10.2 Functional Group Chemistry

Mark Schemes

Course	DP IB Chemistry
Section	10. Organic Chemistry
Topic	10.2 Functional Group Chemistry
Difficulty	Medium

To be used by all students preparing for DP IB Chemistry SL
Students of other boards may also find this useful

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The correct answer is **C** because:

- A primary alcohol has a hydroxyl group (-OH) attached to a saturated carbon atom that has only 1 other carbon atom attached to it
- Secondary alcohol has a hydroxyl group (-OH) attached to a saturated carbon atom that has 2 other carbon atoms
- Xylitol has both primary and secondary hydroxyl groups
- Primary alcohols are oxidised to aldehydes and carboxylic acids
- Secondary alcohols are oxidised to ketones

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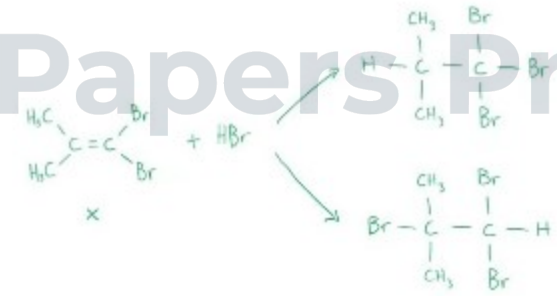
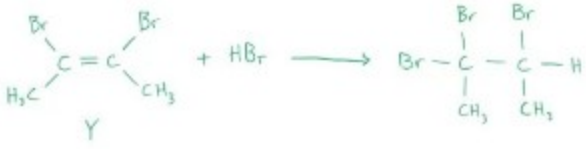
The correct answer is **B** because:

- Bromine is an electrophile (electron loving species)
- It reacts with the alkene isomers via electrophilic addition by breaking the C=C double bond
- The best way to approach a question like this is to completely draw out the structural formula of each product:





- So, the reaction between HBr and isomers **X** and **Y** form:
  - $(CH_3)_2CHCBr_3$
  - $(CH_3)_2CBrCHBr_2$
  - $CH_3CBr_2CHBrCH_3$

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The correct answer is **C** because:

- In the initiation step, free radical $Cl^{\bullet}$ atoms are formed:
- Initiation step: $Cl_2 \rightarrow 2Cl^{\bullet}$
  - Initiation = net formation of radicals
- These free radical $Cl^{\bullet}$ atoms remove a hydrogen from the ethane making an ethyl free radical, $C_2H_5^{\bullet}$
- Propagation step: $C_2H_6 + Cl^{\bullet} \rightarrow C_2H_5^{\bullet} + HCl$
  - Propagation = no change in the number of free radicals
- Two of these radicals can then pair-up in a termination step to form butane $CH_3CH_2CH_2CH_3$ (or C_4H_{10}):
- Termination step: $C_2H_5^{\bullet} + C_2H_5^{\bullet} \rightarrow C_4H_{10}$
  - Termination = net destruction of free radicals
- Therefore, option **C** is the only option which shows a possible compound that could be present

A, **B** and **D** are incorrect as	it's not possible to produce these products from ethane and chlorine

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A, **B** and **D** are incorrect as it's not possible to produce these products from ethane and chlorine

4

The correct answer is **A** because:

- In dichlorodifluoromethane, there are:
  - Two C–F bonds and two C–Cl bonds
- Both of these are incredibly strong bonds, and the carbon-fluorine bond energy is the larger of the two
- The C–F bond strength is the reason for the inertness of CCl_2F_2 and CFCs in general
- They are so strong that such bonds don't break under the energy of ordinary visible light
  - UV light is required to break them

B is incorrect as the polarity of a bond tells us how electronegative an atom is, which contributes to the strength of the bond, but is not the direct reason for the inertness of the molecule overall

C is incorrect as halogens are electronegative and create bond polarity, but this is not directly the reason for the inertness

D is incorrect as this is another consequence of the inertness of CCl_2F_2, not a reason for it

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The correct answer is **D** because:

- The reaction between bromoethane and sodium hydroxide is **nucleophilic substitution**
- It begins with the nucleophilic attack of OH^- from NaOH on the slightly positive carbon atom in the C-Br bond
- The leaving group is the Br^- ion, which is a species with a lone pair of electrons, thus both of the attacking and leaving groups are nucleophiles
- Therefore, **both** the attacking group and leaving groups are nucleophiles

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The correct answer is **A** because:

- **Step 1:** Write out the equation for the complete combustion of propane
  - $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$
- **Step 2:** Balance the equation
  - $C_3H_8 + 5O_2 \rightarrow \mathbf{3}CO_2 + \mathbf{4}H_2O$
- **Step 3:** Determine moles of oxygen using molar ratios
  - For every 1 mole of propane, 5 moles of oxygen are required
  - So, 0.1 mol of propane completely combusts in 0.5 mol of oxygen
- **Step 4:** Multiply moles of oxygen by 24 dm^3 to determine volume occupied by oxygen
  - Volume of oxygen = 0.5 x 24 dm^3 = **12 dm^3**

