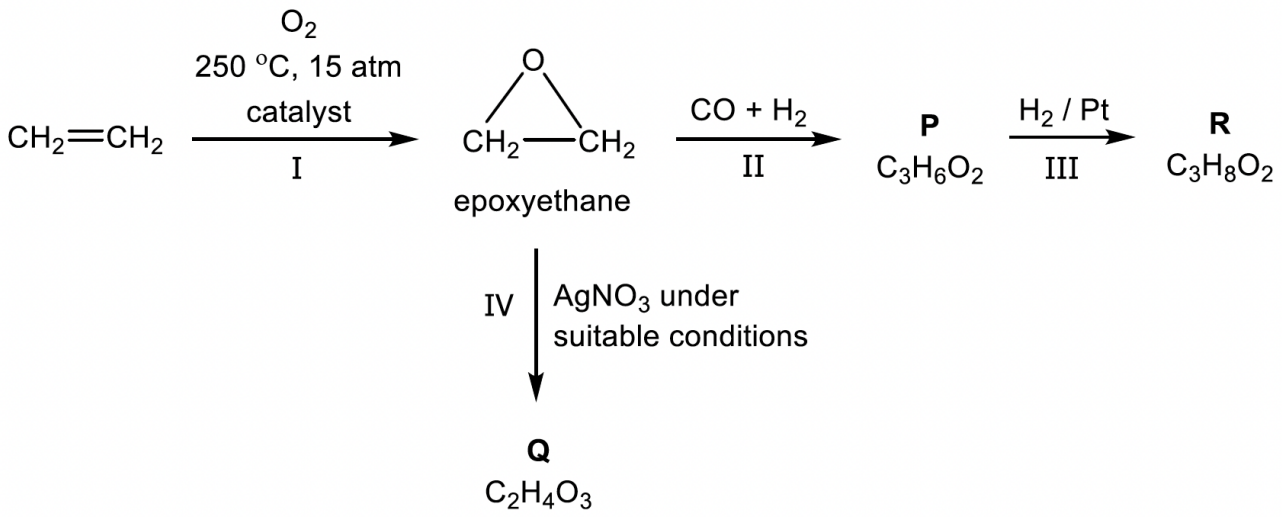


Fig. 1.1

Compounds **P** and **Q** give effervescence with sodium metal.

Both compounds do not exhibit enantiomerism.

P also gives a brick-red precipitate when warmed with Fehling's solution.

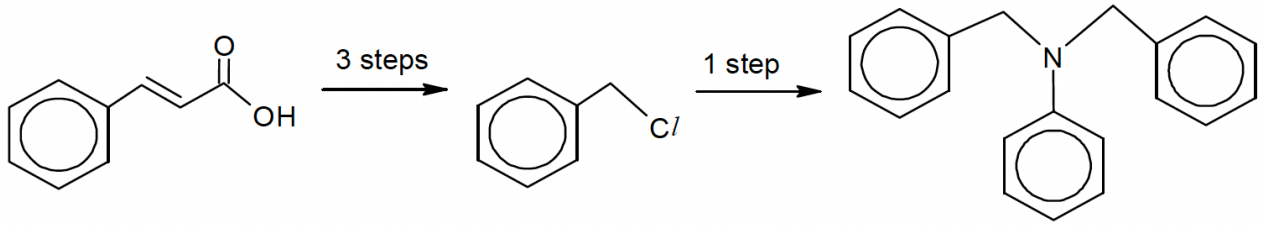
Q also gives effervescence with aqueous sodium carbonate.

Suggest the structures for **P**, **Q** and **R**. [3]

9. 2022 JJC P2 Q3

The diagram below shows a reaction scheme involving cinnamic acid.

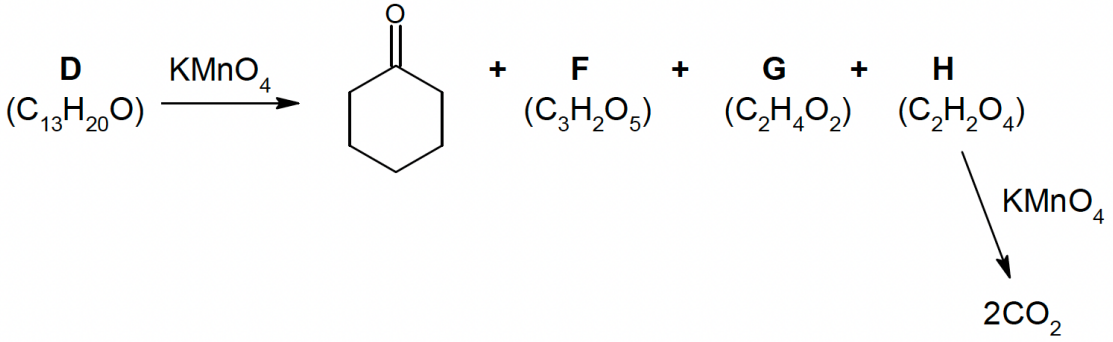
Suggest a possible synthetic pathway involving 4 steps, stating clearly the reagents and conditions required, and the intermediate organic compounds formed for every step.



10. 2022 JJC P3 Q2

Hot acidified $KMnO_4$ oxidises several classes of organic compounds to ketones, carboxylic acids or carbon dioxide. By this means, the structures of compounds can be determined. Some compounds are easily oxidised while others require longer heating.

The following scheme shows the reaction with hot acidified $KMnO_4$, of compound **D** and its oxidation products.



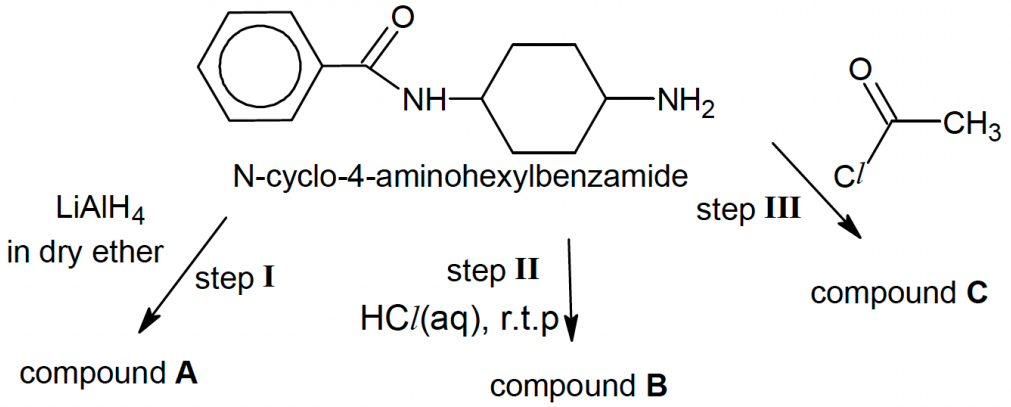
- Compound **D** effervesces with sodium metal. **D** also reacts with hot acidified potassium dichromate(VI) to give a product with the formula $C_{13}H_{18}O$.
- Compound **F** gives an orange precipitate with 2,4-dinitrophenyhydrazine.
- Compounds **F**, **G** and **H** all dissolve in NaOH(aq).

(i) Explain these observations. [2]

(ii) Suggest the structures of compounds **D**, **F** and **G**. [3]

11. 2022 JJC P3 Q3

The diagram below shows some reactions involving N-cyclo-4-aminohexylbenzamide.



(i) Give the structures of compounds **A, B** and **C**. [3]

12. 2022 JJC P3 Q1

4-bromopentanol can be used to synthesise Compound **C** as shown in Fig. 1.1.

