

Week 27

A-Level Chemistry

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

Topic 15 quiz	2
Exercise sheet 15.1	5
Past-paper questions 15.1	10

A-Level Chemistry

Name: _____ Score: _____

1. A halogenoalkane is:
 - ☐ an alkane with one or more halogen atoms in place of hydrogen (a C-X bond)
 - ☐ an alkene with a C=C bond
 - ☐ an alcohol
 - ☐ a carboxylic acid
2. Heating a halogenoalkane with NaOH dissolved in ethanol gives:
 - ☐ an alkene (by elimination)
 - ☐ an alcohol (by substitution)
 - ☐ an alkane
 - ☐ a nitrile
3. A tertiary halogenoalkane has the halogen on a carbon joined to:
 - ☐ three other carbons
 - ☐ one other carbon
 - ☐ two other carbons
 - ☐ no other carbons
4. The SN1 mechanism:
 - ☐ has two steps, going through a carbocation; the rate depends only on the halogenoalkane
 - ☐ is a single step through a transition state
 - ☐ never forms a carbocation
 - ☐ depends on the nucleophile only
5. Warming a halogenoalkane with aqueous NaOH produces:
 - ☐ an alcohol
 - ☐ an alkene
 - ☐ an alkane
 - ☐ a nitrile
6. An SN1 mechanism goes via a carbocation intermediate.
 - ☐ True ☐ False

7. In nucleophilic substitution, OH^- attacks the $\delta+$ carbon and the halogen leaves as a halide ion.
- ☐ True ☐ False
8. The $\text{S}_{\text{N}}2$ mechanism:
- ☐ is one step through a transition state; the rate depends on both reactants
- ☐ has two steps via a carbocation
- ☐ is favoured by tertiary halogenoalkanes
- ☐ depends only on the halogenoalkane
9. Reaction with KCN in ethanol gives a nitrile, which is useful because it:
- ☐ adds one carbon to the chain
- ☐ removes a carbon
- ☐ forms an alkene
- ☐ forms an amine
10. Which halogenoalkane reacts fastest?
- ☐ an iodoalkane (C–I is the weakest bond)
- ☐ a chloroalkane
- ☐ a fluoroalkane
- ☐ they all react at the same rate

A-Level Chemistry

1. an alkane with one or more halogen atoms in place of hydrogen (a C–X bond)

A halogenoalkane has a polar C–X bond, which is the reactive site.

2. an alkene (by elimination)

NaOH in ethanol with heat favours elimination of HX to form an alkene; NaOH in water favours substitution.

3. three other carbons

Primary = 1 carbon attached, secondary = 2, tertiary = 3, on the carbon bearing the halogen.

4. has two steps, going through a carbocation; the rate depends only on the halogenoalkane

SN1: C–X breaks first to a carbocation, then the nucleophile attacks; tertiary halogenoalkanes favour it.

5. an alcohol

NaOH(aq) substitutes the halogen for –OH, giving an alcohol.

6. True

SN2 is a one-step concerted mechanism.

7. True

The C–X bond is polar, so the carbon is $\delta+$ — exactly where an electron-pair donor attacks.

8. is one step through a transition state; the rate depends on both reactants

SN2 is a single concerted step; primary halogenoalkanes favour it and its rate depends on both species.

9. adds one carbon to the chain

The CN group adds a carbon, lengthening the chain; NH₃ instead gives an amine.

10. an iodoalkane (C–I is the weakest bond)

The weaker the C–X bond, the faster the reaction, so C–I (weakest) reacts fastest and C–Cl slowest.

15.1 Halogenoalkanes

Name: _____ Class: _____ Date: _____

Total: 12 marks

KEY WORDS elimination 消去 • secondary 仲 • tertiary 叔 • nucleophilic substitution 亲核取代 • primary 伯

Objective

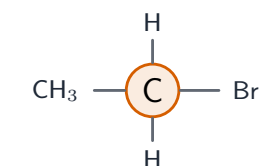
Build the skills to answer exam questions on **halogenoalkanes** 卤代烷 — **nucleophilic substitution** 亲核取代, **elimination** 消去, the **S_N1/S_N2** mechanisms, and the trend in reactivity.

