IB · DP · Chemistry

2 hours 15 questions

Structured Questions: Paper 2

10.2 Functional Group Chemistry

10.2.1 Alkanes - Combustion / 10.2.2 Alkanes - Halogenation / 10.2.3 Alkenes - Reactivity / 10.2.4 Alkenes - Hydrogenation / 10.2.5 Alkenes - Halogenation / 10.2.6 Alkenes - Hydrohalogenation / 10.2.7 Alkenes - Hydration / 10.2.8 Addition Polymers / 10.2.9 Alcohols - Combustion / 10.2.10 Alcohols - Oxidation / 10.2.11 Alcohols - Esterification / 10.2.12 Halogenoalkanes / 10.2.13 Reactions of Benzene

Easy (5 questions)	/38
Medium (5 questions)	/63
Hard (5 questions)	/41
Total Marks	**/142**

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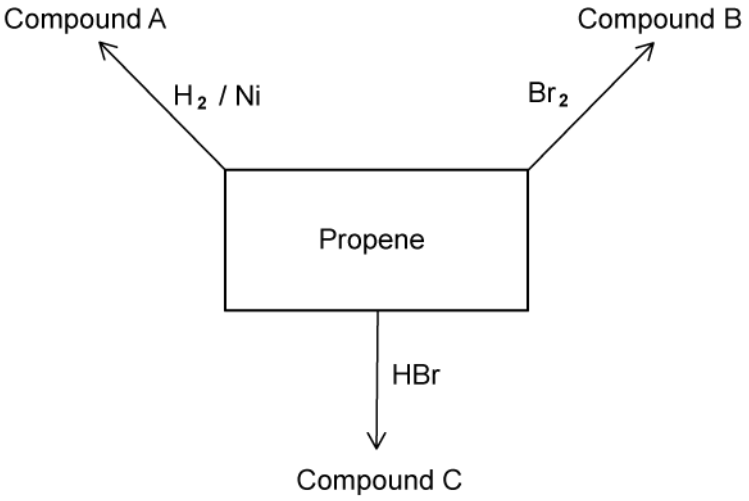
Easy Questions

1 (a) A reaction scheme for propene is shown below.



State the condensed structural formula of propene.

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(1 mark)

(b) State the IUPAC names for compounds A, B and C shown in the reaction scheme in part (a)

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(3 marks)

(c) Propene will also react to form an alcohol. State the reagents and conditions required for the formation of an alcohol from propene.

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(3 marks)

(d) State the colour change when compound B is formed from propene.

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(1 mark)

(e) Propene can form polypropene. Draw the repeating unit that will be formed via the addition polymerisation of propene.

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(2 marks)

2 (a) There are three steps to the free radical substitution mechanism. When ethane and chlorine react in the presence of UV light, chloroethane is produced. Write the equation for the initiation step.

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(1 mark)

(b) Write two equations for the propagation steps for the reaction outlined in part (a).

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(2 marks)

(c) Write the equation using structural formulae for the termination reaction between two $CH_3CH_2^{\bullet}$ free radicals.

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(1 mark)

(d) State the type of bond breaking that occurs in the initiation reaction to produce free radicals.

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(1 mark)

3 (a) State the balanced symbol equations for the complete combustion of propane and propanol.

(4 marks)

(b) The following reaction profile shown produces propanoic acid after three steps.

Step 1		Step 2		Step 3		
Propene	**→**	**Propan-1-ol**	**→**	**Propanal**	**→**	**Propanoic acid**

State the reagents and conditions that can be used for steps 2 and 3.

(3 marks)

(c) Using your answer to part (b) to state the colour change for step 2.

(1 mark)

(d) Explain why 2-methylpropan-2-ol will not form a carboxylic acid.

(2 marks)

4 (a) Benzene undergoes substitution reactions. State the equation for the reaction of benzene with nitric acid to produce nitrobenzene and water.

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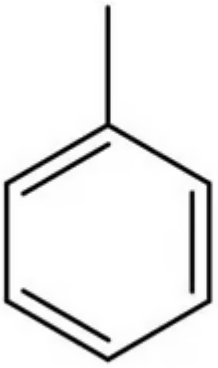
(2 marks)

(b) The structure of methylbenzene is shown below.



