Cambridge AS & A Level

CHEMISTRY

Paper 2

Topical Past Paper Questions

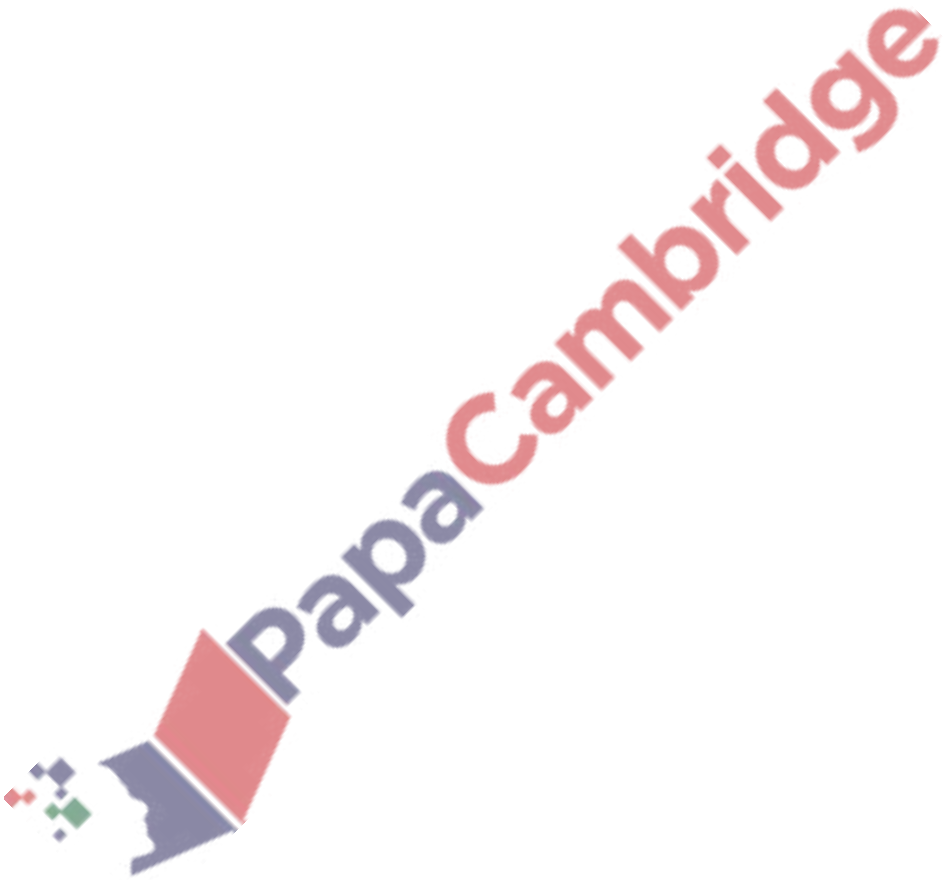
+ Answer Scheme

2015 - 2021

PapaCambridge

Chapter 15

Halogen derivatives



15.1 Halogenoalkanes

119. 9701_s21_qp_21 Q: 6

Propene, C_3H_6, reacts with H_2O in the presence of an acid catalyst to form an alcohol with molecular formula C_3H_8O.

(a) Name this type of reaction.

..... [1]

(b) Name the catalyst used and state the conditions needed for this reaction to occur.

catalyst .....

conditions .....

[2]

(c) Complete the table to show the numbers of sigma (σ) bonds and pi (π) bonds present in propene, C_3H_6, and C_3H_8O.

	σ	π
C_3H_6		
C_3H_8O		

[2]

(d) The reaction of propene, C_3H_6, with H_2O occurs in a two-step mechanism. In step 1 C_3H_6 reacts with the catalyst, H^+, to form a carbocation.

(i) Draw structures to identify the more stable and less stable carbocations which can form in step 1. Explain your answer.

more stable carbocation	**less** stable carbocation

explanation .....

