1 Methylbenzene, $C_6H_5CH_3$, is an aromatic hydrocarbon and is used widely as a solvent. It is readily nitrated and it can form mono-, di-, or tri-nitromethylbenzenes.

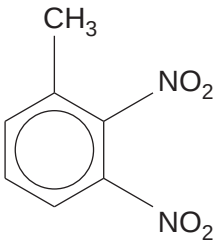
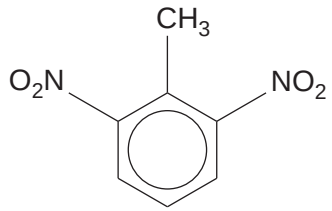
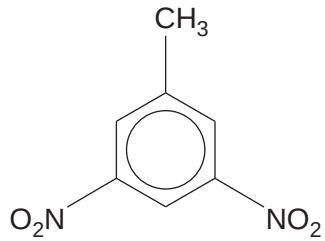
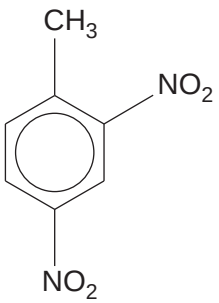
(a) 4-Nitromethylbenzene can be formed by the nitration of methylbenzene.

Outline the mechanism for the formation of 4-nitromethylbenzene from methylbenzene using NO_2^+ as the electrophile.

[4]

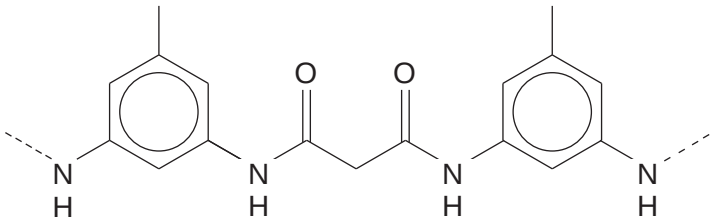
(b) There are six possible structural isomers of $CH_3C_6H_3(NO_2)_2$ that are dinitromethylbenzenes. Four of the isomers are shown below.

Draw the structures of the other two isomers in the boxes provided.

 **isomer 1**	 **isomer 2**	 **isomer 3**
 **isomer 4**	**isomer 5**	**isomer 6**

[2]

(c) A research chemist investigated whether dinitromethylbenzenes could be used in the manufacture of fibres.
The chemist devised a **two**-stage synthesis of the condensation polymer below, starting from one of the isomers in part **(b)**.



For the **first** stage of the synthesis,

- Which of the isomers **1**, **2**, **3** or **4** could be used?
- Identify the product formed and state suitable reagents.
- Write an equation.

For the **second** stage of the synthesis,

- Suggest an organic compound that could react with the organic product from the **first** stage to form the polymer.
- State the type of condensation polymer formed.

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

[Total: 12]

2 A chemist was investigating the reactions of benzene, phenol and cyclohexene with bromine. She found that they all reacted with bromine but under different conditions.

(a) The chemist found that when benzene reacts with bromine, a halogen carrier is required as a catalyst.

Write an equation for this reaction.
You do **not** need to show the halogen carrier in your equation.

[1]

(b) The chemist also found that when phenol or cyclohexene reacts with bromine, a halogen carrier is **not** required.

(i) The chemist observed that bromine decolourises when it reacts with phenol.

What other observation would she have made?

Draw the structure of the organic product formed.

Observation .....

Organic product:

[2]

(ii) Cyclohexene also decolourises bromine.

Name the organic product formed.

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

(iii) Explain the relative resistance to bromination of benzene compared to phenol and compared to cyclohexene.

In your answer, you should use appropriate technical terms, spelt correctly.

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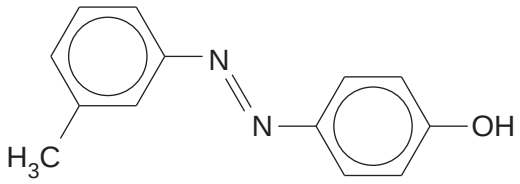
..... **[5]**

(c) Compound **A**, shown below, is being considered as an azo dye by a chemical company. A chemist planned a two-stage synthesis of compound **A** starting from an aromatic amine.



compound A

The aromatic amine is first converted into a diazonium ion.