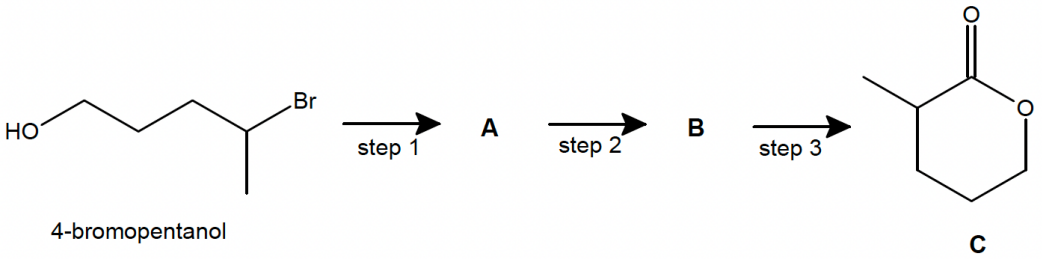
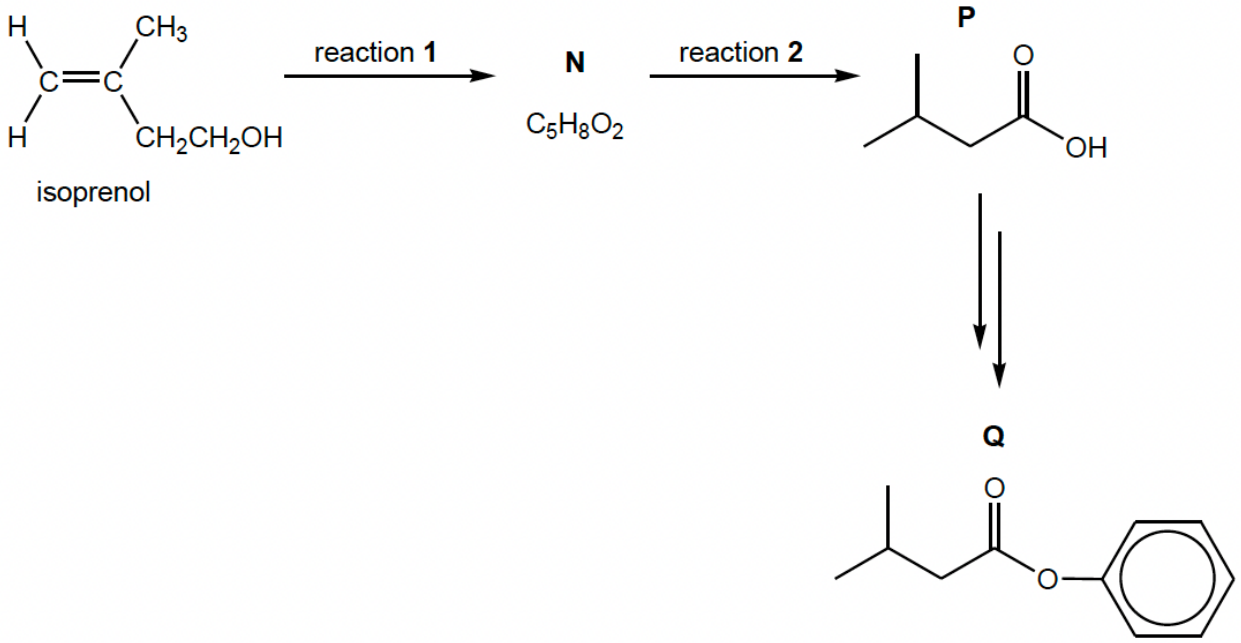


Fig. 1.1

Suggest the structures for compounds **A**, **B**, and reagents and conditions for steps 1, 2 and 3 in this route. [4]

13. 2022 NJCP2 Q5

Isoprenol is a structural isomer of prenol. The series of reactions below shows how isoprenol can be used to form **Q**, a sweet-smelling liquid.



(i) Suggest the structure of N [1]

(ii) Suggest the reagents and conditions for reactions **1** and **2**. [2]

(iii) Suggest the step(s) to convert **P** to **Q**, showing the structure of any intermediate formed. [3]

14. 2022 NJC P3 Q1

Amines can be synthesised from methylbenzene, shown by the following steps.

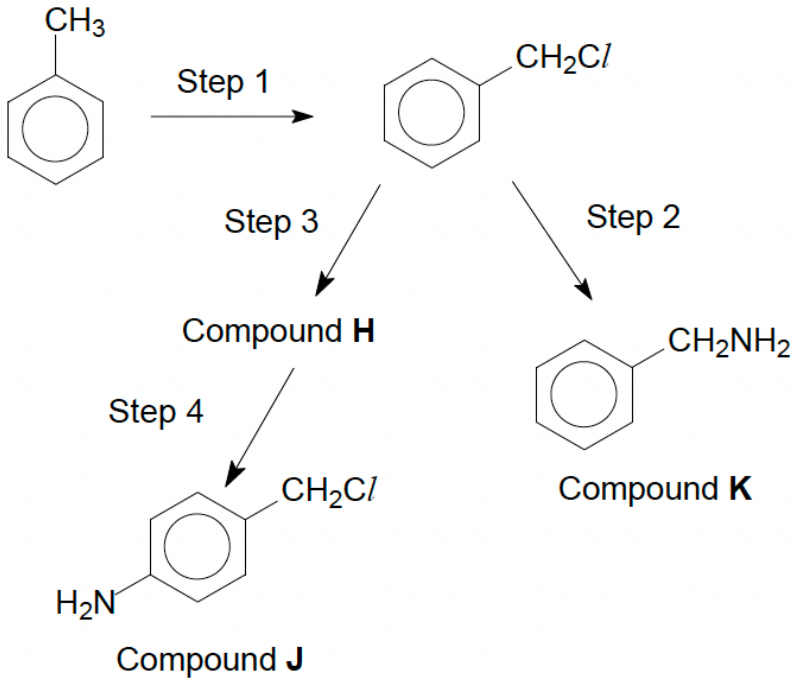


Fig. 1.1

(i) Suggest the structure for compound **H**. [1]

(ii) Suggest reagents and conditions for steps 1, 2, 3 and 4 in Fig. 1.1. [4]

(iii) Suggest why the yield for step 2 is not high. [1]

15. 2023 RI P3 Q4

(e) Compound **H** can be synthesised from cumene in three steps as shown in Fig 4.2.

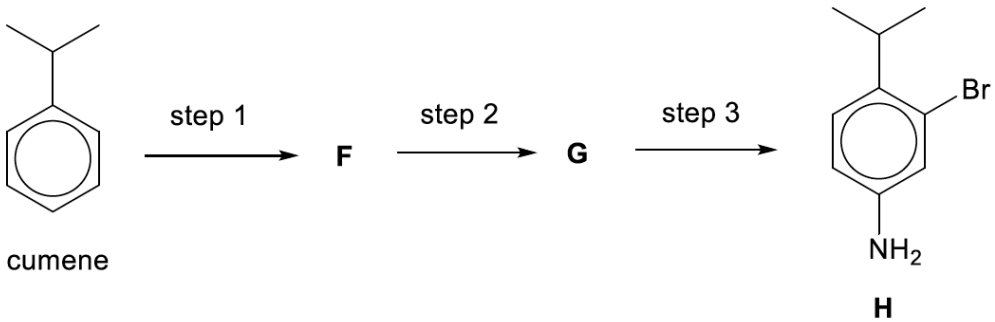


Fig. 4.2

(i) Suggest structures for the organic compounds **F** and **G**. [2]

(ii) Suggest reagents and conditions for each of the steps 1, 2 and 3. [3]

16. 2023 RI P3 Q5

(e) Indene undergoes the following reactions, as shown in Fig. 5.1.