You must be able to:

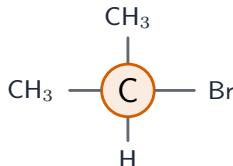
- classify halogenoalkanes and describe their nucleophilic substitution reactions
- describe the elimination reaction and the S_N1 and S_N2 mechanisms
- explain the different reactivities in terms of C–X bond strength

1 Worked examples

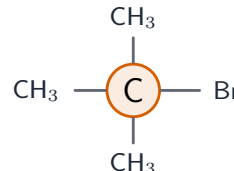
■ Classes and nucleophilic substitution



primary
1 C on the C–Br carbon



secondary
2 C

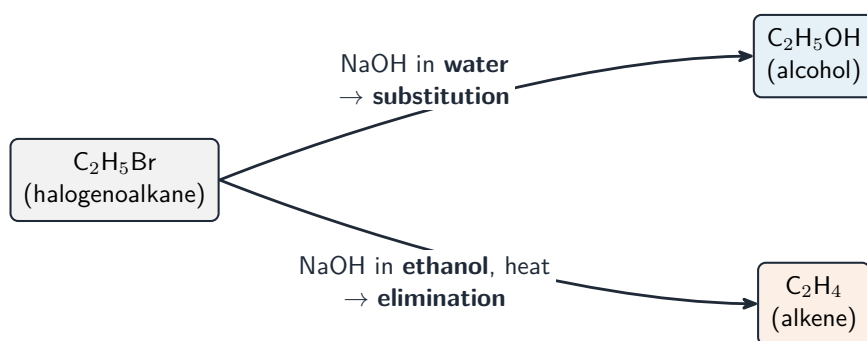


tertiary
3 C

Primary/secondary/tertiary = 1/2/3 carbons joined to the carbon bearing the halogen

The polar C–X carbon is attacked by **nucleophiles**: NaOH(aq) → alcohol; KCN/ethanol → nitrile (+1 C); NH₃/ethanol/pressure → amine. **Test the halogen** with AgNO₃ in ethanol (white AgCl, cream AgBr, yellow AgI).

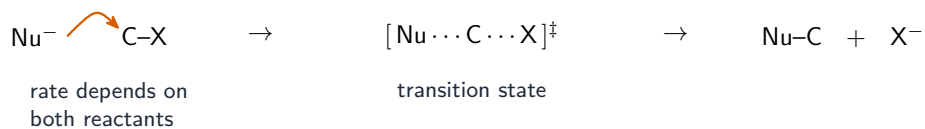
■ Substitution vs elimination



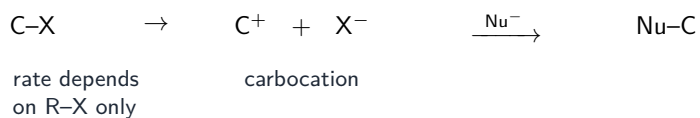
$\text{NaOH(aq)} \rightarrow \text{substitution (alcohol)}$; $\text{NaOH in ethanol} + \text{heat} \rightarrow \text{elimination (alkene)}$