Draw the structures of the two isomers of choromethylbenzene formed from the reaction of methyl benzene and Cl_2 in the presence of $AlCl_3$.

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(2 marks)

(c) State the type of reaction that benzene will typically undergo.

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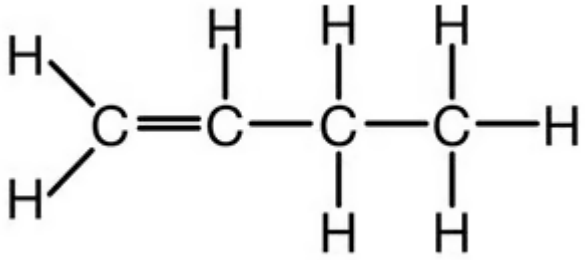
(1 mark)

5 (a) The structure of but-1-ene is shown below.



Draw and state the name of the secondary halogenoalkane formed when but-1-ene reacts with HCl.

(2 marks)

(b) Explain why halogenoalaknes are more reactive than alkanes.

(2 marks)

(c) State the reagents and conditions required for the formation of propan-1-ol from 1-bromopropane.

(3 marks)

(d) The type of reaction outlined in part (c) is *nucleophilic substitution*. State the meaning of the term *nucleophile*.

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(1 mark)

Medium Questions

1 (a) Ethene, C_2H_4, can be made into a number of useful compounds. A reaction sequence for this is shown below:

$$C_2H_4 \xrightarrow{\text{Step 1}} C_2H_5Cl \xrightarrow{\text{Step 2}} C_2H_6O \xrightarrow{\text{Step 3}} C_2H_4O$$

i) Name the type of reaction shown in step 1

ii) Write an equation, using structural formulas, for the reaction in step 2 in which C_2H_5Cl reacts with aqueous NaOH to form C_2H_6.

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(2 marks)

(b) The product of step 2 can undergo combustion.

i) Write a balanced equation for the *complete* combustion of the product of step 2.

ii) Write a balanced equation for the *incomplete* combustion of the product of step 2.

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(2 marks)

(c) Give the reagents and conditions needed to carry out step 3.

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(2 marks)

(d) The product of step 2 has a higher boiling point than the product of step 3.

State the names of the products of step 2 and 3, and explain the difference in their boiling points.

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(3 marks)

2 (a) Phenylethene, $C_6H_5CH=CH_2$, is a substance that can be polymerized. Draw a section of the polymer showing three repeat units and name the resulting polymer.

(2 marks)

(b) A solution of bromine in hexane reacts with phenylethene.

i) Draw the displayed structure of the product.

ii) Name the product of the reaction.

iii) State the reaction conditions.

iv) State what observations would be seen in this reaction.

(4 marks)

(c) Phenylethene can undergo catalytic hydrogenation. Draw the displayed structure of the product of the reaction, name the product, and state the reaction conditions.

(3 marks)

(d) 2-phenylethanol, $C_6H_5CH_2CH_2OH$, is a colourless liquid with a pleasant floral smell widely found in nature. Under the right conditions, it can be made from phenylethene in a two-step reaction using sulfuric acid.

State the reaction conditions and write balanced equations for the two-step reactions.

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(3 marks)

3 (a) Alkanes are generally unreactive and do not react with acids, bases, or with oxidising or reducing agents. However, they will react with halogens under suitable conditions, to form halogenoalkanes.

Methane reacts with chlorine in this way to form chloromethane.

i) State the name of this type of reaction mechanism.

ii) Write an overall equation for the reaction and give the reaction conditions.

(3 marks)

(b) The reaction described in part (a) consists of three steps. In the first step, the Cl-Cl bond is broken to form two chlorine free radicals.

i) State and explain the type of bond breaking that occurs in the initiation step.

ii) Define the term *free radical*.

iii) Explain why the C-H bond in the alkane does not break in the initiation step instead of the Cl-Cl bond.

(3 marks)

(c) Give the equations for each step of the reaction between methane and chlorine as described in part (a).

Label each equation with the name of the correct step. You only need to provide one equation for the final step.

(4 marks)

(d) Chlorofluorocarbons (CFCs) are organic compounds consisting of carbon, chlorine, and fluorine atoms. They are believed to destroy the ozone layer in a similar reaction to the one described in part (a).