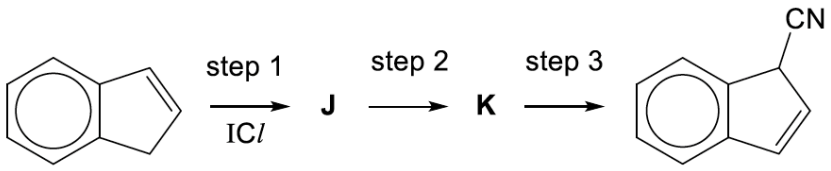


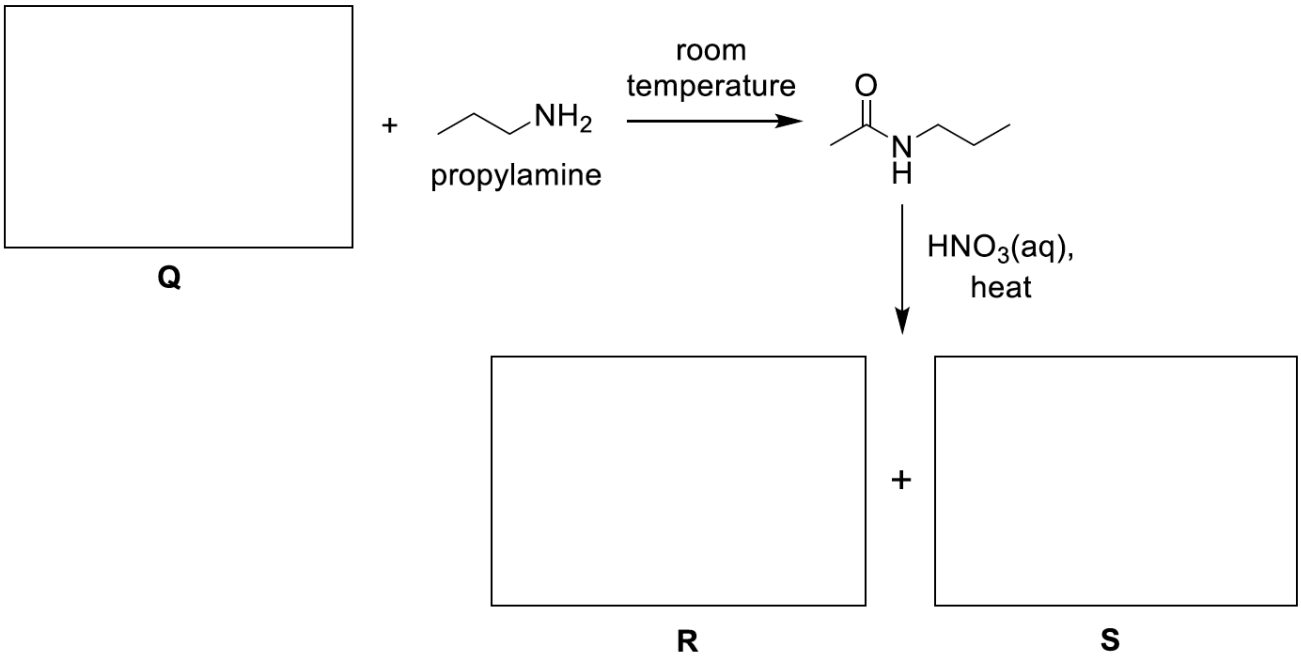
Fig. 5.1

(i) Compound **J** is the major product of the reaction between indene and iodine monochloride, IC*l*, in step 1. Draw the structure of compound **J**. [1]

(ii) State the reagents and conditions required for steps 2 and 3, and suggest the structure of compound **K**. [3]

17. 2023 RI P2 Q4

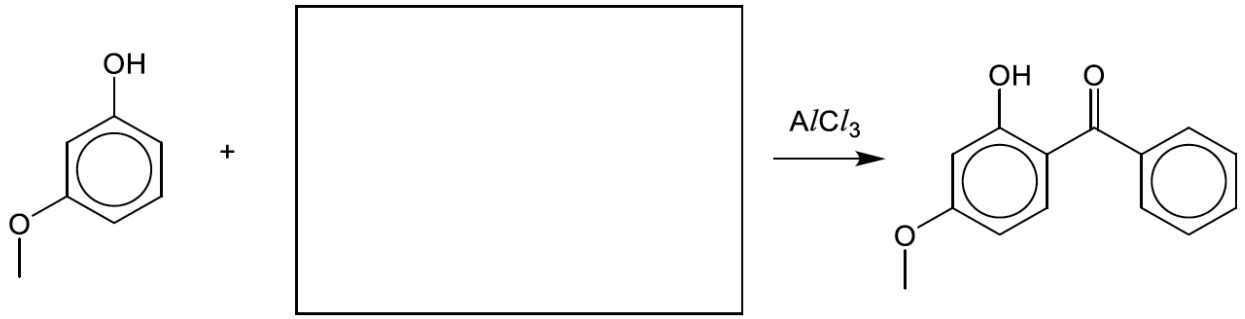
4 (a) Draw the structures of the compounds, **Q**, **R** and **S**.



[3]

18. 2023 RI P2 Q5

(b) Oxybenzone is produced by a substitution reaction of 3-methoxyphenol with compound **V**.



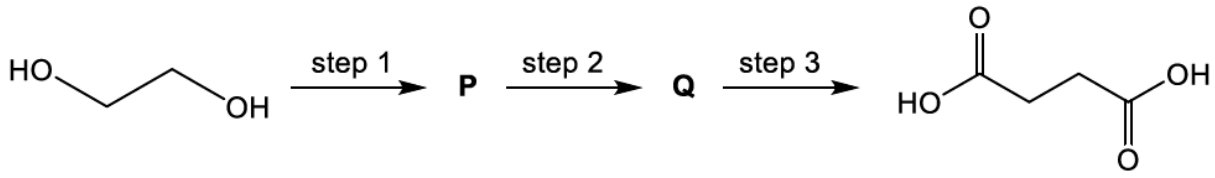
3-methoxyphenol compound **V** oxybenzone

(i) Draw the structure of compound **V** in the space provided. [1]

(ii) Suggest a simple chemical test to distinguish between 3-methoxyphenol and oxybenzone.

19. 2023 HCI P2 Q3(c)

(c) Succinic acid can be synthesised from ethane-1,2-diol in three steps.



ethane-1,2-diol succinic acid

(i) State the reagents and conditions required for steps 1 to 3.

step 1 .....

step 2 .....

step 3 .....

[3]

(ii) Draw the structures of intermediates **P** and **Q** in the boxes below.

P	Q

[2]

20. 2023 HCI P2 Q2(f)

(f) Lidocaine is used as an anaesthetic. It can be synthesised from compound **W**, as shown in Fig. 2.1.

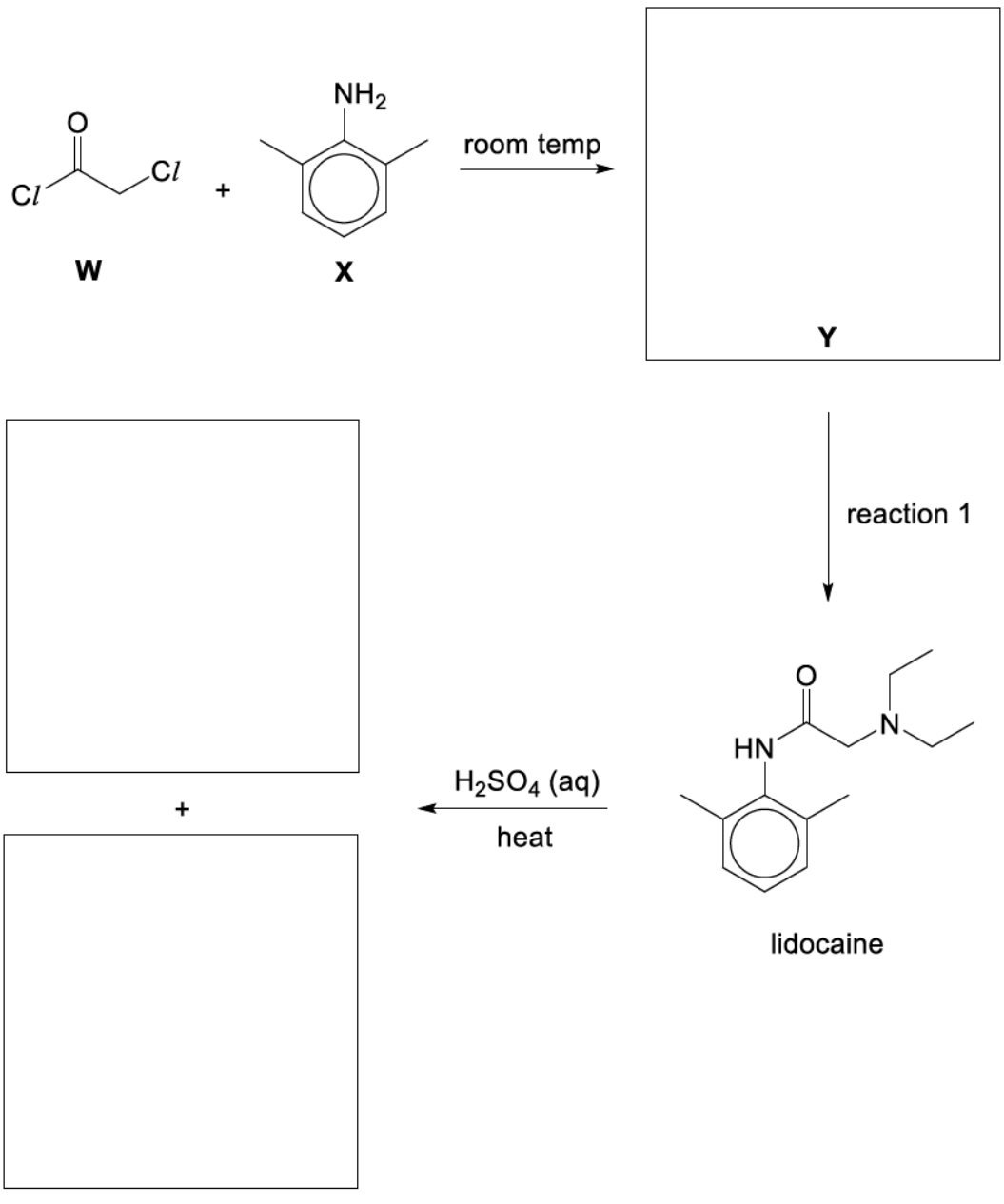


Fig. 2.1

(i) Compare the relative reactivity of the two chlorine atoms in **W**. Give two reasons for your answer.