■ $\text{S}_{\text{N}}1$ and $\text{S}_{\text{N}}2$

$\text{S}_{\text{N}}2$: one step



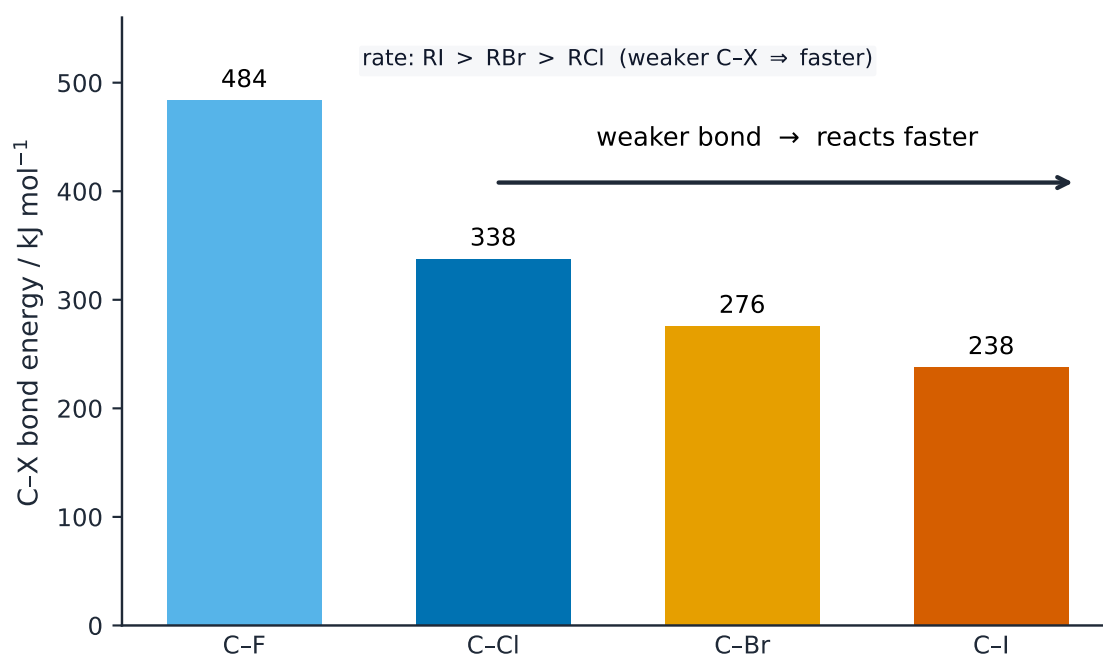
$\text{S}_{\text{N}}1$: two steps



$\text{S}_{\text{N}}2$: one step (rate depends on both). $\text{S}_{\text{N}}1$: via a carbocation (rate depends only on the halogenoalkane)

Primary $\rightarrow$ mostly $\text{S}_{\text{N}}2$; tertiary $\rightarrow$ mostly $\text{S}_{\text{N}}1$ (stable carbocation).

■ Reactivity



The weaker the C-X bond, the faster — iodoalkanes react fastest, chloroalkanes slowest

2 Practice

2.1 State the reagent and condition to convert a halogenoalkane into an alcohol. [2]

2.2 Name the organic product when a halogenoalkane reacts with KCN in ethanol. [1]

3 Exam-style questions

3.1 Which conditions favour **elimination** of a halogenoalkane to an alkene? [1]

- A NaOH in water, warm
- B NaOH in ethanol, heat
- C aqueous silver nitrate
- D KCN in ethanol

3.2 Which halogenoalkane reacts **fastest** with aqueous silver nitrate? [1]

- A 1-chlorobutane

- **B** 1-bromobutane
 - **C** 1-iodobutane
 - **D** they react at the same rate
-

3.3 (a) Describe the S_N2 mechanism for the reaction of bromoethane with hydroxide ions. [3]

(b) Explain why tertiary halogenoalkanes tend to react by the S_N1 mechanism. [2]

3.4 Explain why iodoalkanes are more reactive than chloroalkanes in substitution reactions. [2]

Solutions

2.1 aqueous sodium hydroxide, NaOH(aq); and heat.

2.2 a nitrile.

3.1 B. NaOH in ethanol with heat favours elimination.

3.2 C. The C–I bond is weakest, so the iodoalkane reacts fastest.

3.3 (a) the OH[−] nucleophile attacks the $\delta+$ carbon (curly arrow from the lone pair); at the same time the C–Br bond breaks, with both electrons going to Br; passing through a transition state with both half-bonded, giving ethanol and Br[−].

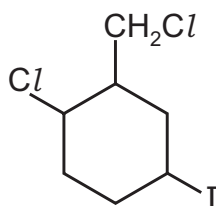
(b) the tertiary carbocation is stabilised by three electron-pushing alkyl groups, so the C–X bond breaks first to form it (S_N1).

3.4 the C–I bond is weaker (lower bond energy) than C–Cl, so it breaks more easily, making the substitution faster.

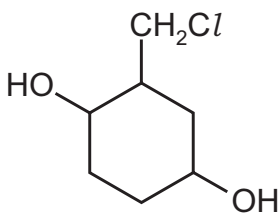
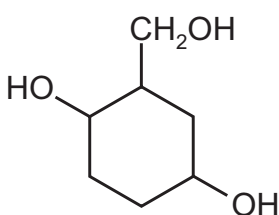
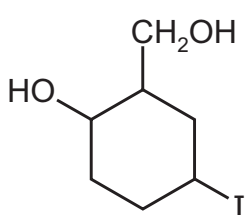
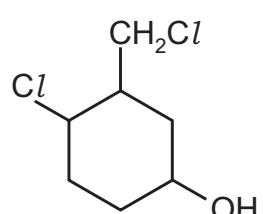
- 30** Compound X, $C_7H_{11}ICl_2$, is dissolved in ethanol and the solution mixed with warm aqueous silver nitrate.