.....

.....

.....

.....

[3]

(ii) Name the major organic product formed from the reaction of propene, C_3H_6, with H_2O.

..... [1]

(e) 2-bromopropane reacts to form propene, hydrogen bromide and water under certain conditions.

(i) Name this type of reaction.

..... [1]

(ii) Describe the reagents and conditions needed to favour this reaction.

reagents .....

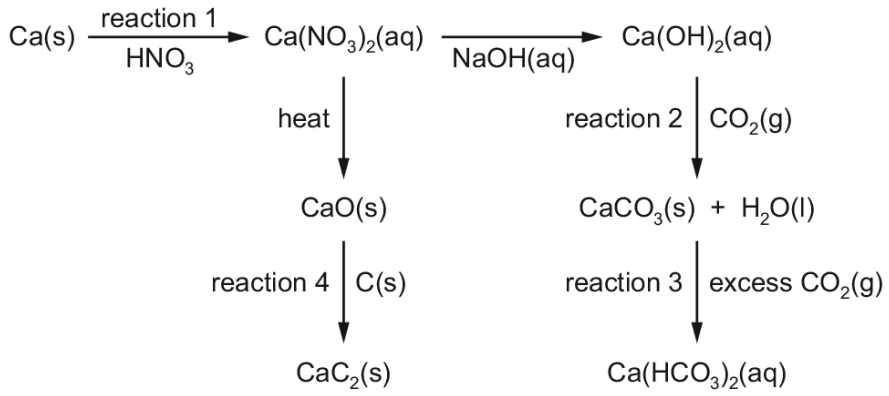
conditions .....

[2]

[Total: 12]

120. 9701_w21_qp_21 Q: 2

The reaction scheme shows some reactions of calcium.



(a) (i) Reaction 1 produces $Ca(NO_3)_2$ and one other product.

Identify the other product.

..... [1]

(ii) Construct an equation for the thermal decomposition of $Ca(NO_3)_2(s)$.

..... [1]

(iii) State the trend in the thermal stability of the Group 2 nitrates down the group.

..... [1]

(iv) In reaction 3, excess CO_2 is bubbled through water containing $CaCO_3$. A solution of $Ca(HCO_3)_2(aq)$ forms.

Construct an equation for reaction 3.

..... [1]

(b) Describe how $Ca(OH)_2$ is used in agriculture.

.....

..... [1]

(c) In reaction 4, calcium carbide, CaC_2, is formed from CaO.

CaC_2 contains the C_2^{2-} anion. Each carbon in C_2^{2-} is sp hybridised.

(i) Describe how sp hybridised orbitals are formed.

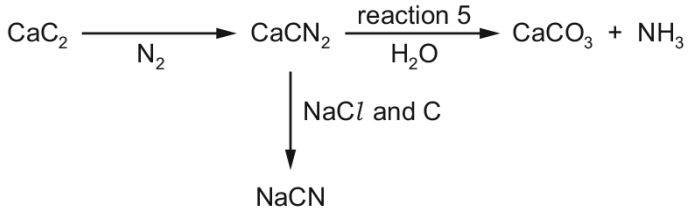
.....

..... [1]

(ii) Sketch a diagram to show how two sp hybrid orbitals can form a sigma (σ) bond.

[2]

(d) The flowchart shows some reactions of CaC_2.