[2]

(ii) In the space provided in Fig. 2.1, draw the structure of intermediate **Y**. [1]

(iii) After **W** and **X** have reacted together, an excess of $CH_3CO_2^-Na^+(aq)$ is added to the reaction mixture. Suggest why.

..... [1]

(iv) Suggest the reagents and conditions for reaction 1.

..... [1]

(v) In the space provided in Fig. 2.1, draw the structure of the two organic products formed when lidocaine is heated with $H_2SO_4(aq)$. [2]

21. 2024 ACJC P3 Q1(c)

The reactions of ethylbenzene to form **H**, **J** and **K** are shown in Fig.1.1.

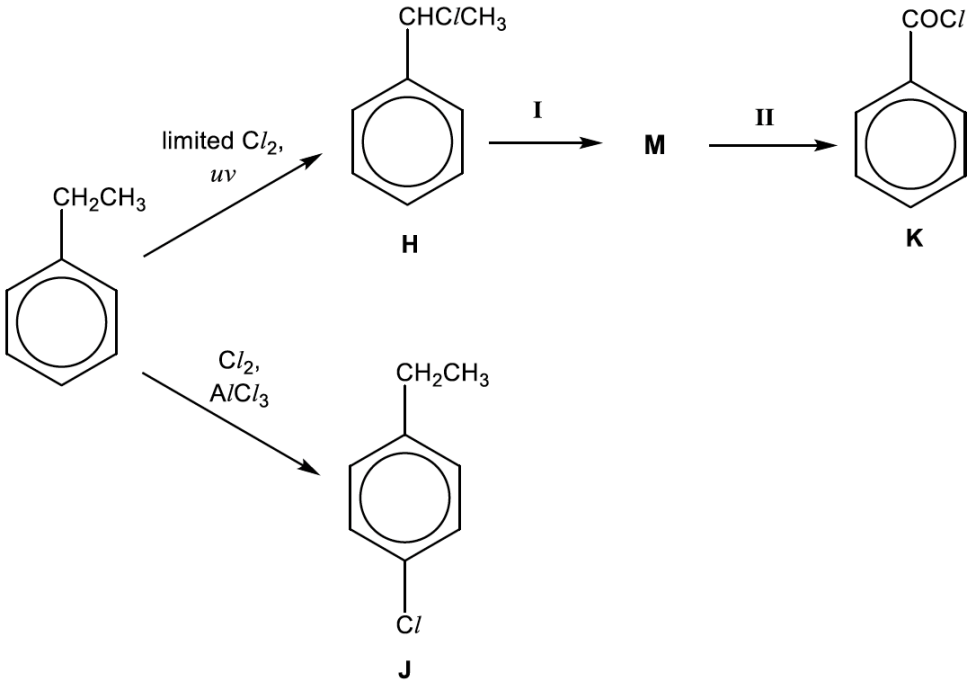


Fig. 1.1

(i) Suggest the reagents and conditions needed for reactions **I** and **II** and suggest the structure of **M** in Fig. 1.1. [3]

22. 2024 ACJC Prelim Paper 2 Q5

2–(2–chloroethyl)phenol can be used in a synthesis pathway shown in Fig. 5.1.

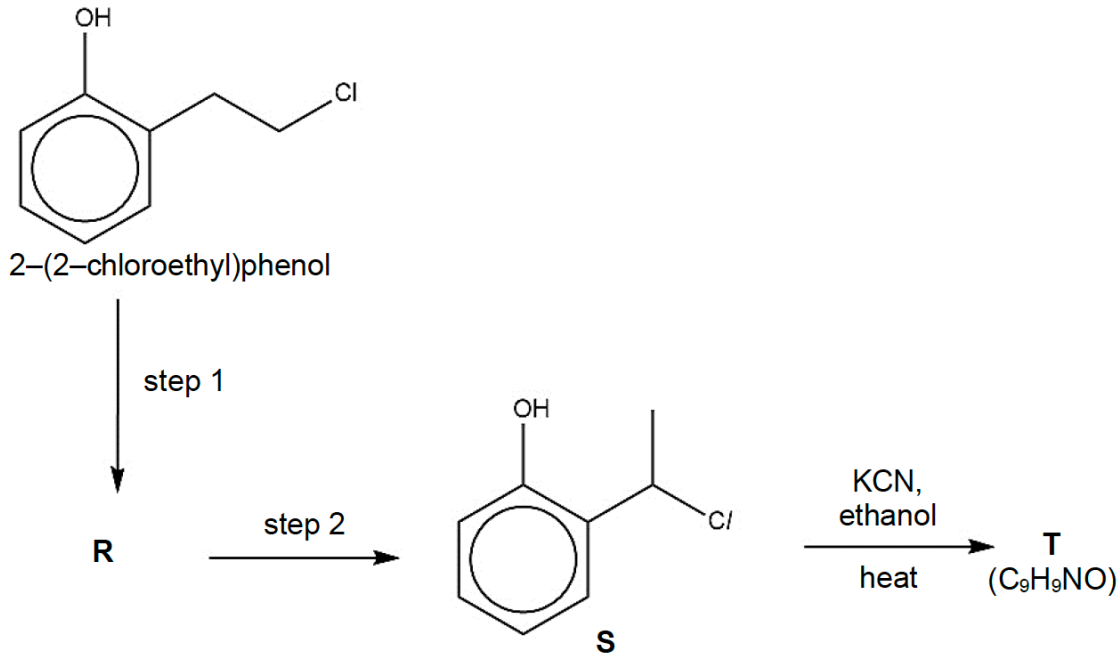


Fig. 5.1

1 mol of compound **R** reacts with 3 mol of aqueous Br_2 to give a white precipitate.

(a)(i) Suggest what this observation indicate about the functional groups in R. [1]

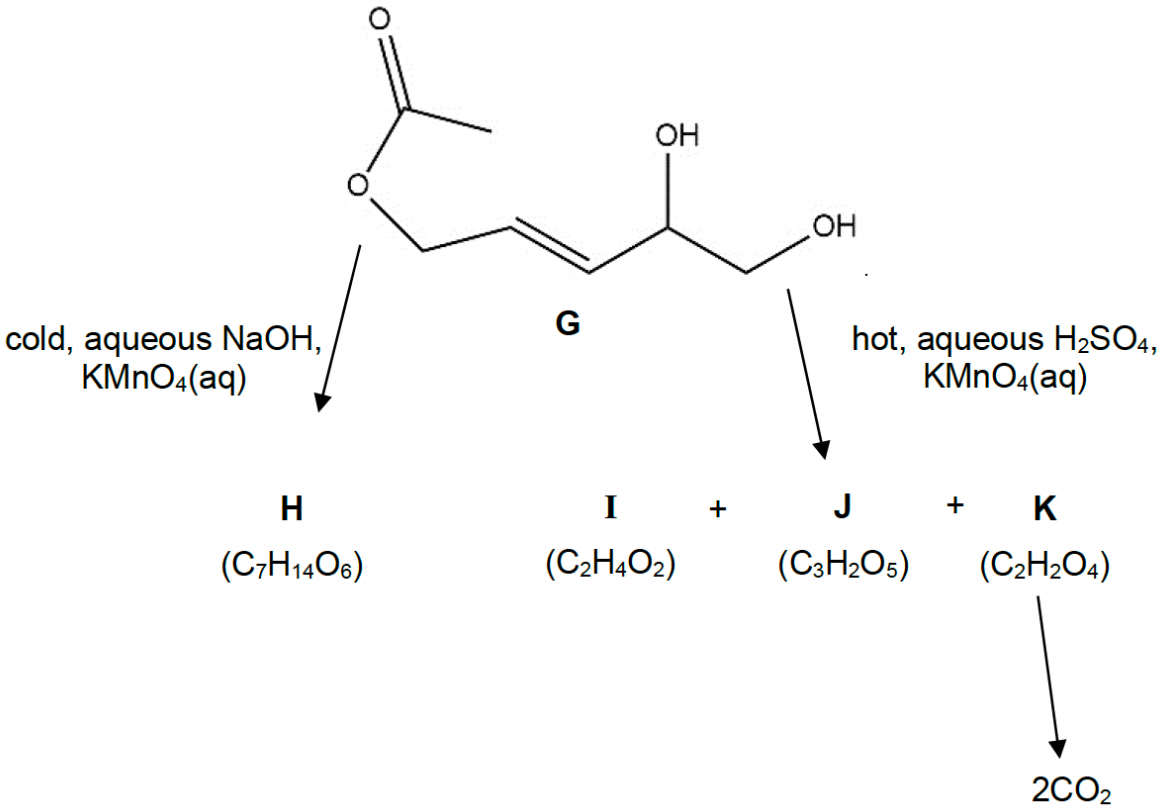
(ii) Describe the reagents and conditions needed for steps 1 and 2. [2]

(iii) Suggest the structures of R and T. [2]

(iv) Describe the relationship between 2-(2-chloroethyl)phenol and compound **S**. [1]

(b) Hot, concentrated potassium manganate(VII) oxidises several classes of organic compounds to ketones, carboxylic acids or carbon dioxide. By this means, the structures of compounds can be determined. Some compounds are easily oxidised, while others require longer heating.