Ozone can be broken down by radicals formed in the atmosphere. The ozone layer is important to protecting the Earth from harmful exposure to ultraviolet light.
Without this ozone layer, life on Earth would be very different.

An example of a CFC which can damage the ozone layer is CCl_3F.

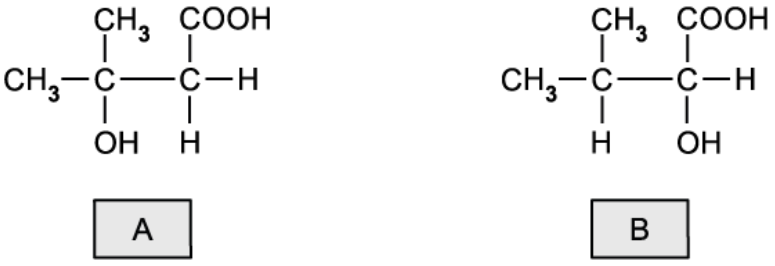
i) Explain why these free radicals act as catalysts in the breakdown of ozone to oxygen. Support your answer by writing suitable equations.

ii) Draw the three-dimensional structure of CCl_3F and name the shape of the molecule.

(4 marks)

4 (a) Two isomeric compounds are shown below in **Figure 1**.

Figure 1



i) State the name of each isomer.

ii) Suggest a chemical reagent to distinguish between these isomers and deduce the type of reaction taking place.

iii) State the observations made in each case.

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(5 marks)

(b) Compound B, $CH_3CH(CH_3)CH(OH)COOH$, can be oxidized into compound C.

i) Deduce the half-equation for the conversion of compound B into C.

ii) The half equation for the oxidation reaction using acidified potassium dichromate(VI) is as follows:

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \quad 2Cr^{3+}(aq) + 7H_2O(l)$$

Deduce the overall redox equation for the conversion of B into C.

(3 marks)

(c) The same reaction in part (b) can be used to oxidize ethanol into ethanal or ethanoic acid, depending on the reaction conditions.

Outline how the reaction conditions can be changed to produce ethanal or ethanoic acid.

(2 marks)

(d) Under the right conditions, the two molecules of compound A can react together to produce a dimer.

i) Name the type of reaction taking place and state the reaction conditions.

ii) Draw the structure of the product, showing clearly how the two molecules are joined.

(3 marks)

5 (a) Benzene, C_6H_6, typically undergoes *electrophilic substitution*

i) State the meaning of the term *electrophile*.

ii) Write an equation for the reaction between benzene and concentrated nitric acid.

iii) Identify the electrophile in the reaction and show, by means of an equation, how it is generated.

(4 marks)

(b) Benzene is a highly unsaturated molecule.

i) Discuss why benzene undergoes substitution reactions rather than addition reactions.

ii) Show, by means of an equation, the reaction of benzene with chlorine and state any necessary conditions.

(5 marks)

(c) An aromatic organic compound with molecular formula C_7H_8 reacts with bromine in the presence of UV light to produce a compound with molecular formula C_7H_7

i) Name the type of reaction taking place.

ii) Deduce the structures of the reactant and product.

iii) Give the formula of an additional organic product that could be obtained in the reaction.

(3 marks)

(d) The same aromatic compound in part (c), C_7H_8, can be reacted with concentrated nitric acid to produce a multiple substituted product, with molecular formula $C_7H_5N_3O_6$.

i) Deduce the systematic IUPAC name for this compound.

ii) Draw the structure of $C_7H_5N_3O_6$.

iii) Name a use for the product.

(3 marks)

Hard Questions

1 (a) Dichloromethyl benzene reacts with chlorine to produce trichloromethyl benzene. State the name of this type of mechanism and the required condition.

(2 marks)

(b) Outline the mechanism for the reaction occurring in part a).

(4 marks)

(c) A reaction pathway is shown below. Compound **J** reacts with bromine water to form a colourless solution.

State the IUPAC name for Compound J.

(1 mark)

(d) Identify the reagents and conditions for the formation of Compound Y from Compound J.

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(2 marks)

2 (a) Compounds **W**, **X** and **Y** are all carbohydrates with **X** and **Y** each containing five carbons. Compound **W** and a byproduct, compound **Z**, are formed from the reaction between compound **X** and **Y**. Compound **X** can be oxidised by the reaction with acidified potassium dichromate to give compound **Y**.