(i) Reaction 5 can be used to prepare NH_3.

$$CaCN_2 + 3H_2O \rightarrow CaCO_3 + 2NH_3$$

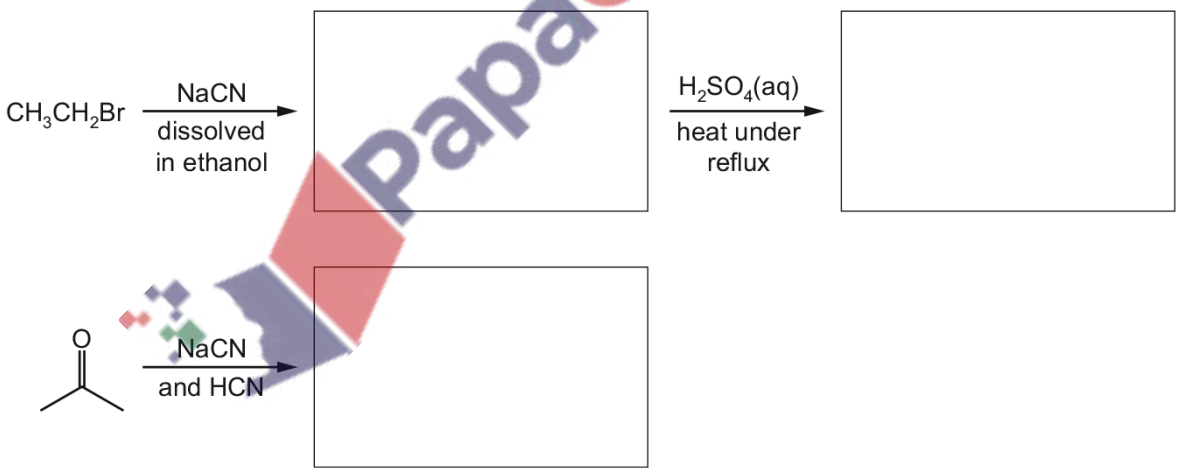
Calculate the minimum mass, in tonnes, of calcium cyanamide, $CaCN_2$, that is required to produce 1.50×10^6 tonnes of NH_3.

Show your working.

1 tonne = 1.00×10^6 g

minimum mass of $CaCN_2$ = ... tonnes
[2]

(ii) Draw the structure of the organic products formed in the following reactions.



[3]

[Total: 13]

121. 9701_s20_qp_22 Q: 4

(a) An unlabelled bottle contains a straight-chain halogenoalkane, **Q**. The molecular formula of **Q** is C_5H_{11}**X**, where **X** is a halogen; bromine, chlorine or iodine.

A test is carried out to identify the halogen present in **Q**.
A sample of **Q** is added to NaOH(aq) and warmed. Dilute nitric acid is then added followed by a few drops of aqueous silver nitrate. A cream precipitate is observed.

(i) Suggest the identity of **X**.

..... [1]

(ii) Write an ionic equation to describe the formation of the cream precipitate. Include state symbols.

..... [1]

(iii) Describe a further test which would confirm the identity of **X**.

test .....

expected result .....
[2]

(b) The reaction of **Q** with NaOH(aq) tends to proceed via an S_N2 mechanism.

(i) Suggest the structural formula of the straight-chain halogenoalkane **Q**.

[1]

(ii) Explain why the reaction tends to proceed via an S_N2 mechanism rather than an S_N1 mechanism.

.....

.....

..... [2]

(c) Two different halogenoalkanes, **P** and **R**, both with the molecular formula C_4H_9Cl, are separately dissolved in ethanol and heated under reflux with sodium hydroxide.

The major organic product of each of these reactions is methylpropene.

(i) Name the type of reaction occurring.

..... [1]

(ii) Write an equation, using molecular formulae, to represent the reaction occurring.

..... [1]

(iii) Draw the skeletal formula of methylpropene.

[1]

(iv) Give the names of **P** and **R**.

..... [2]

[Total: 12]

122. 9701_s19_qp_23 Q: 5

Halogenoalkanes react with a number of different reagents in nucleophilic substitution reactions.

(a) A sample of potassium cyanide dissolved in ethanol is added to a sample of 1-bromobutane, $CH_3(CH_2)_3Br$, and heated under reflux. A nucleophilic substitution reaction occurs and compound **A** is formed.

(i) Name compound **A**.

..... [1]

(ii) What is meant by the term *nucleophile*?

.....

..... [1]

(iii) Identify the nucleophile in this reaction.