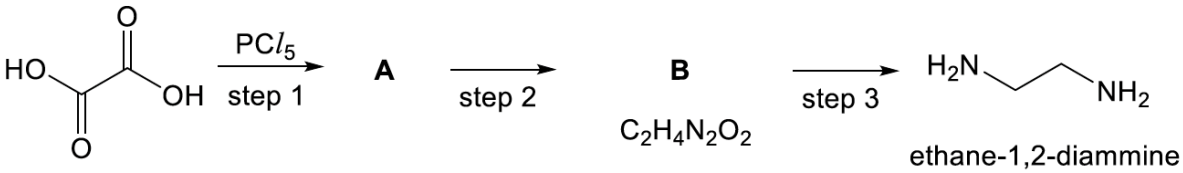
Compound **G** can be oxidised by $KMnO_4$ under different conditions to give various products.



Suggest the structures of the compounds **H**, **I**, **J** and **K**.

23. 2024 RI P3 Q2

(b) Ethane-1,2-diamine can be synthesised from ethanedioic acid as shown below.

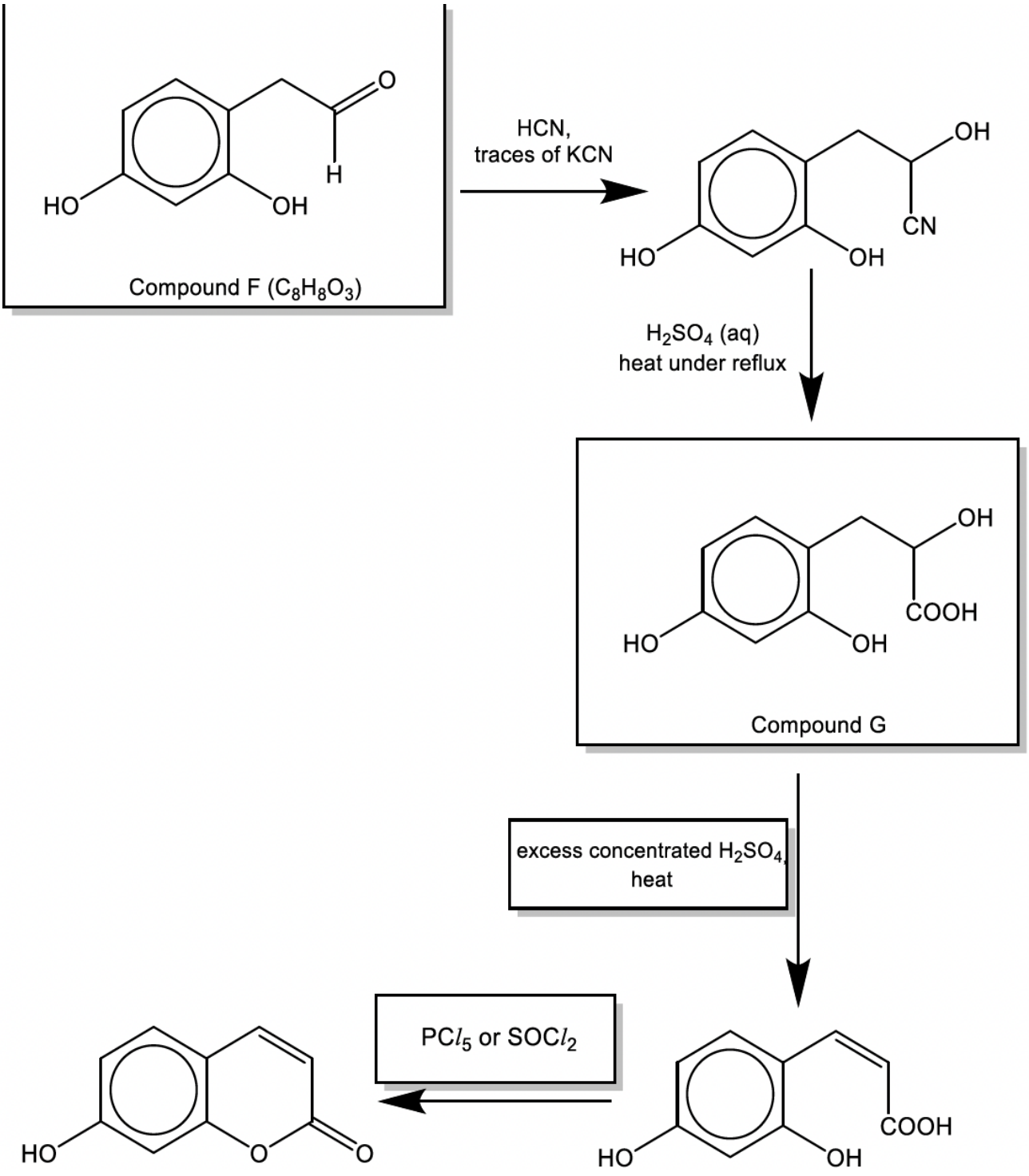


ethanedioic acid

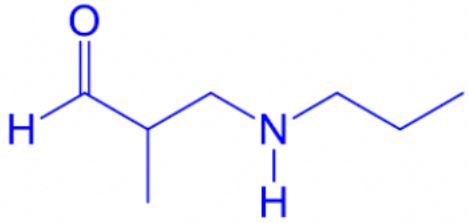
State the reagents and conditions needed for steps 2 and 3. Suggest structures for **A** and **B**. [2]

H2 Chemistry Reaction Scheme Answers

1. 2022 ACJC P2 Q4



b(i)

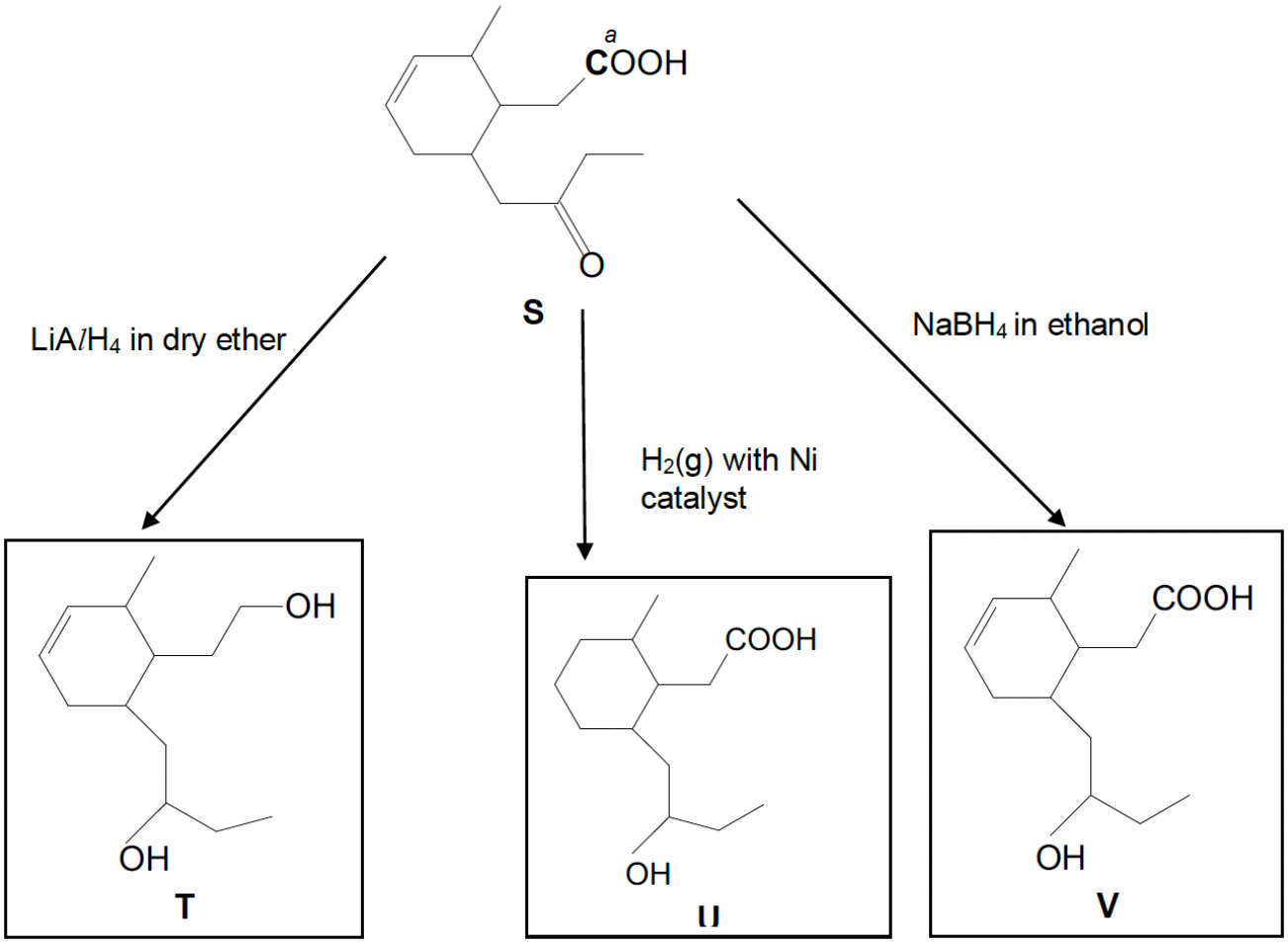


[1]