- Draw the displayed formula of the aromatic amine **and** of the diazonium ion.
- State the reagents and conditions for each stage in the synthesis of compound **A** from an aromatic amine.

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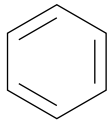
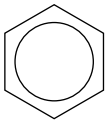
..... **[5]**

[Total: 14]

3 Chemists often use two different structures to represent a molecule of benzene, as shown below.



structure A



structure B

(a) (i) Describe, with the aid of suitable diagrams showing orbital overlap, the difference in bonding between structure **A** and structure **B**.

In your answer, you should use appropriate technical terms, spelled correctly.

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..... **[4]**

(ii) The table below shows the enthalpy changes for the reactions of cyclohexene, C_6H_{10}, and benzene, C_6H_6, with hydrogen.

reaction	enthalpy change / kJ mol^{-1}
$C_6H_{10} + H_2 \rightarrow C_6H_{12}$	−119
$C_6H_6 + 3H_2 \rightarrow C_6H_{12}$	−208

Using this information, suggest and explain whether structure **A** or structure **B** is a better representation of benzene.

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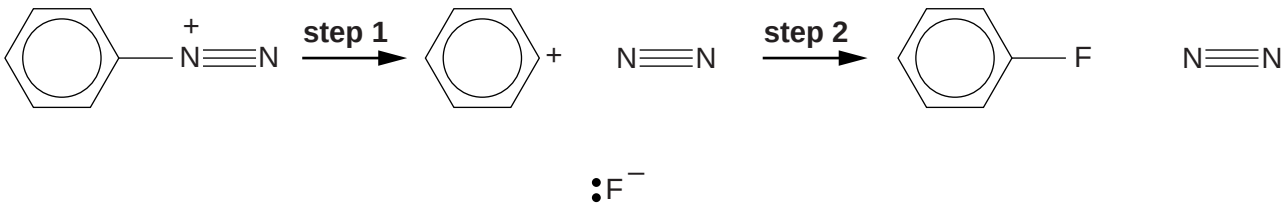
..... **[2]**

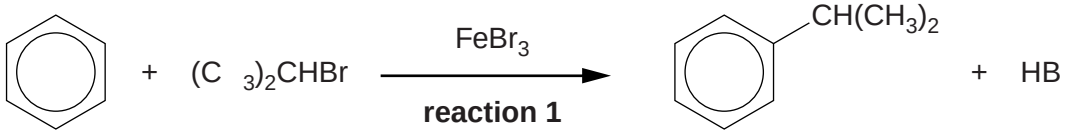
(b) Benzene compounds can undergo nucleophilic substitution reactions.

Add curly arrows to the diagram below to show the two-step mechanism of $C_6H_5N_2^+$ with F^-.



[2]

(c) Benzene can react with halogenoalkanes in the same way as with bromine, as shown in **reaction 1** below.

