SL Paper 2

Ethene belongs to the homologous series of the alkenes.

A bromoalkane, C_4H_9Br, reacts with a warm, aqueous sodium hydroxide solution, NaOH.

The time taken to produce a certain amount of product using different initial concentrations of C_4H_9Br and NaOH is measured. The results are shown in the following table.

Reaction	$[C_4H_9Br]$ / 10^{-2} mol dm^{-3}	[NaOH] / 10^{-3} mol dm^{-3}	t / s
A	1.0	2.0	46
B	2.0	2.0	23
C	2.0	4.0	23

a.i. Outline **three** features of a homologous series. [3]

a.ii. Describe a test to distinguish ethene from ethane, including what is observed in **each** case. [2]

a.iii. Bromoethane can be produced either from ethene or from ethane. State an equation for **each** reaction. [2]

b.i. State the equation for the reaction of C_4H_9Br with NaOH. [1]

b.ii. Suggest what would happen to the pH of the solution as the reaction proceeds. [1]

c.i. Deduce the effect of the concentration of C_4H_9Br and NaOH on the rate of reaction. [2]

C_4H_9Br:

NaOH:

c.ii. Suggest why **warm** sodium hydroxide solution is used. [1]

c.iii. Deduce whether C_4H_9Br is a primary or tertiary halogenoalkane. [2]

c.iv. Determine the structural formula of C_4H_9Br. [1]

c.v. Describe, using an equation, how C_4H_9Br can be converted into $C_4H_8Br_2$. [1]

d. Explain the mechanism for the reaction in (c) of C_4H_9Br with NaOH, using curly arrows to represent the movement of electron pairs. [4]

Markscheme

a.i. same functional group / same general formula;

difference between successive members is CH_2;

similar chemical properties;

Do not accept "same" chemical properties.

gradually changing physical properties;

a.ii. adding bromine (water);

ethene: brown/orange to colourless / decolourizes bromine water **and**

ethane: does not change colour;

OR

adding acidified potassium permanganate solution/$KMnO_4(aq)$;

ethene: purple to colourless/brown **and**

ethane: does not change colour;

OR

adding Baeyer's reagent;

ethene: purple/pink to brown **and**

ethane: does not change colour;

Do not accept "clear" or "transparent" for "colourless".

a.iii. $C_2H_4 + HBr \rightarrow C_2H_5Br$;

$C_2H_6 + Br_2 \rightarrow C_2H_5Br + HBr$;

Accept structural formulas.

Penalise missing H atoms or incorrect bonds (such as C–HO, C–H_2C) in structural formulas only once in the paper.

b.i. $C_4H_9Br + OH^- \rightarrow C_4H_9OH + Br^-$;

Accept NaOH in the equation.

b.ii. decreases;

c.i. *C_4H_9Br:*

[C_4H_9Br] doubles **and** time halves/rate doubles / rate proportional to [C_4H_9Br];

Do not accept rate increases when [C_4H_9Br] increases.

NaOH:

[NaOH] doubles **and** time/rate does not change / rate independent of [NaOH];

c.ii. increases rate;

Accept increases number of collisions.

c.iii. rate depends on $[C_4H_9Br]$ only / rate does not depend on $[OH^-]$ / S_N1 reaction /

first order reaction / if it was primary, reaction would be S_N2;

tertiary;

Accept ECF.

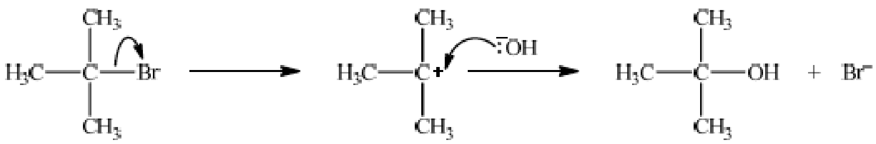
c.iv. $(CH_3)_3CBr$;

Allow both condensed and full structural formula.

Accept ECF.

c.v. $C_4H_9Br + Br_2 \rightarrow C_4H_8Br_2 + HBr$;

d.



curly arrow showing Br^- leaving;

representation of tertiary carbocation;

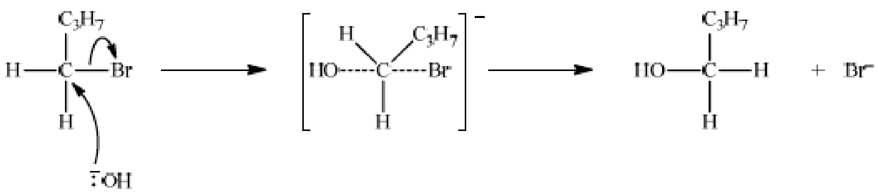
curly arrow going from lone pair/negative charge on O in ^-OH to C^+;

Do not allow arrow originating on H in ⁻OH.

formation of $(CH_3)_3COH$ **and** Br^-;

Accept Br⁻ anywhere on product side in the reaction scheme.

If primary halogenoalkane has been answered in (c)(iii) apply ECF for the mechanism:



curly arrow going from lone pair/negative charge on O in ^-OH to C;

Do not allow curly arrow originating on H in ⁻OH.

curly arrow showing Br^- leaving;

Accept curly arrow either going from bond between C and Br to Br in bromobutane or in the transition state.

representation of transition state showing negative charge, square brackets and partial bond;

Do not penalize if HO and Br are not at 180° to each other.

Do not award M3 if OH—C bond is represented.

formation of organic product C_4H_9OH **and** Br^-;

Accept Br– anywhere on product side in the reaction scheme.

Examiners report

a.i. Students had surprisingly difficulties to name the features of a homologous series. Common mistakes were to say SAME chemical or physical properties or same empirical/molecular/structural formula.

a.ii. Most candidates did well describing the test to distinguish alkanes and alkenes.

a.iii. The formation of dibromobutane was a common error.

b.i. The equation for the reaction of the C_4H_9Br with NaOH presented no problem.

b.ii. Some did not realize that pH decreases as NaOH is reacting, often referring as the pH would become more neutral.

c.i. Candidates could deduce that the concentration of NaOH does not affect the rate, but could not accurately explain and quantify the relationship between the concentration of C_4H_9Br and the rate of reaction. Time and rate were often confused.

c.ii.This was well answered.

c.iii.Very few candidates could relate rate information to deduce that C_4H_9Br was tertiary.

c.iv.The structural formula was generally gained by ECF.

c.v.Students did not have problems with the equation.

d. Mechanism with curly arrows was done very poorly, students confused S_N1 and S_N2 mechanisms, drew arrows that did not show clearly origin and end or did not draw any arrow at all.

Electrolysis is an important industrial process used to obtain very reactive elements from their common ores.

Molten magnesium chloride can be electrolysed using inert graphite electrodes at 800 °C.

a.i. Describe, using a labelled diagram, the essential components of this electrolytic cell. [2]

a.ii.Molten magnesium chloride can be electrolysed using inert graphite electrodes at 800 °C. [3]

Deduce the half-equations, including state symbols, for the reactions occurring at each electrode. (The melting points of $MgCl_2$ and Mg are 714 °C and 649 °C respectively.)

Positive electrode (anode):

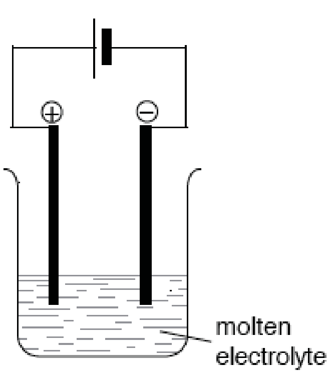
Negative electrode (cathode):

b. Outline why solid magnesium chloride does not conduct electricity. [1]

c. Aluminium can also be obtained by electrolysis. Suggest **one** reason why aluminium is often used instead of iron by engineers. [1]

Markscheme

a.i. *Cell showing:*



molten electrolyte/$MgCl_2(l)$, electrodes **and** battery/DC supply;

correct labelling of positive electrode/anode/+ **and** negative electrode/cathode/–;

a.ii. *Positive electrode (anode):*

$$2\mathrm{Cl^-(l)} \rightarrow \mathrm{Cl_2(g)} + 2\mathrm{e^-} / \mathrm{Cl^-(l)} \rightarrow \tfrac{1}{2}\mathrm{Cl_2(g)} + \mathrm{e^-};$$

Negative electrode (cathode):

$$\mathrm{Mg^{2+}(l)} + 2\mathrm{e^-} \rightarrow \mathrm{Mg(l)};$$

Accept e instead of e^-.

*Award **[1 max]** for correct half-equations given at the wrong electrode.*

Penalize use of reversible arrows once only.

correct state symbols in both equations;

b. ions are not free to move when solid / ions in rigid lattice / *OWTTE*;

c. aluminium/Al is less dense (compared to iron/Fe) / Al is more ductile or malleable/ aluminium forms a protective oxide layer / Al does not corrode / iron/Fe rusts /*OWTTE*;

Do not accept "Al is lighter" OR "less expensive" OR "Al can be recycled".

Examiners report

a.i. There were very few carefully drawn correct diagrams as well as too many diagrams showing half-cells. The importance of the solution being molten was not appreciated. The equations did pick up marks, but it was extremely rare for candidates to access the mark for the correct state symbols. Far too many associated electrical conductivity in molten compounds with mobile electrons. The awareness that mobile ions are responsible for conductivity was poorly understood. The difference between "lightness" and density is still confused.

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