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The correct answer is **A** because:

- **Step 1:** Write the chemical equation
  - $C_2H_5OH + [O] \rightarrow CH_3CHO + H_2O$
- **Step 2:** Calculate the moles of ethanol
  - Moles = $\frac{Mass}{M_r}$
  - Moles = $\frac{2.3}{(12 \times 2 + 6 + 16)} = 0.05\ mol$
- **Step 3:** Calculate the mass of ethanal
  - From the chemical equation, we can see that 1 mol of ethanol produces 1 mol of ethanal
  - So, the number of moles of ethanal is 0.05 mol
- **Step 4:** Calculate the theoretical yield of ethanal
  - Mass = Moles x M_r
  - So, the mass of ethanal = $0.05 \times ((12 \times 2) + (1 \times 4) + 16) = 0.05 \times 44$ g
  - Therefore, the theoretical yield of ethanal is 2.2 g
- **Step 5:** Calculate the actual yield
  - % yield = $\frac{actual}{theoretical}$
  - So, the actual yield of ethanal = $\frac{50}{100} \times 2.2$ g = **10 g**

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The correct answer is **B** because:

- Primary alcohols are oxidised to aldehydes and then to carboxylic acids
- Secondary alcohols are only oxidised to ketones, and cannot be oxidised further
- Tertiary alcohols cannot be oxidised
- Therefore, the only alcohol which would give only **one** oxidation product is the secondary alcohol, butan-2-ol

A & **C** are incorrect as butan-1-ol and 2-methylpropan-1-ol are primary alcohols, so they could produce **two** products when oxidised: aldehydes and carboxylic acids

D is incorrect as 2-methylpropan-2-ol is a tertiary alcohol, so, it cannot be oxidised

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The correct answer is **C** because:

- **Acidified potassium dichromate(VI)** is an oxidising agent
  - An **oxidising agent** is a species that **oxidises** another species and gets **reduced** itself
  - The reaction mixture turns green as the **orange** $Cr_2O_7^{2-}$ ions (dichromate) are reduced to **green** Cr^{3+} ions
  - Only **primary alcohols**, **secondary alcohols** and **aldehydes** can be oxidised by acidified potassium dichromate(VI)
- **Hydroxyethanal** contains a **primary alcohol** and **aldehyde** group
- Since the compound is heated **under reflux** until no further oxidation takes place, both the primary alcohol and the aldehyde are oxidised to **carboxylic acid groups**
  - Primary alcohol → aldehyde → carboxylic acid
  - Aldehyde → carboxylic acid
- The correct answer is therefore **C**

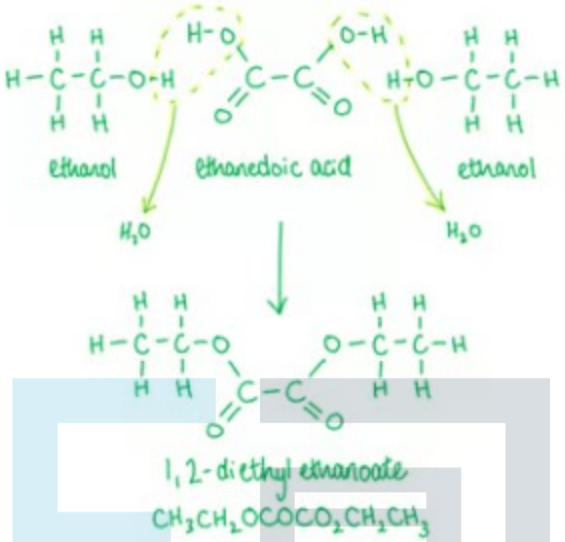
A is incorrect as **only** the **aldehyde** group has been oxidised

B is incorrect as this compound contains the **incorrect** number of **carbon atom** in the carbon chain (there should be only 2 carbon atoms and not 3)

D is incorrect as the molecule is not fully oxidised; the aldehyde can undergo further oxidation to a carboxylic acid

10

The correct answer is **B** because:



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The correct answer is **A** because:

- Compound Q is an **ester** made from propanoic acid, $CH_3CH_2CO_2H$, and methanol, CH_3OH
- The naming of the ester starts with the alkyl attached to the alcohol – in this case methyl – and ends with the carboxylic acid, in this case propanoate
    - '-oate' is the suffix of compounds produced from carboxylic acids
- Therefore, the name is **methyl propanoate**
- The boiling point of methyl propanoate is **lower** than butanoic acid because it has only **dipole-dipole attractions** between the molecules, whereas butanoic acid has stronger **hydrogen bonds**

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The correct answer is **C** because: