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ANSWER BOOK

Elimination from halogenoalkanes, and CFCs and the ozone layer

Alkanes and halogenoalkanes · Unit C17

AQA 3.3.3.2, 3.3.3.3 · OCR A 4.2.2 (e)

17 questions · 58 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 EH-Q3

B1 in elimination the hydroxide ion acts as a base, accepting an H^+ from the carbon next to the C–X carbon. **B1** in substitution it acts as a nucleophile, donating its lone pair to the δ+ carbon. [2]

A2 EH-Q6

B1 the three carbons next to the C–Br carbon are identical CH_3 groups, so removing H from any of them gives the same product. **B1** the alkene is 2-methylpropene, $(CH_3)_2C{=}CH_2$. [2]

A3 EH-Q16

B1 $NO\bullet + O_3 \rightarrow NO_2\bullet + O_2$. **B1** $NO_2\bullet + O \rightarrow NO\bullet + O_2$, regenerating NO•; allow $NO_2\bullet + O_3 \rightarrow 2O_2 + NO\bullet$ by analogy with the chlorine cycle. [2]

SECTION B · Standard, 3 to 5 marks

B1 EH-Q1

B1 potassium hydroxide dissolved in ethanol; reject aqueous KOH. **B1** the mixture is heated under reflux. **B1** bromine water is added to the product, or the gas is bubbled through it. **B1** an alkene turns the orange bromine water colourless; an alcohol leaves it orange; reject 'clear' for colourless. [4]

B2 EH-Q2

B1 the dipole: δ+ on the carbon bonded to bromine and δ- on the bromine. **B1** a curly arrow from a lone pair on the oxygen of OH^- to an H atom on a carbon next to the C–Br carbon; reject an arrow that ends on the carbon. **B1** a curly arrow from that C–H bond to the C–C bond, forming the C=C. **B1** a curly arrow from the C–Br bond to the bromine, giving propene, water and Br^-. [4]

B3 EH-Q4

B1 removing H from carbon 1 gives pent-1-ene, $CH_2{=}CHCH_2CH_2CH_3$. **B1** removing H from carbon 3 gives pent-2-ene, $CH_3CH{=}CHCH_2CH_3$. **B1** pent-2-ene has two different groups on each carbon of the C=C and restricted rotation, so it exists as E and Z isomers. **B1** three alkenes in all: pent-1-ene, E-pent-2-ene and Z-pent-2-ene; allow cis and trans for Z and E. [4]

B4 EH-Q7

B1 substitution is favoured by an aqueous solvent; elimination by ethanol as the solvent. **B1** substitution is favoured by warm conditions; elimination by heating strongly under reflux. **B1** primary halogenoalkanes favour substitution; tertiary ones favour elimination. **B1** substitution gives an alcohol; elimination gives an alkene, with water and a halide ion. [4]

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B5 EH-Q12 — [4]

B1 CFCs are very unreactive, so they are not broken down in the lower atmosphere and slowly drift upwards. **B1** the C–Cl bond (346 kJ mol^{-1}) is weaker than the C–F bond (467 kJ mol^{-1}), so ultraviolet light breaks C–Cl homolytically and leaves C–F intact. **B1** HFCs contain no chlorine, so no chlorine radicals can be released. **B1** their C–F bonds are too strong to be broken by the ultraviolet light in the stratosphere, so no radicals form.

B6 EH-Q14 — [4]

B1 HFCs have the properties that made CFCs useful: they are volatile, non-toxic and non-flammable. **B1** they do not deplete ozone, because they contain no C–Cl bond to release chlorine radicals. **B1** but they are powerful greenhouse gases, absorbing infrared radiation and contributing to global warming. **B1** so they solve the ozone problem but not the climate one, which is why their use is now being phased down in favour of hydrocarbons and other alternatives.

B7 EH-Q20 — [4]

B1 laboratory data were used to predict that CFCs reach the stratosphere and that chlorine radicals from them break down ozone. **B1** measurements over Antarctica, later confirmed by satellites, showed a large springtime fall in ozone. **B1** aircraft measurements found high concentrations of ClO• exactly where the ozone was depleted. **B1** since CFCs were phased out, stratospheric chlorine has fallen and the ozone layer has begun slowly to recover, as the explanation predicts.

