InkChemistry

ANSWER BOOK

Reaction types, curly arrows and how a mechanism is written

Introduction to organic chemistry · Unit C16

AQA 3.3.1.2 · OCR A 4.1.1

20 questions · 63 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 RTC-Q3 — **B1** the covalent bond breaks with one electron of the shared pair going to each atom. **B1** two radicals form, each a species with an unpaired electron. [2]

A2 RTC-Q4 — **B1** both electrons of the C–Br bond go to the bromine, the more electronegative atom. **B1** forming a bromide ion, Br^-, and a carbocation, $(CH_3)_3C^+$. [2]

A3 RTC-Q6 — **B1** propene and hydrogen bromide react by (electrophilic) addition. **B1** ethanol forming ethene and water is an elimination, also called dehydration. [2]

A4 RTC-Q14 — **B1** the hydroxide ion carries a full negative charge, whereas a water molecule is neutral. **B1** so the hydroxide ion is more strongly attracted to the δ+ carbon and donates its lone pair more readily. [2]

SECTION B · Standard, 3 to 5 marks

B1 RTC-Q1 — **B1** a nucleophile is an electron pair donor; reject 'attracted to a positive charge' as the definition. **B1** an electrophile is an electron pair acceptor. **B1** the cyanide ion is the nucleophile, donating the lone pair on its carbon to the δ+ carbon of bromoethane. **B1** hydrogen bromide is the electrophile, its δ+ hydrogen accepting a pair of electrons from the C=C; accept H^+ or Hδ+. [4]

B2 RTC-Q10 — **B1** the C–Br bond is shown polar, with δ+ on the carbon and δ- on the bromine. **B1** the first arrow starts on a lone pair on the oxygen of OH^- and ends on the δ+ carbon; allow the arrow from the minus sign on O, reject an arrow from the H. **B1** the second arrow starts on the C–Br bond and ends on the bromine atom. **B1** the products are ethanol, CH_3CH_2OH, and a bromide ion, Br^-. [4]

B3 RTC-Q11 — **B1** the C–Br bond is shown with δ+ on the carbon and δ- on the bromine. **B1** an arrow starts on the lone pair on the carbon of CN^- and ends on the δ+ carbon. **B1** an arrow starts on the C–Br bond and ends on the bromine, which leaves as Br^-. **B1** the organic product is $CH_3CH_2CH_2CN$, butanenitrile. [4]

B4 RTC-Q17 — **B1** a curly arrow shows the movement of an electron pair, so it must start where electrons are, on a lone pair or a bond. **B1** the first arrow is reversed: it should start on a lone pair on the oxygen of OH^- and end on the δ+ carbon. **B1** the second arrow is also reversed: it should start on the C–Br bond and end on the bromine, which leaves as Br^-. **B1** the student has identified the correct atoms involved, but both arrows show electrons moving the wrong way, so neither is correct. [4]

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B5 RTC-Q5 **B1** Cl• is a radical, since it has an unpaired electron. **B1** NH_3 is a nucleophile, since it has a lone pair on nitrogen to donate. **B1** NO_2^+ is an electrophile, since it is positive and accepts an electron pair. [3]

B6 RTC-Q7 **B1** the nitrogen atom in ammonia has a lone pair of electrons. **B1** it can donate that lone pair to an electron-deficient δ+ carbon, forming a new covalent bond. **B1** a nucleophile is defined as an electron pair donor, so a lone pair is required, not a negative charge. [3]

B7 RTC-Q8 **B1** bromine is more electronegative than carbon. **B1** the bonding pair is drawn towards the bromine, so the carbon is δ+ and the bromine δ−. **B1** the lone pair of a nucleophile is attracted to the δ+ carbon and can form a bond to it. [3]

B8 RTC-Q9 **B1** the high electron density of the C=C repels the electrons in the Br–Br bond as the molecule approaches, inducing a dipole. **B1** the bromine atom nearer the C=C becomes δ+ and can accept a pair of electrons from the double bond. **B1** the product with ethene is 1,2-dibromoethane, CH_2BrCH_2Br, one bromine atom added to each carbon of the C=C. [3]