2.754 g of compound **Y** contains 0.027 moles.

Using the information given, state the name of compound **Y** and justify your answer.

(3 marks)

(b) Deduce the structural formula of compound **W** and explain how compound **Z** is formed in the reaction.

(2 marks)

(c) Compound **X** will oxidise to compound **Y** if allowed to fully oxidise. Explain how a student could stop the full oxidation of compound **X**.

(4 marks)

(d) Deduce the formula of an isomer of compound **X** that will not react with acidified potassium dichromate, H^+ / $K_2Cr_2O_7$.

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(1 mark)

3 (a) Ester **A** is responsible for a raspberry scent and has the molecular formula $C_5H_{10}O_2$. Ester **A** can be produced by the reaction of an acid with a branched primary alcohol. Identify the acid and alcohol used to prepare ester **A**.

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(2 marks)

(b) State the IUPAC name and draw the structural formula of ester **A**.

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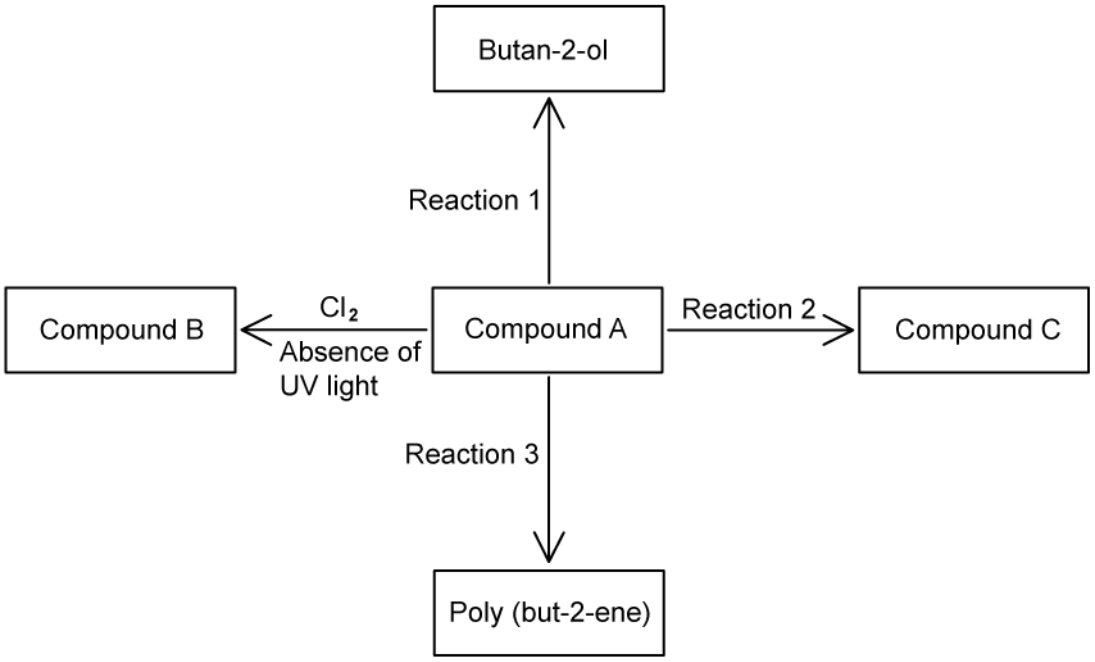
(2 marks)

State the name of the product when the alcohol used to form ester **A** reacts with potassium permanganate, $KMnO_4$ (aq).

(c) .....

(1 mark)

4 (a) The following scheme shows reactions of Compound **A.**



i) Deduce the structural formula of compound **A**.

[1]

ii) Apply IUPAC rules to name compound **B**.

[1]

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(2 marks)

(b) Reaction **1** forms an alcohol when reacted with concentrated sulfuric acid, H_2SO_4 and steam.

i) State the conditions required for this reaction.

[1]

ii) Deduce the structure of the intermediate in this reaction.

[1]

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(2 marks)

(c) Butan-2-ol can also be directly formed from a halogenoalkane.

i) State the name of of the type of reaction occurring in this conversation.

[2]

ii) State the conditions for this reaction.