V ($C_7H_{15}NO$)

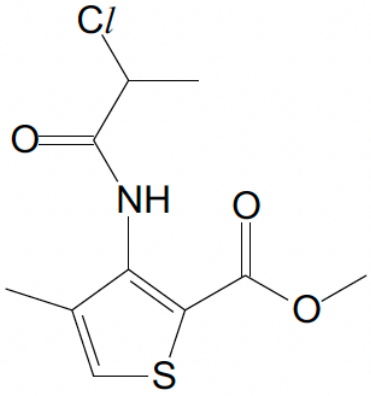
(ii) Step 1: Nucleophilic addition
Step 2: Elimination

2. 2022 ASRJC P2 Q4



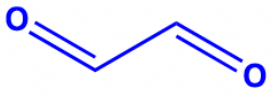
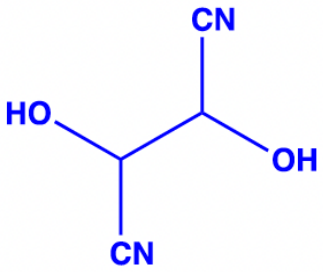
3. 2022 ASRJC P3 Q3

Structure of K [1]



step 2 reagent: $CH_3CH_2CH_2NH_2$ [1]

4. 2022 CJC P3 Q2

A	B	C
		

Step 1: cold, NaOH(aq), $KMnO_4$

Step 2: $K_2Cr_2O_7$ in dilute H_2SO_4, heat with (immediate) distillation

Step 3: HCN(aq), trace amount of NaCN(aq)/NaOH(aq), cold

Step 4: dilute H_2SO_4, heat

5. 2022 CJC P3 Q4

(i) 0

(ii)

Step 1: **anhydrous PCl_5 / $SOCl_2$, r.t.p. OR anhydrous PCl_3, heat**

Step 2: **$HOCH_2CH_2Cl$, r.t.p.**

Step 3: **1) Sn, conc. HCl, heat under reflux; 2) NaOH(aq)**

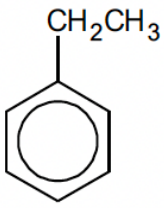
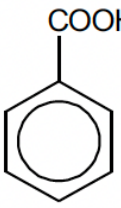
Step 4: **$NH(CH_2CH_3)_2$, heat under reflux**

NOTE: Step 3 and 4 are interchangeable

6. 2022 DHS P2 Q3

(i) KMnO4(aq), NaOH(aq), cold

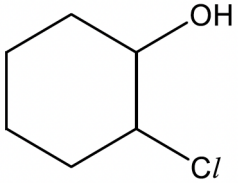
(ii)

P	Q
	

Reagent and conditions required for reaction II: **H_2, Ni, heat**

7. 2022 HCl P2 Q2

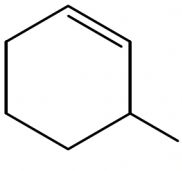
Intermediate **A**



[1], step 1: Cl_2(aq) **[1]**, step 2: excess conc H_2SO_4, heat OR concentrated H_3PO_4, heat OR Al_2O_3, heat **[1]**

WRONG INTERMEDIATE **A** LOSES MARKS FOR STEP 1 AND STEP 2.

Intermediate **B**



[1]

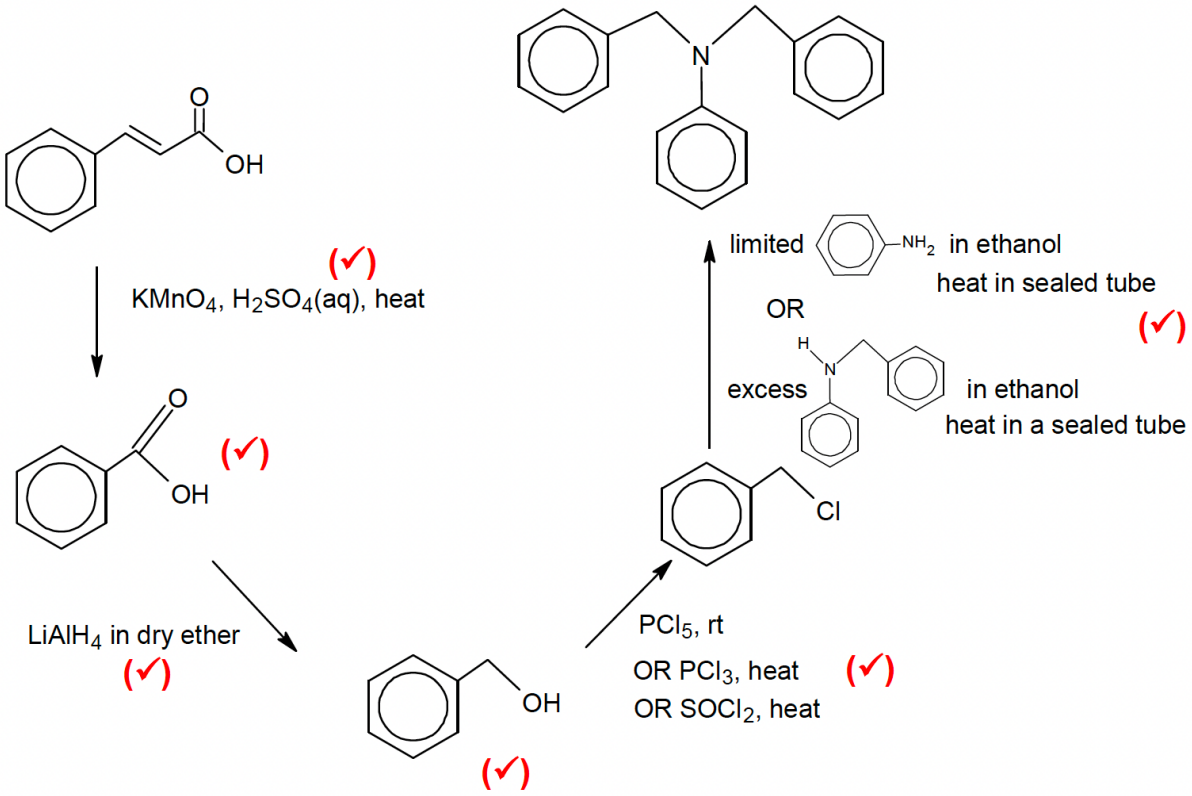
8. 2022 HCl P3 Q1

[1] P: $HOCH_2CH_2CHO$

[1] R: $HOCH_2CH_2CH_2OH$
(allow ecf from P only if student's P can be reduced to student's R using the H_2/Pt)

[1] Q: $HOCH_2CO_2H$
(all three structures must fit their given molecular formula)

9. 2022 JJC P2 Q3



10. 2022 JJC P3 Q2

(i)

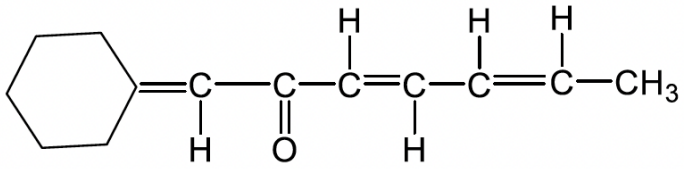
D undergoes redox reaction with Na and oxidation with warm acidified potassium dichromate(VI). D contains secondary alcohol.

F undergoes condensation with 2,4-DNPH to give orange ppt. F contains ketone.

F and H undergo acid-base reaction with NaOH(aq). F and H contain carboxylic acid.