A precipitate is seen immediately.

compound X



What is the colour of this precipitate and what is the structural formula of the **first** organic product?

	colour of the precipitate	structural formula of the first organic product
A	cream	
B	cream	
C	white	
D	yellow	

- 31** 1,4-dibromobutane reacts with an excess of ethanolic sodium hydroxide until no further reaction takes place.

What is the relative formula mass of the major organic product?

- A** 54 **B** 56 **C** 74 **D** 90

30 Which reaction mixture produces a nitrile?

- A** halogenoalkane with KCN in ethanol
- B** halogenoalkane with NH_3 in ethanol
- C** ketone with 2,4-DNPH
- D** carboxylic acid with NH_3 in water

31 Which reaction is classified as $\text{S}_{\text{N}}1$?

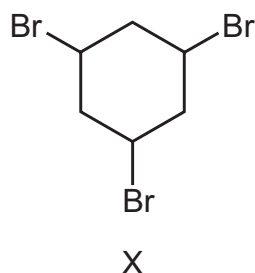
- A** the reaction of 1-chloropropane with ammonia in ethanol
- B** the reaction of 1-chloropropane with potassium hydroxide in ethanol
- C** the reaction of 2-chloro-2-methylpropane with potassium cyanide in ethanol
- D** the reaction of 2-chloro-2-methylpropane with potassium hydroxide in ethanol

31 2-chloropropane and 2-bromopropane react separately with aqueous NaOH.

Which row is correct?

	comparison of rates of reaction	explanation of the difference in reaction rates
A	2-chloropropane reacts faster	chlorine is more reactive than bromine
B	2-chloropropane reacts faster	the C–Cl bond is more polar than the C–Br bond
C	2-bromopropane reacts faster	the first ionisation energy of bromine is lower than chlorine's
D	2-bromopropane reacts faster	the C–Br bond is weaker than the C–Cl bond

32 The diagram shows the structure of compound X.



X undergoes hydrolysis to form product Y in which all of the bromine atoms are replaced by hydroxyl groups. Product Z is formed by oxidation of Y.

Two suggestions are listed.

- 1 Y is a secondary alcohol.
- 2 Z is a ketone.

Which suggestions are correct?

- A** both 1 and 2
- B** 1 only
- C** 2 only
- D** neither 1 nor 2

38 When bromoethane, $\text{C}_2\text{H}_5\text{Br}$, is heated with NaOH in ethanol, which type of reaction occurs?

- A** electrophilic substitution
- B** elimination
- C** nucleophilic substitution, mainly via an $\text{S}_{\text{N}}1$ mechanism
- D** nucleophilic substitution, mainly via an $\text{S}_{\text{N}}2$ mechanism

- 4 Fig. 4.1 shows how propane, C_3H_8 , can be converted to propanoic acid, CH_3CH_2COOH .

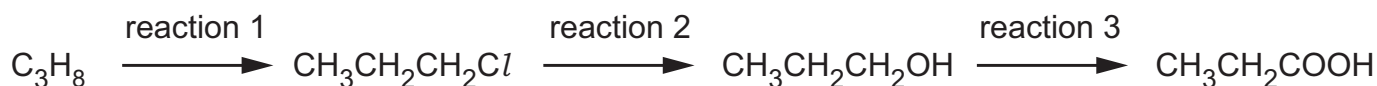
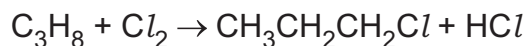


Fig. 4.1

- (a) Reaction 1 in Fig. 4.1 takes place in the presence of sunlight.



The reaction takes place via initiation, propagation and termination steps.

- (i) Name the mechanism shown by reaction 1.

..... [1]

- (ii) Complete the mechanism for reaction 1.

Construct equations to describe the steps of the mechanism.



propagation 1

propagation 2

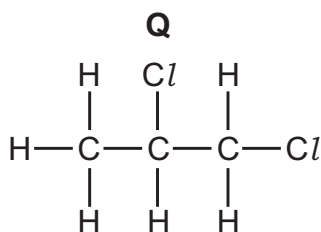
termination $\rightarrow CH_3CH_2CH_2Cl$
[3]

- (iii) Reaction 1 is initiated by the bond fission of Cl_2 .

State the type of bond fission shown in the initiation step.

..... [1]

- (iv) Compound **Q** is a by-product of reaction 1.



Name **Q**.

