CHEMISTRY

ORGANIC CHEMISTRY & ANALYSIS

LEVEL: A LEVEL

BOARD: EDEXCEL

TOPIC: BENZENE & AROMATIC COMPOUNDS

PAPER TYPE: QUESTION PAPER



Time Allowed:80MinScore:/64Percentage:/100

Question 1a

a)

Describe the structure of cyclohexene. Explain why the molecule is not planar. Your answer should include any necessary bond angles.

[4 marks]



Question 1b

The following information is known about the hydrogenation of cyclohexene:

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cyclohexene + hydrogen \rightarrow cyclohexane \Delta H^{\Theta} = -120 \text{ kJ mol}^{-1}
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Use this data to predict a value for the hydrogenation of the theoretical compound, cyclohexa-1,3,5-triene.

b)

State and explain the stability of benzene compared to the theoretical cyclohexa-1,3,5-triene compound.

[3 marks]



Question 1c

Benzene and three of its chemical derivatives, chlorobenzene, methylbenzene and phenol, are aromatic compounds which have a variety of industrial applications.

Benzene is mainly used in the manufacture of other more complex chemicals, such as ethylbenzene and cumene. Billions of kilograms of ethylbenzene and cumene are produced annually.

Like benzene, chlorobenzene is used to make several other chemicals. It is also used to degrease car parts and in some pesticide formulations.

In industry, methylbenzene is known by its common name, toluene. It is used as a solvent in paint thinner, permanent markers, contact cement and glue.

Phenol is a benzene ring with an -OH group attached in place of one of the hydrogen atoms, and its chemical derivatives are used in the manufacture of various plastics, nylon, detergents, herbicides and various pharmaceutical drugs.

c)

Compare the relative reactivities of benzene, chlorobenzene, methylbenzene and phenol in terms of electrophilic substitution reactions.



[5 marks]

Question 1d

d)

Explain why a molecule of benzene, C_6H_6 won't tend to react with bromine whereas hexene, C_6H_{12} , will react to form dibromohexane, $C_6H_{12}Br_2$.

[5 marks]

Question 2a

Benzene can undergo electrophilic substitution with ethanoyl chloride in the presence of a suitable catalyst.

a)

Name the catalyst and write an equation to show the formation of the electrophile.

Outline the mechanism for this reaction

[5 marks]



Question 2b

The organic product from part (a) can be reduced to form an alcohol.

b)

Name a suitable reducing agent and write a chemical equation to show this reduction, using [H] to represent the reducing agent.

[2 marks]

Question 2c

c)

Outline the mechanism for the reaction of the ethanoyl chloride with the catalyst to form the acylium ion needed for electrophilic substitution.



[2 marks]

Question 2d

d)

Aluminium chloride is used as the catalyst in the reaction between benzene and ethanoyl chloride. Explain how the catalyst reforms.

[2 marks]

Question 3a

a)

State the reagents and the name of the mechanism used to convert benzene into nitrobenzene.

[2 marks]

Question 3b

b)

Using your answer to (a), formulate the equation for the formation of the nitronium ion.

[4 marks]

Question 3c

c)

Using curly arrows to indicate the movement of electron pairs, explain the mechanism for the nitration of benzene.



Question 3d

d)

Nitrobenzene can be converted into aniline in a two-step process. State the reagents for this conversion.

[2 marks]

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Question 4a

Paracetamol is a common painkiller that is often manufactured in a multi-step process using 4-aminophenol. Phenol is a common organic chemical, comprised of a benzene ring with one hydroxyl group attached.

a)

Suggest a two-step synthetic route to form 4-aminophenol from phenol.

Step 1 of your route should include reagents, conditions, equations to form the electrophile and the identity of the product.

Step 2 of your synthetic route should include the reagents to form 4-aminophenol from your Step 1 product.

[5 marks]



Question 4b

b)

The uncontrolled nitration of phenol can lead to the formation of 2,4,6-trinitrophenol, commonly known as picric acid.

This reaction would require formation of a dinitrophenol intermediate. Draw the possible isomers of this intermediate and name the type of isomerism displayed.

[5 marks]



Question 4c

c)

A student reacted phenol with bromine at room temperature forming a white precipitate. Draw the structure for the organic product that forms the white precipitate.

[2 marks]

[3 marks]



Question 4d

d)

When phenol reacts with sodium hydroxide it acts as a weak acid. Explain why phenol can act as a weak acid.



Question 5a

A student investigated two reactions of phenylethene, $C_6H_5CHCH_2$. First she reacted phenylethene with excess bromine at room temperature to form Compound **A**. She then added aluminium bromide, $AlBr_3$ to the reaction mixture to form Compound **B**.



Question 5c

2,4,6-trinitrotoluene (TNT) can be manufactured from benzene as shown below.



Step 1 involves the Friedel-Crafts alkylation of benzene to produce methylbenzene, commonly known as toluene.

Calculate the percentage atom economy for Step 1.

[3 marks]

Question 5d

d)

Step 2 involves the formation of a nitronium ion for the nitration of Toluene, as shown in the following equation:

 $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$

i)

Explain the role of the nitric acid in the formation of the electrophile.

ii)

Explain the role of the sulphuric acid in the overall nitration reaction.



[3 marks]