Week 23

A-Level Chemistry

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

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 SN2 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

15. Halogen compounds

Answers · 答案

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; NH_3 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.

A-LEVEL CHEMISTRY • EXERCISE SHEET

15.1 Halogenoalkanes

Name: _____ Class: _____ Date: _____ **Total: 12 marks**

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

Objective

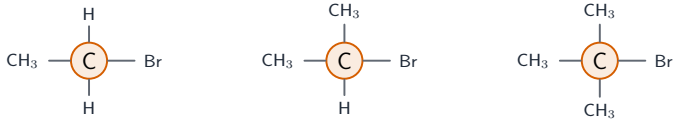
Build the skills to answer exam questions on **halogenoalkanes** 卤代烷 — **nucleophilic substitution** 亲核取代, **elimination** 消去, the **S_N1/S_N2** mechanisms, and the trend in reactivity.

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

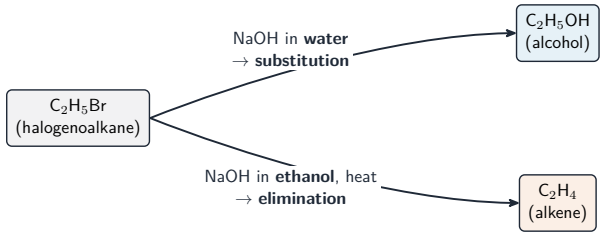
secondary
2 C

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); NH_3/ethanol/pressure → amine. **Test the halogen** with $AgNO_3$ in ethanol (white AgCl, cream AgBr, yellow AgI).

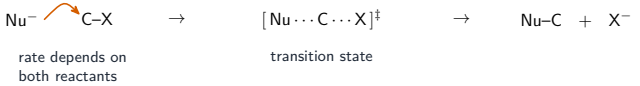
Substitution vs elimination



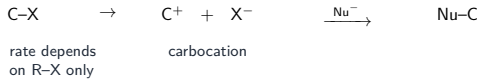
NaOH(aq) → substitution (alcohol); NaOH in ethanol + heat → elimination (alkene)

S_N1 and S_N2

S_N2: one step



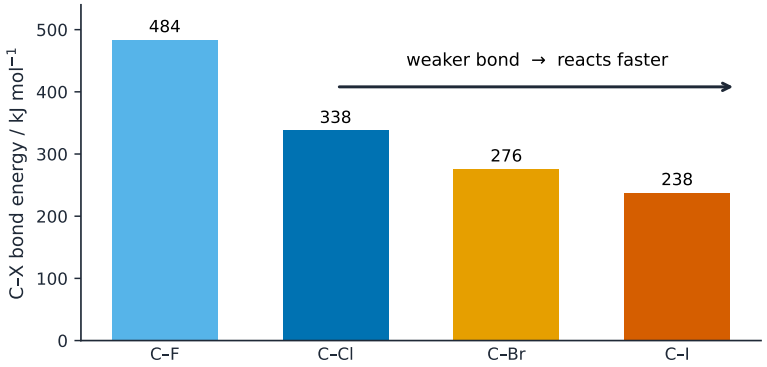
S_N1: two steps



S_N2: one step (rate depends on both). S_N1: via a carbocation (rate depends only on the halogenoalkane)

Primary → mostly S_N2; tertiary → mostly S_N1 (stable carbocation).

Reactivity



rate: RI > RBr > RCl (weaker C–X ⇒ faster)

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.

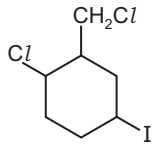
3.3 (a) the OH^- nucleophile attacks the $\delta+$ carbon (curly arrow from the lone pair); at the same time the C–Br bond breaks, with both electrons going to Br; passing through a transition state with both half-bonded, giving ethanol and Br^-.
(b) the tertiary carbocation is stabilised by three electron-pushing 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.

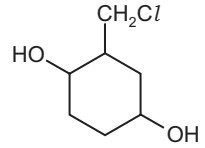
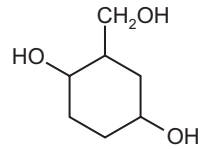
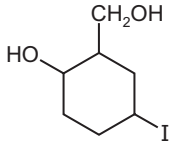
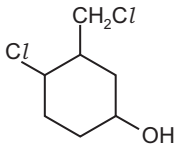
30 Compound X, $C_7H_{11}IC\mathit{l}_2$, is dissolved in ethanol and the solution mixed with warm aqueous silver nitrate.

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 S_N1?

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

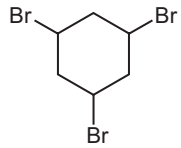
D the reaction of 2-chloro-2-methylpropane with potassium hydroxide in ethanol

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–C*l* 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–C*l* bond

32 The diagram shows the structure of compound X.



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, C_2H_5Br, is heated with NaOH in ethanol, which type of reaction occurs?

A electrophilic substitution

B elimination

C nucleophilic substitution, mainly via an S_N1 mechanism

D nucleophilic substitution, mainly via an S_N2 mechanism

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

$$C_3H_8 \xrightarrow{\text{reaction 1}} CH_3CH_2CH_2Cl \xrightarrow{\text{reaction 2}} CH_3CH_2CH_2OH \xrightarrow{\text{reaction 3}} CH_3CH_2COOH$$

Fig. 4.1

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

$$C_3H_8 + Cl_2 \rightarrow CH_3CH_2CH_2Cl + HCl$$

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.

initiation $Cl_2 \rightarrow 2Cl\bullet$

propagation 1 .....

propagation 2 .....

termination ..... $\rightarrow CH_3CH_2CH_2Cl$ [3]

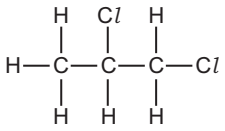
(iii) Reaction 1 is initiated by the bond fission of Cl_2.

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

..... [1]

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

Q



Name **Q**.

..... [1]

(v) The molecular formula of **Q** is $C_3H_6Cl_2$.

Identify the types of structural isomerism and stereoisomerism that a molecule with molecular formula $C_3H_6Cl_2$ 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 $CH_3CH_2CH_2OH$ 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) CH_3CH_2COOH 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.

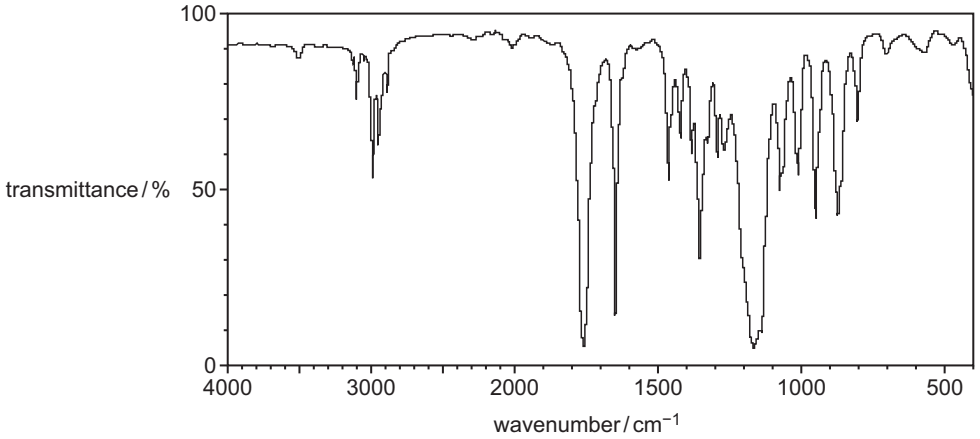


Fig. 4.2

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	$c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$)

The Periodic Table of Elements

Group 1	2												13	14	15	16	17	18
								1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0												5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3												13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

Key

atomic number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

3 Propan-2-ol, $(CH_3)_2CHOH$, is sometimes added to fuel to help it burn.

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

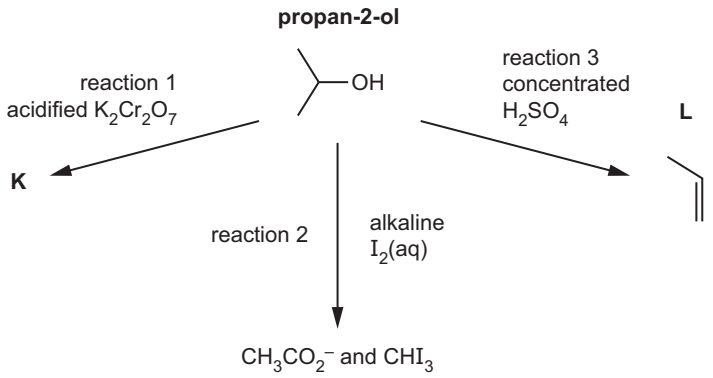


Fig. 3.1

(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.

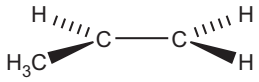


Fig. 3.2

[1]

(b) Propan-2-ol reacts with sodium to produce $(CH_3)_2CH–O^-$ anions.

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

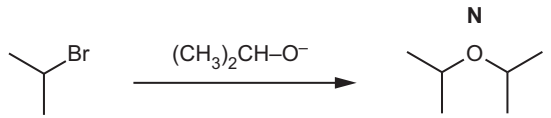


Fig. 3.3

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

..... [1]

(ii) The reaction of 2-bromopropane with $(CH_3)_2CH–O^-$ anions follows an S_N1 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 S_N1 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**, $C_6H_{14}O$.

$C_6H_{14}O$ ..... [1]

[Total: 11]