..... [1]

(iv) Explain why this reaction is described as a substitution reaction.

.....

..... [1]

(b) State the reagent(s) and conditions needed for $CH_3(CH_2)_3Br$ to react to form $CH_3(CH_2)_3NH_2$.

reagent(s) .....

conditions .....

[2]

(c) Equal amounts of three different halogenoalkanes are added to three separate test-tubes. An equal amount of aqueous silver nitrate and ethanol is added to each test-tube. The time taken for a precipitate to form is recorded for each halogenoalkane.

halogenoalkane	time taken for precipitate to form / s
$(CH_3)_3CCl$	460
$(CH_3)_3CBr$	190
$(CH_3)_3CI$	40

(i) Describe and explain the trend in reactivity of the different halogenoalkanes shown in this experiment.

.....

.....

..... [2]

(ii) All three halogenoalkanes tend to react via the S_N1 mechanism.

Explain why the S_N1 mechanism is favoured.

.....

.....

.....

..... [3]

(iii) Identify a halogenoalkane which tends to react with an aqueous solution of silver nitrate and ethanol via the S_N2 mechanism.

..... [1]

[Total: 12]

123. 9701_s19_qp_23 Q: 6

(a) Three alkenes, **X**, **Y** and **Z**, have the same molecular formula.

(i) Describe what is seen when aqueous bromine is added to **X**.

..... [1]

X, **Y** and **Z** are reacted separately with hot, concentrated, acidified manganate(VII) ions until no further reaction occurs. The carbon-containing products are shown in the table.

alkene	carbon-containing products
X	CO_2 + $(CH_3)_2CO$
Y	CO_2 + $CH_3CH_2CO_2H$
Z	CH_3CO_2H

(ii) Draw the structures of **X**, **Y** and **Z**.

X **Y** **Z**

[3]

(iii) Deduce the molecular formula of **X**, **Y** and **Z**.

..... [1]

(b) The structures of **V** and **W** are shown.

$CH_3(CH_2)_2CH_2OH$ **V** $(CH_3)_3COH$ **W**

(i) Name the class of compound that **V** and **W** each belong to.

V .....

W .....

[2]

(ii) **V** and **W** both react with sodium metal.

Write an equation for the reaction of **V** with sodium metal.

..... [1]

(iii) Name a reagent used to distinguish **V** from **W**. Describe any observations.

reagent .....

observations with **V** .....

observations with **W** .....

[3]

[Total: 11]

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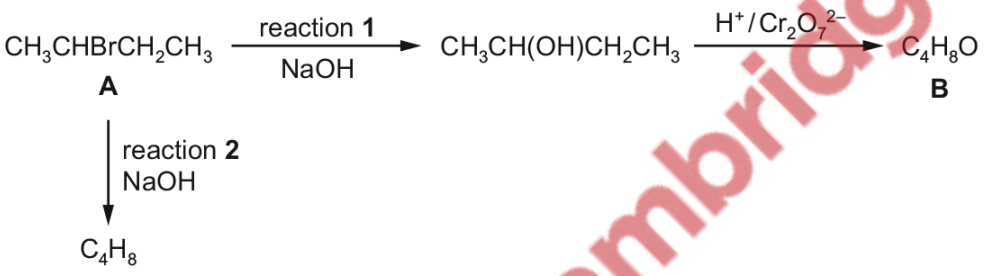
124. 9701_s18_qp_23 Q: 4

A is $CH_3CHBrCH_2CH_3$.

(a) Some reactions of **A** are shown.



(i) Name **A**.

..... [1]

(ii) Name the class of compound to which **B** belongs.

..... [1]

(b) There are three structural isomers of **A**.

Draw the structures of these three isomers of **A**.

[2]

(c) Reaction **1** occurs by two different mechanisms at the same time.

These mechanisms are referred to as S_N1 and S_N2.