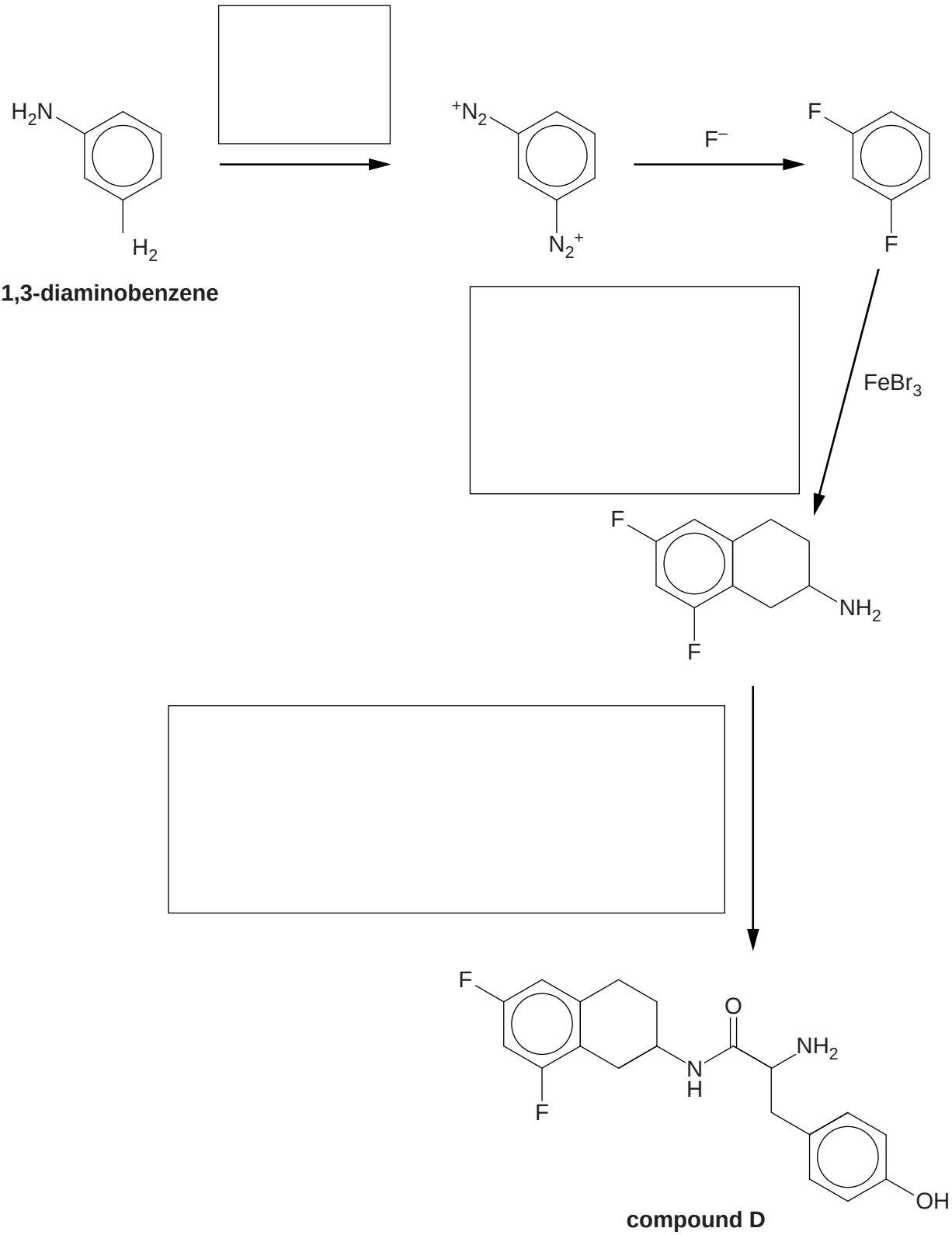


Write an equation to show the formation of the electrophile that reacts with benzene in **reaction 1**.

[1]

(d) The types of reaction in **(b)** and **(c)** can be used to synthesise compound **D**, as shown in the flowchart below.

(i) Complete the boxes below to suggest formulae for the reactants involved in the synthesis of compound **D**.
Give structures for organic compounds.

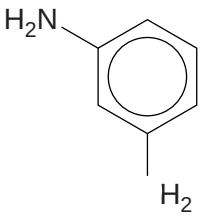


1,3-diaminobenzene

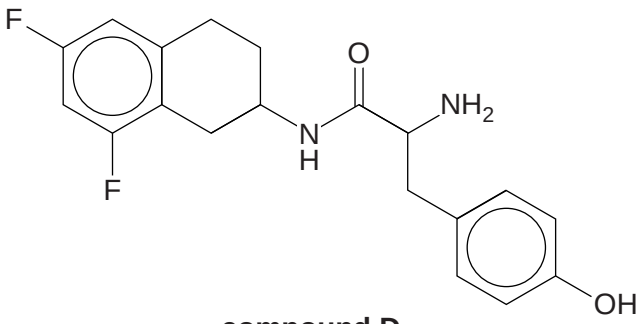
compound D

[3]

(ii) In a synthesis of compound **D** from 1,3-diaminobenzene shown in the flowchart, 1.73 g of compound **D** was prepared. These structures have been repeated below:



1,3-diaminobenzene



compound D

The overall percentage yield of compound **D** was 40.0%.

M_r of compound **D** = 346.0

Calculate the mass of 1,3-diaminobenzene needed for this synthesis.

mass = ... g **[3]**

(iii) Compound **D** has been developed for possible use as a drug to treat heart conditions. When compound **D**, prepared in this synthesis, was given to patients, only 25% of the dose was effective in treating their heart conditions.

Explain why only 25% of the dose was effective. Suggest how the synthesis of compound **D** might be changed to make the dose more effective.

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

[Total: 18]