B9 RTC-Q12 **M1** Mr of CH_3Cl = 50.5 and Mr of HCl = 36.5, so the total mass of products is 87.0. **M1** atom economy = 50.5 ÷ 87.0 × 100. **A1** atom economy = 58.0%, to three significant figures; allow 58%. [3]

B10 RTC-Q13 **M1** Mr of CH_3CH_2Br = 108.9 and of NaOH = 40.0, so the total mass of reactants is 148.9. **M1** Mr of CH_3CH_2OH = 46.0, and atom economy = 46.0 ÷ 148.9 × 100. **A1** atom economy = 30.9%, to three significant figures. [3]

B11 RTC-Q15 **B1** the I–Cl bond is polar, Iδ+ and Clδ−, so ICl acts as an electrophile and the reaction is electrophilic addition. **B1** an arrow from the C=C to the δ+ iodine, and an arrow from the I–Cl bond to the chlorine, give a carbocation and Cl^-. **B1** an arrow from a lone pair on Cl^- to the positive carbon gives the product CH_2ICH_2Cl, 1-chloro-2-iodoethane. [3]

B12 RTC-Q16 **B1** in both, the hydroxide ion donates a lone pair of electrons from its oxygen. **B1** as a base it donates the pair to a hydrogen ion, whereas as a nucleophile it donates it to an electron-deficient carbon. **B1** it acts mainly as a nucleophile in warm aqueous solution, giving substitution, and mainly as a base in hot ethanol, giving elimination. [3]

B13 RTC-Q19 **B1** an addition reaction has a single product, 1,2-dibromoethane, and no by-product. **B1** so all the atoms, and the whole mass, of the reactants end up in the desired product. **B1** a substitution always forms a second product, such as HCl or a halide salt, so part of the mass of the reactants ends up outside the desired product. [3]

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B14 RTC-Q20 **M1** Mr of $CH_3CH_2CH_2OH$ = 3 × 12.0 + 8 × 1.0 + 16.0 = 60.0. **M1** Mr of $CH_3CH{=}CH_2$ = 42.0, and atom economy = 42.0 ÷ 60.0 × 100. **A1** atom economy = 70.0%, to three significant figures. [3]

B15 RTC-Q21 **B1** the reaction of ethene with steam is an addition with a single product, so its atom economy is 100%. **B1** the reaction of bromoethane with sodium hydroxide is a substitution that also forms sodium bromide, so its atom economy is only about 31%. **B1** the addition route turns all of the reactants into ethanol, wasting less material and producing no by-product to dispose of. [3]

SECTION C · Long, 6 marks or more

C1 RTC-Q18 **Indicative content** [6]

B1 in homolytic fission each atom takes one electron from the shared pair. **B1** this forms two radicals, for example Cl_2 in ultraviolet light giving two Cl• radicals. **B1** it is shown by two half-headed (fishhook) arrows starting on the bond, one ending on each atom. **B1** in heterolytic fission one atom, the more electronegative, takes both electrons of the shared pair. **B1** this forms a positive and a negative ion, for example $(CH_3)_3CBr$ giving $(CH_3)_3C^+$ and Br^-. **B1** it is shown by one full-headed curly arrow from the bond to the atom that keeps the pair.

Levels

Level 3 (5–6 marks) both kinds of fission are defined in terms of where the electrons go, each has a correct example with the species formed, and the curly arrows are distinguished with the fishhook arrows for homolysis and the full-headed arrow for heterolysis.

Level 2 (3–4 marks) both kinds of fission are defined with an example each; the two kinds of curly arrow are not told apart, or one example gives the wrong species.

Level 1 (1–2 marks) one kind of fission is defined, commonly with homolytic fission said to give ions, and the examples and arrows are largely missing.

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