(i) State what the letters 'S' and 'N' represent in the abbreviation S_N1.

S .....

N .....

[1]

(ii) Complete the S_N1 mechanism for reaction **1**.

Include the structure of the intermediate and all necessary charges, dipoles, lone pairs and curly arrows.

[3]

(d) The S_N1 mechanism for reaction **1** is repeated using $CH_3CHClCH_2CH_3$ or $CH_3CHICH_2CH_3$ in place of the $CH_3CHBrCH_2CH_3$.

State and explain how the rates of these two reactions will compare with the rate of the original reaction using $CH_3CHBrCH_2CH_3$.

.....

.....

.....

.....

..... [3]

(e) Reaction **2** uses the same reagent as reaction **1**, but under different conditions.

State **two** differences in the conditions needed to ensure that reaction **2** is more likely to take place than reaction **1** when this reagent is added.

.....

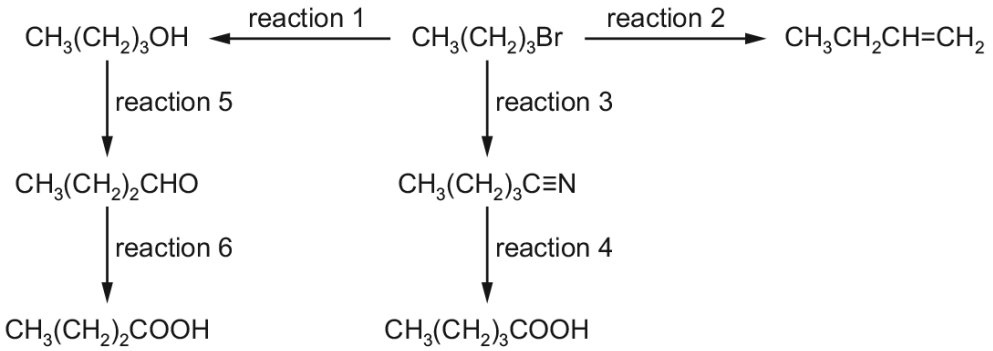
.....

..... [2]

[Total: 13]

125. 9701_w17_qp_21 Q: 3

Some reactions based on 1-bromobutane, $CH_3(CH_2)_3Br$, are shown.



(a) For each of the reactions state the reagent(s), the particular conditions required, if any, and the type of reaction.

For the type of reaction choose from the list.
Each type may be used once, more than once or not at all.
Each reaction may be described by more than one type.

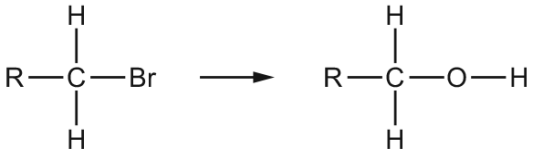
elimination hydrolysis substitution

oxidation addition condensation

reaction	reagent(s) and conditions	type(s) of reaction
1		
2		
3		
4		
5		
6		

[6]

(b) Complete the diagram to show the S_N2 mechanism of reaction 1. R represents the $CH_3(CH_2)_2$ group.
Include all necessary charges, dipoles, lone pairs and curly arrows.



[2]

(c) 2-bromo-2-methylpropane is a tertiary halogenoalkane that is a structural isomer of 1-bromobutane.

(i) Define the term *structural isomer* and name the three different types of structural isomerism.

definition .....

.....

.....

.....

types of structural isomerism

1 .....

2 .....

3 .....

[4]

(ii) 2-bromo-2-methylpropane is treated with the same reagents as in reaction 1.
Methylpropan-2-ol is formed.

Identify the mechanism for this reaction.
Explain why this reaction proceeds via a different mechanism from that of reaction 1.

mechanism .....

explanation .....

.....

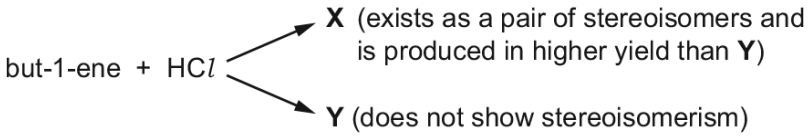
.....

.....

.....

[3]

(d) The product of reaction 2, but-1-ene, does **not** show stereoisomerism. However, but-1-ene reacts with HC*l* to form a mixture of structural isomers **X** and **Y**.



(i) Explain the meaning of the term *stereoisomers*.

.....

.....

..... [2]

(ii) Give **two** reasons why but-1-ene does **not** show stereoisomerism.

.....

.....

..... [2]

(iii) Name **X** and **Y**.

X .....

Y .....

[2]

(iv) Name the type of stereoisomerism shown by **X**.

..... [1]

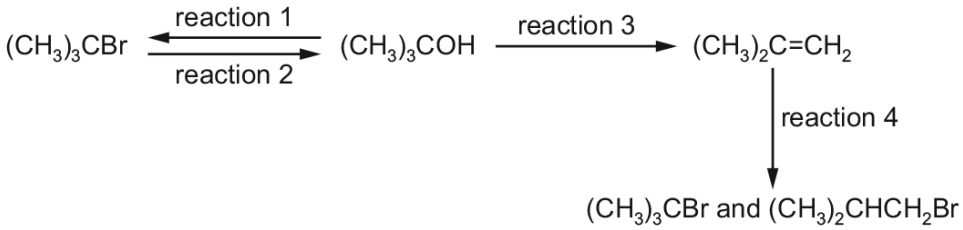
(v) Use the conventional representation to draw the two stereoisomers of **X**.

[2]

[Total: 24]

126. 9701_w17_qp_22 Q: 4

Some reactions are shown, based on methylpropan-2-ol, $(CH_3)_3COH$.



(a) For each of the reactions state the reagent(s), the particular conditions required, if any, and the type of reaction.

For the type of reaction choose from the list.
Each type may be used once, more than once or not at all.
Each reaction may be described by one or more than one type.

hydrolysis dehydration substitution

oxidation addition condensation

reaction	reagent(s) and conditions	type(s) of reaction
1		
2		
3		
4		

[5]

(b) Draw a diagram to show the S_N1 mechanism of reaction 2.
Include all necessary charges, dipoles, lone pairs and curly arrows.

[3]

(c) 1-bromobutane is a structural isomer of the product of reaction 1.

(i) Define the term *structural isomer* and name the three different types of structural isomerism.

definition .....

.....

.....

.....

types of structural isomerism

1 .....

2 .....

3 .....

[4]

(ii) 1-bromobutane is treated with the same reagents as in reaction 2. Butan-1-ol is formed.

Identify the mechanism of this reaction.
Explain why this reaction proceeds via a different mechanism from that of reaction 2.

mechanism .....

explanation .....

.....

.....

.....

.....

[3]

(d) The product of reaction 3, methylpropene, does **not** show stereoisomerism.

(i) Give **two** reasons why methylpropene does **not** show stereoisomerism.

.....

.....

..... [2]

(ii) Methylpropene can be polymerised to form a poly(alkene).

State the type of polymerisation and draw the repeat unit of the polymer formed from methylpropene.

type of polymerisation .....

repeat unit

[3]

(iii) State the difficulty associated with the disposal of poly(alkenes).

.....

..... [1]

(e) Name the two products of reaction 4.

name of $(CH_3)_3CBr$ .....

name of $(CH_3)_2CHCH_2Br$ .....

[2]

[Total: 23]

127. 9701_w16_qp_22 Q: 4

In each section of this question the structural formula of an organic compound is shown. For each compound answer the questions about it.

(a) $CH_3CH_2CHBrCH_3$

(i) Name this compound.

..... [1]

(ii) This compound shows stereoisomerism.

Draw the **two** stereoisomers in the conventional way.