..... [1]

- (v) The molecular formula of **Q** is $\text{C}_3\text{H}_6\text{Cl}_2$.

Identify the types of structural isomerism and stereoisomerism that a molecule with molecular formula $\text{C}_3\text{H}_6\text{Cl}_2$ can show.

type of structural isomerism

type of stereoisomerism

[2]

- (b) State the reagent and solvent required for reaction 2.

..... [1]

- (c) Reaction 3 takes place when $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ is heated under reflux with acidified potassium dichromate(VI) solution.

- (i) State the colour change that takes place in the reaction mixture.

..... [1]

- (ii) Construct an equation to represent reaction 3. Use [O] to represent an atom of oxygen from the oxidising agent.

..... [1]

(d) $\text{CH}_3\text{CH}_2\text{COOH}$ reacts with an unsaturated alcohol **R** to form unsaturated ester **S**.

(i) State the **type** of reaction that forms **S**.

..... [1]

(ii) The infrared spectrum of **S** is shown in Fig. 4.2.

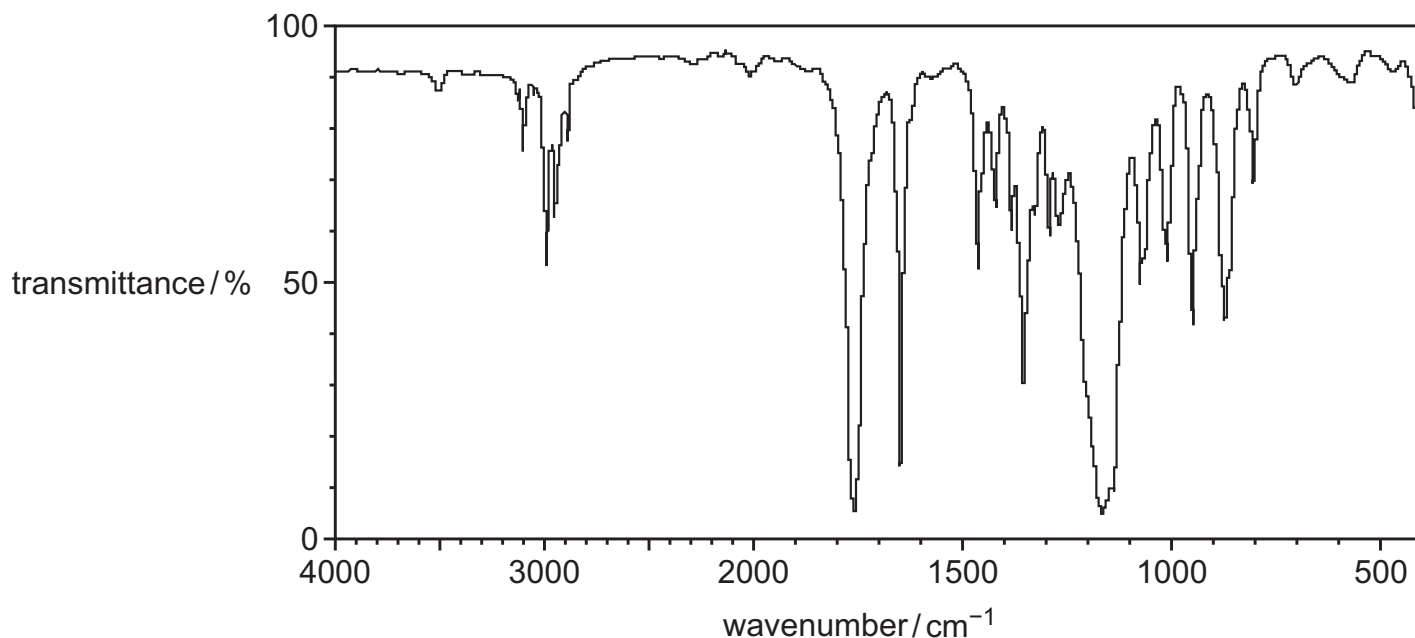


Fig. 4.2

Three absorptions in the infrared spectrum in Fig. 4.2 confirm that **S** is an ester and is unsaturated.

- Write **1**, **2** or **3** on Fig. 4.2 against each of these three absorptions.
- Complete Table 4.1 to show which bond is responsible for each absorption that you have identified in Fig. 4.2.

Table 4.1

absorption	1	2	3
bond responsible			

[3]

Table 4.2

bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers)/cm ⁻¹
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

(iii) The mass spectrum of **S** shows the following peaks.

Table 4.3

peak	relative abundance
M ⁺	4.7
[M+1] ⁺	0.31

Use Table 4.3 to calculate the number of carbon atoms in **S**.

number of carbon atoms in **S** = [1]

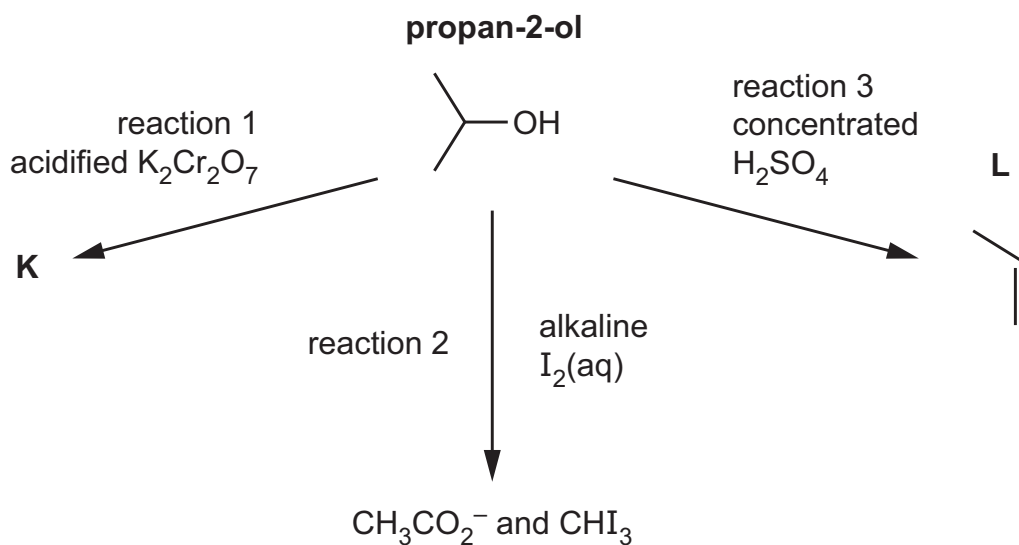
[Total: 16]

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

- 3 Propan-2-ol, $(\text{CH}_3)_2\text{CHOH}$, is sometimes added to fuel to help it burn.

Fig. 3.1 shows some reactions of propan-2-ol.



- (a) (i) Draw the structure of organic compound **K**.

[1]

- (ii) State an observation you would make in reaction 2.

..... [1]

- (iii) State the type of reaction that is shown in reaction 3.

..... [1]

- (iv) Complete Fig. 3.2 to show the pi (π) bond in **L** that is formed from orbital overlap.

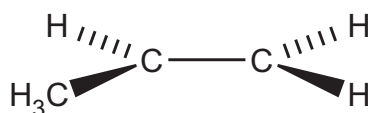


Fig. 3.2

[1]

- (b) Propan-2-ol reacts with sodium to produce $(\text{CH}_3)_2\text{CH-O}^-$ anions.

These anions react with 2-bromopropane to form compound **N**, as shown in Fig. 3.3.

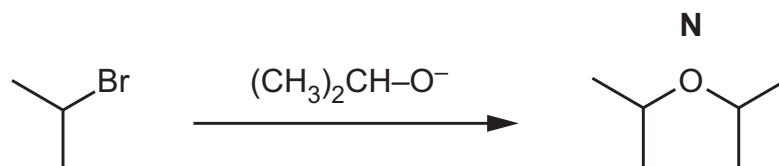


Fig. 3.3

- (i) Write an equation for the reaction of propan-2-ol with sodium.

..... [1]

- (ii) The reaction of 2-bromopropane with $(\text{CH}_3)_2\text{CH-O}^-$ anions follows an $\text{S}_{\text{N}}1$ mechanism.

Complete Fig. 3.4 to show this mechanism. Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.



Fig. 3.4

[3]

- (iii) Suggest how the rate of the $\text{S}_{\text{N}}1$ reaction would change, if at all, if 2-chloropropane were used instead of 2-bromopropane.

Explain your answer.

.....
.....
..... [2]

- (iv) **N** is also added to petrol to make it burn more smoothly.

Construct an equation for the complete combustion of **N**, $\text{C}_6\text{H}_{14}\text{O}$.

$\text{C}_6\text{H}_{14}\text{O}$ [1]

[Total: 11]