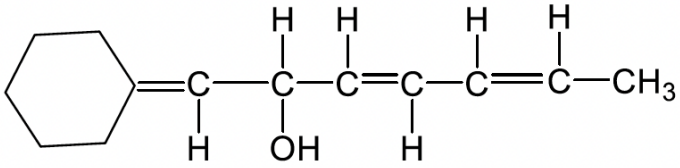
(ii)

$C_{13}H_{18}O$:

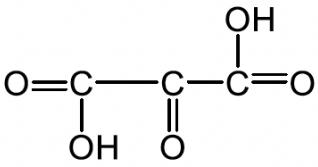


Note: Alkene is not oxidised by $K_2Cr_2O_7(aq)$, $H_2SO_4(aq)$, heat

D



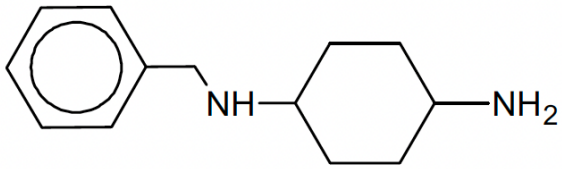
F



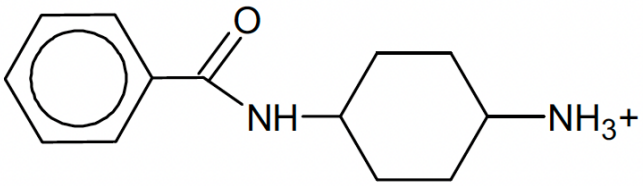
G CH_3COOH

11. 2022 JJC P3 Q3

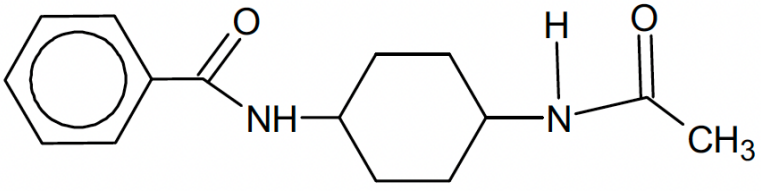
A:



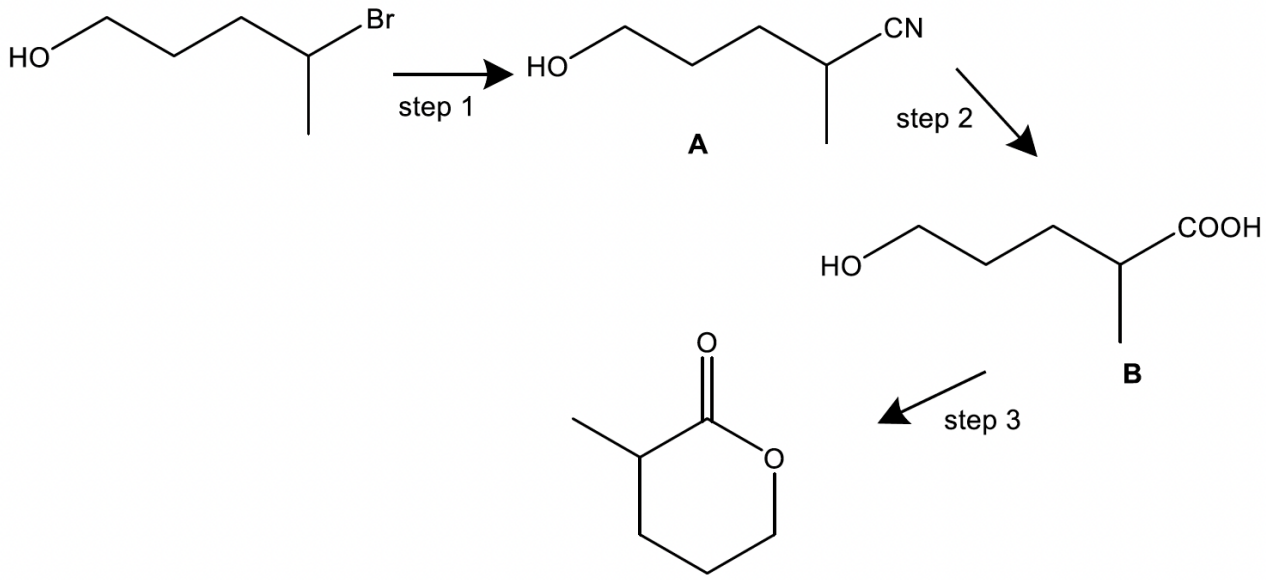
B:



C:



12. 2022 JJC P3 Q1

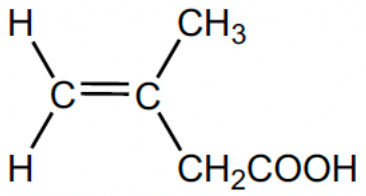


step 1 : NaCN (or KCN), ethanol, heat (✓)

step 2 : H_2SO_4(aq) (or HC*l*(aq)), heat (✓)

Step 3 : conc. H_2SO_4, heat

13. 2022 NJC P2 Q5

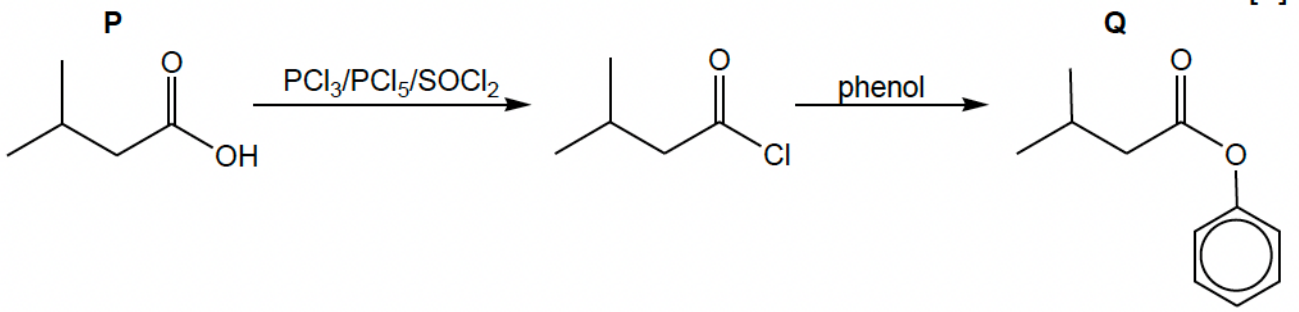


[1]

Step 1: $K_2Cr_2O_7$, H_2SO_4(aq), heat with reflux **[1]**
(Cannot be $KMnO_4$, otherwise will cleave C=C bond)

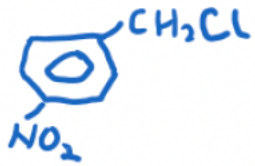
Step 2: H_2, Ni, high temperature/ H_2, Pt **[1]**
(Cannot be $LiAlH_4$, $NaBH_4$, cos non-polar C=C bond)

[3]



Intermediate **[1]**
Step 1: PCl_3/ PCl_5/$SOCl_2$, anhydrous **[1]** **or zero**
Step 2: Phenol **[½]**, NaOH(aq) **[½]**

14. 2022 NJC P3 Q1



(i) 1 or 0

(ii) Step1: UV light, **limited** Cl_2. 1 or 0

Step 2: ethanolic NH_3, heat in sealed tube.

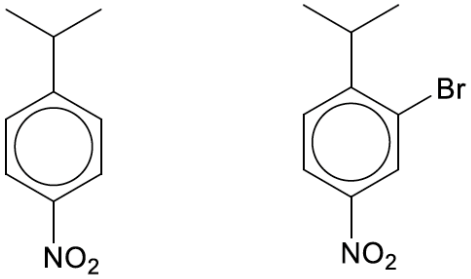
Step 3: conc H_2SO_4, Conc HNO_3, 60°C ($-CH_2Cl$ has negligible effect on benzene) -accept T lower than 60°C.