[2]

(iii) Give the structures of **three** other structural isomers of C_4H_9Br.

[3]

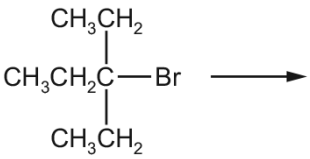
(b) $(C_2H_5)_3CBr$

(i) Name this compound.

..... [1]

(ii) $(C_2H_5)_3CBr$ reacts with aqueous OH^-.

Complete the mechanism for this reaction including all necessary curly arrows, charges, partial charges and lone pairs.



[3]

(iii) What *type of mechanism* occurs in **(ii)**?

..... [1]

(c) $CH_3CH_2CH_2CHBrCH_3$

(i) Give the reagents and conditions necessary for the conversion of this compound into a mixture of alkenes.

.....

..... [2]

(ii) Give the name of the mechanism for the conversion in **(i)**.

..... [1]

(iii) Draw the skeletal formulae of the three alkenes produced by the conversion in **(i)**.

[3]

[Total: 17]

15.2 Relative strength of the C–Hal bond

128. 9701_s21_qp_22 Q: 3

A large excess of 2-bromo-2-methylpropane is added to 0.0010 mol of NaOH(aq), which contains a few drops of phenolphthalein indicator. A stopwatch is started as soon as the substances are mixed. The time taken for the pink colour to disappear is recorded.

The experiment is repeated at different temperatures, keeping all concentrations and volumes of reagents constant.

temperature /°C	time taken for pink colour to disappear/s
20	300
25	65
35	20

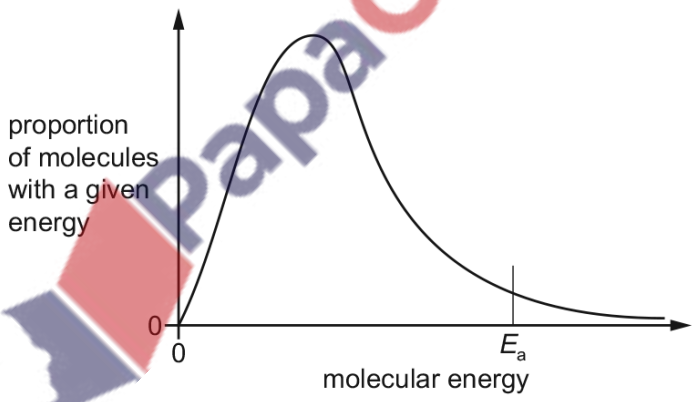
(a) Explain what is meant by the term *rate of reaction*.

.....

..... [1]

(b) The graph shows the energy distribution of molecules in a sample of 2-bromo-2-methylpropane at 25 °C.

E_a represents the activation energy for the reaction.



(i) Label the graph to show the proportion of 2-bromo-2-methylpropane molecules which have sufficient energy to react. [1]

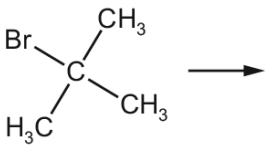
(ii) Use the same axes to sketch the distribution of energies of molecules in a sample of 2-bromo-2-methylpropane at 50 °C. [2]

(iii) State the effect of an increase in temperature on E_a for this reaction.

..... [1]

(c) **(i)** Draw the mechanism to show the reaction of 2-bromo-2-methylpropane with OH^-(aq). Show the intermediate formed in this reaction.

Include all charges, partial charges, lone pairs and curly arrows as appropriate.



[3]

(ii) Name the mechanism for this reaction.

..... [1]

(d) The original experiment is repeated at 25 °C with 2-chloro-2-methylpropane instead of 2-bromo-2-methylpropane. All other variables remain constant.

Predict the effect of using 2-chloro-2-methylpropane compared to 2-bromo-2-methylpropane on the time taken for the pink colour to disappear. Explain your answer.

.....

.....

..... [2]

[Total: 11]