[1]

(3 marks)

(d) Identify the structure of the repeating unit of poly(but-2-ene).

(1 mark)

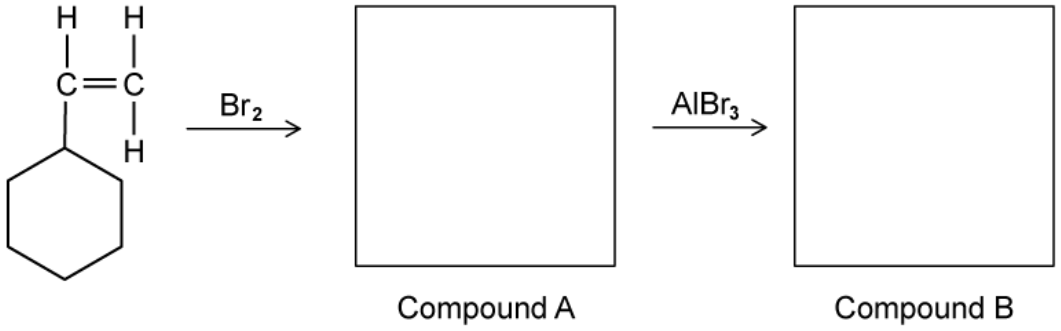
(e) Compound A reacts with hydrogen bromide to form compound C. A student suggested a possible formula of compound C is $CH_2(Br)CH_2CH_2CH_3$.

State whether the student is correct and justify your answer.

(1 mark)

5 (a) 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.**

Draw the structure of Compound **A** and identify one the isomers of $C_8H_7Br_3$ formed in the second reaction.



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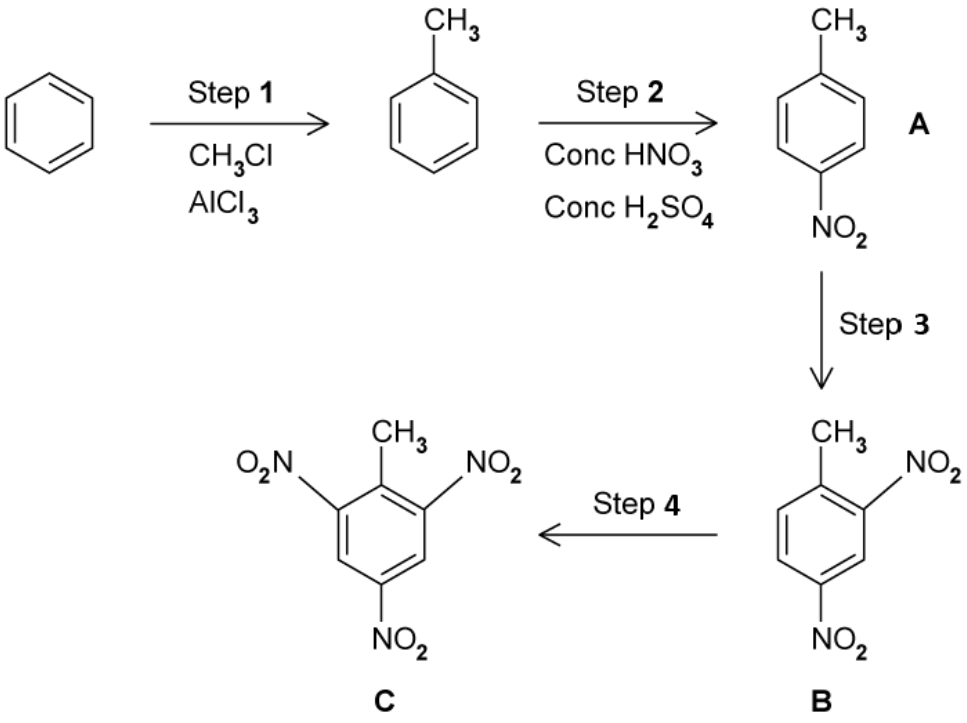
(2 marks)

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



5.00 g of benzene was used in step 1. Use section 6 of the data booklet to determine the theoretical yield for step 1.

(2 marks)

(c) 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.

[2]

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

[1]

(3 marks)

(d) Explain why the product of step 2 is most likely to have the nitro group bonded to the second or fourth carbon atom.

(1 mark)