Step 4: conc HCl, Sn, heat *followed by* NaOH(aq) or *(step 1 then 2)*

(iii) The primary amine produced, due to the electron donating alkyl group ½ , is a stronger nucleophile than NH_3, ½ hence can compete/further react with NH_3 for C_7H_7Cl to form a secondary amine instead of the compound K. (½ for stating polysubstitution)

15 **2023 RI P3 Q4**

(e)(i)(ii)



F **G**

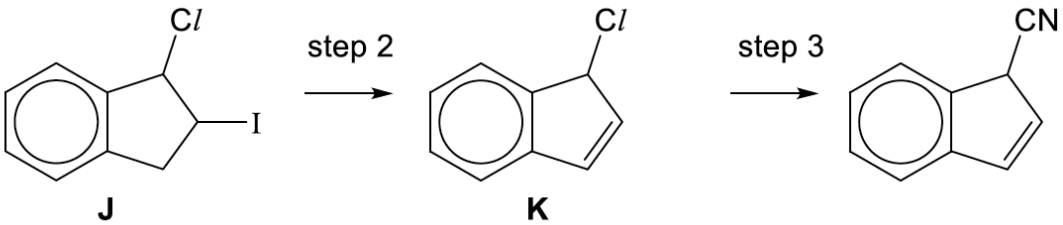
Step 1: conc. HNO_3, conc. H_2SO_4, 30°C

Step 2: Br_2, $FeBr_3$

Step 3: Sn, conc. HCl, heat under reflux, followed by NaOH(aq)

16 **2023 RI P3 Q5**

(e)(i)(ii)

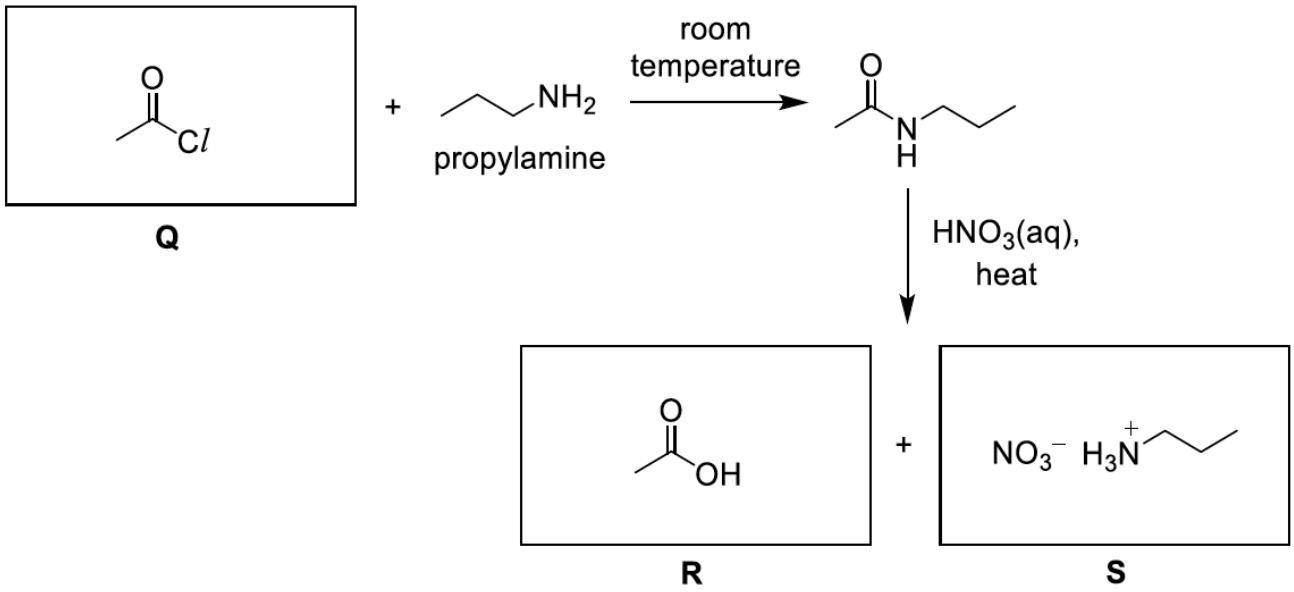


J **K**

Step 2: ethanolic KOH, heat

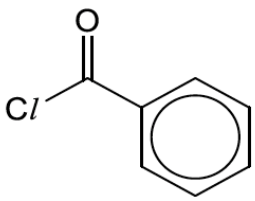
Step 3: ethanolic KCN, heat

17 **2023 RI P2 Q4**



18 **2023 RI P2 Q5**

(b) **(i)**



(ii) Test: Add 2,4-DNPH to each sample placed in separate test tubes.

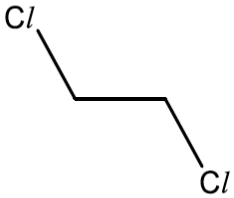
Observation:
For 3-methoxyphenol, no orange ppt formed.
For oxybenzone, orange ppt formed.

19. 2023 HCl P2 Q3(c)

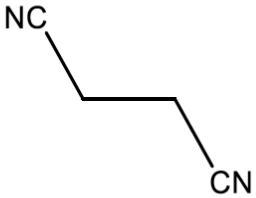
(c) **(i)** Step 1: PCl_5 (or equivalent)
Step 2: ethanolic KCN, heat
Step 3: dil. H_2SO_4 or dil, HCl, heat

[1] for each correct R&C

(ii)



P:



Q:

[1] for **each** intermediate

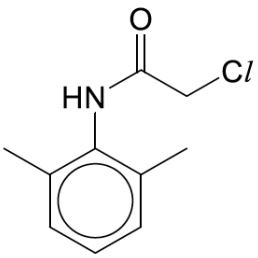
20. 2023 HCI P2 Q2(f)

(f) **(i)** Acyl chloride is more reactive than alkyl chloride.

Electronic factor: Acyl chloride has a highly electron-deficient carbon on C–C*l* due to 2 electronegative atoms C*l* and O, while alkyl chloride has a less electron-deficient carbon with only one electronegative atom Cl. **[1]**

Steric factor: Planar acyl carbon makes it less hindered for the nucleophile to attack, while tetrahedral geometry around chloro-substituted carbon is relatively more hindered. **[1]**

(ii)

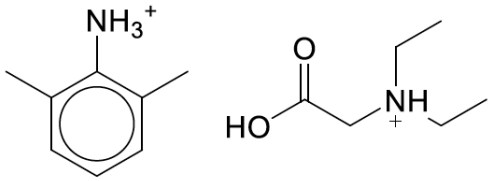


Y **[1]**

(iii) To neutralise acidic HC*l* that is formed as a side product **[1]**

(iv) ethanolic $NH(C_2H_5)_2$, heat (in sealed tube) **[1]**

(v)



[1] for each structure

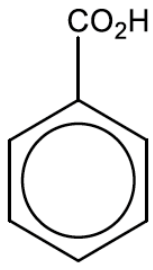
−**[1]** if both amine products are not protonated

21 2024 ACJC P3 Q1(c)

I: $KMnO_4$, H_2SO_4(aq), heat under reflux

II: $SOCl_2$ OR PCl_5 OR PCl_3, heat

M:



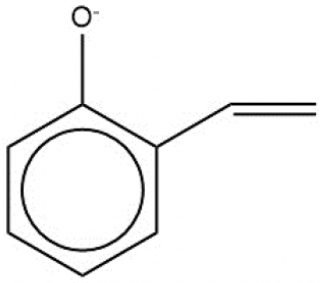
22 **2024 ACJC Prelim Paper 2 Q5**

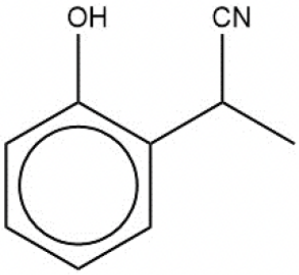
(i) There is 1 phenol (with a substitution on position 2) and 1 alkene on R.

(ii) Step 1: Ethanolic NaOH, heat under reflux [1]

Step 2: HC*l* (g) (no need (g) state symbol, but penalise for (aq)) [1]

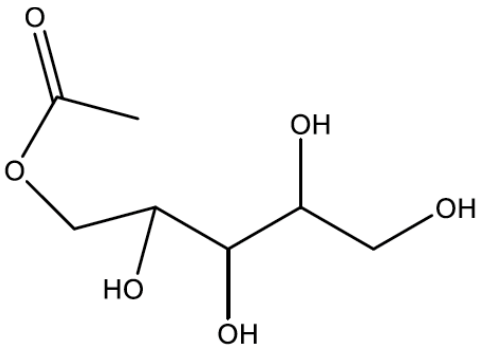
(iii)

R: 

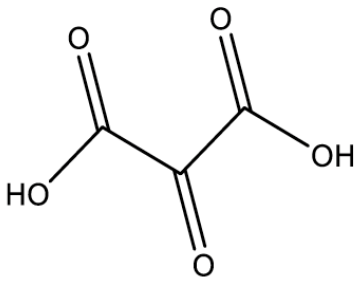
T: 

(iv) Positional isomerism.
OR Constitutional/structural isomerism

(b)

H: 

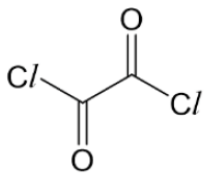
I: CH_3COOH

J: 

K: $(COOH)_2$

23 **2024 RI Paper 3 Q2**

Step 2: NH_3
Step 3: $LiAlH_4$, dry ether

A is 

B is