B8 EH-Q9 — [3]

B1 ultraviolet light splits oxygen molecules into atoms: $O_2 \rightarrow 2O$. **B1** an oxygen atom combines with an oxygen molecule: $O + O_2 \rightarrow O_3$. **B1** ozone absorbs harmful ultraviolet radiation (UV-B), which would otherwise cause skin cancer and cataracts.

B9 EH-Q10 — [3]

B1 $Cl• + O_3 \rightarrow ClO• + O_2$. **B1** $ClO• + O_3 \rightarrow 2O_2 + Cl•$. **B1** overall: $2O_3 \rightarrow 3O_2$.

B10 EH-Q11 — [3]

B1 the chlorine radical is used in the first step and regenerated in the second. **B1** so it speeds up the decomposition without being used up. **B1** each radical goes round the cycle many thousands of times before a termination step removes it.

B11 EH-Q18 — [3]

B1 removing H from carbon 2 gives hex-2-ene, $CH_3CH{=}CHCH_2CH_2CH_3$. **B1** removing H from carbon 4 gives hex-3-ene, $CH_3CH_2CH{=}CHCH_2CH_3$. **B1** each has two different groups on both carbons of its C=C, so there are four alkenes: E- and Z-hex-2-ene, E- and Z-hex-3-ene.

B12 EH-Q19 — [3]

B1 most stratospheric chlorine is normally held in reservoir compounds, HCl and $ClONO_2$, which do not attack ozone. **B1** in the polar winter, ice clouds form and on their surfaces the reservoir compounds react to release Cl_2. **B1** when sunlight returns in spring, ultraviolet light splits the Cl_2 into chlorine radicals all at once, which destroy ozone rapidly.

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B13 EH-Q22

B1 with little water present the hydroxide ion acts as a base, removing an H^+ from a carbon next to the C–Br carbon, so elimination gives propene; in water it acts mainly as a nucleophile and substitution to propan-2-ol competes. **B1** elimination has the higher activation energy of the two reactions, so the hot conditions of reflux favour it, whereas gentle warming favours substitution. **B1** heating under reflux lets the volatile ethanol and 2-bromopropane be heated for long enough without loss, while the propene, a gas, leaves through the condenser to be collected. [3]

SECTION C · Long, 6 marks or more

C1 EH-Q21

Indicative content [6]

B1 CFCs are unreactive, so they are not broken down in the lower atmosphere and drift up into the stratosphere over years. **B1** there, ultraviolet light breaks the weaker C–Cl bond homolytically, releasing chlorine radicals, while the stronger C–F bond survives. **B1** a chlorine radical takes an oxygen atom from ozone: $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$. **B1** the ClO• radical reacts with a second ozone molecule, $ClO\bullet + O_3 \rightarrow 2O_2 + Cl\bullet$, so overall $2O_3 \rightarrow 3O_2$. **B1** the chlorine radical is regenerated in the second step, so it is a catalyst and is not used up by the cycle. **B1** each radical goes round the cycle many thousands of times before termination, such as $ClO\bullet + NO_2 \rightarrow ClONO_2$, removes it.

Levels

Level 3 (5–6 marks) the whole chain is explained: the inertness that lets CFCs reach the stratosphere, homolysis of the C–Cl bond rather than C–F, both propagation equations giving the overall $2O_3 \rightarrow 3O_2$, and the regeneration of the chlorine radical as the reason a little CFC destroys a great deal of ozone, which makes chlorine a catalyst.

Level 2 (3–4 marks) ultraviolet light forms chlorine radicals and both ozone equations are given; how the CFC survives to reach the stratosphere, the regeneration of the radical, or the overall equation is not there.

Level 1 (1–2 marks) CFCs are said to destroy ozone directly, or the C–F bond is said to break; one equation or none, and nothing explains why a small amount does so much damage.

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