Past-paper walk-through

Halogenoalkanes ▪ 15.1

eXercise

Questions in this set

- 9701/11 N25 Q30 ▪ 1 mark
- 9701/11 N25 Q31 ▪ 1 mark
- 9701/12 N25 Q30 ▪ 1 mark
- 9701/12 N25 Q31 ▪ 1 mark
- 9701/14 N25 Q31 ▪ 1 mark
- 9701/14 N25 Q32 ▪ 1 mark
- 9701/14 N25 Q38 ▪ 1 mark
- 9701/22 N25 Q4 ▪ 16 marks
- 9701/24 N25 Q3 ▪ 11 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

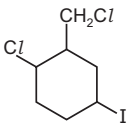
Question 30

9701/11 N25 ▪ Q30 ▪ 1 mark

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.

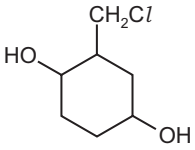
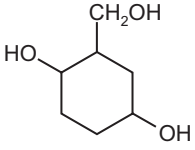
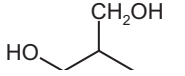
compound X



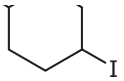
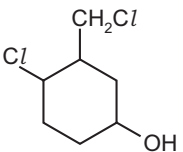
What is the colour of this precipitate and what is the structural formula of the **first** organic product?

	colour of	structural formula of

Question 30

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

Question 30

C	white	
D	yellow	

Solution 30

Answer: **D**

Why

- The C–I bond is the weakest carbon–halogen bond, so it hydrolyses first.
- Silver iodide is a *yellow* precipitate (AgCl is white and AgBr cream).
- So the first organic product has the iodine replaced by OH, with both chlorines still in place.

Question 31

9701/11 N25 ▪ Q31 ▪ 1 mark

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

Solution 31

Answer: **A**

Why

- Ethanolic NaOH causes elimination rather than substitution.
- With a bromine at each end both eliminate, giving buta-1,3-diene, C_4H_6.
- $M_r = 4(12.0) + 6(1.0) = 54$.

Question 30

9701/12 N25 ▪ Q30 ▪ 1 mark

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

Solution 30

Answer: **A**

Why

- KCN in ethanol substitutes CN for the halogen, giving a nitrile.
- Ammonia in ethanol gives an amine instead.
- 2,4-DNPH is a test for a carbonyl, and a carboxylic acid with ammonia gives an ammonium salt.

Question 31

9701/12 N25 ▪ Q31 ▪ 1 mark

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

Solution 31

Answer: **C**

Why

- S_N1 goes through a carbocation, so it needs a *tertiary* halogenoalkane.
- Both C and D use 2-chloro-2-methylpropane, but KOH in *ethanol* causes elimination, not substitution.
- KCN in ethanol does substitute, so C is the S_N1 reaction.

Question 31

9701/14 N25 ▪ Q31 ▪ 1 mark

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

Question 31

	reacts faster	bromine is lower than chlorine's
D	2-bromopropane reacts faster	the C–Br bond is weaker than the C–Cl bond

Solution 31

Answer: **D**

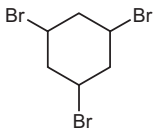
Why

- The rate of hydrolysis is decided by the carbon–halogen *bond enthalpy*, not by the bond polarity.
- C–Br is weaker than C–Cl, so it breaks more easily.
- So 2-bromopropane reacts faster – the C–Cl bond is more polar but stronger.

Question 32

9701/14 N25 ▪ Q32 ▪ 1 mark

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.

Question 32

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

Solution 32

Answer: **A**

Why

- Replacing each Br with OH gives the alcohol Y.
- The bromine on a carbon bonded to two other carbons becomes a *secondary* alcohol group.
- Oxidising a secondary alcohol gives a ketone, so both statements hold.

Question 38

9701/14 N25 ▪ Q38 ▪ 1 mark

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

Solution 38

Answer: **B**

Why

- The solvent decides the outcome: *aqueous* NaOH substitutes, *ethanolic* NaOH eliminates.
- Here the reagent is in ethanol, so HBr is eliminated to give ethene.
- That is elimination, not substitution.

Question 4

9701/22 N25 ▪ Q4 ▪ 16 marks

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

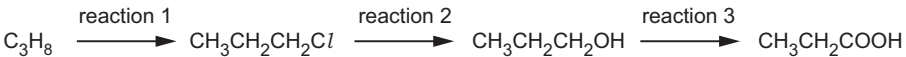


Fig. 4.1

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

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

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

(i) Name the mechanism shown by reaction 1.

Question 4

(ii) Complete the mechanism for reaction 1.

Construct equations to describe the steps of the mechanism.

initiation $Cl_2 \rightarrow 2Cl\bullet$

Question 4

Question 4

Question 4

[3]

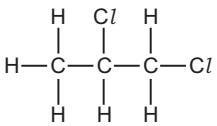
(iii) Reaction 1 is initiated by the bond fission of Cl_2.

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

Question 4

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

Q



Name **Q**.

Question 4

(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.

Question 4

Question 4

[2]

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

Question 4

(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.

Question 4

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

Question 4

(d) CH_3CH_2COOH reacts with an unsaturated alcohol **R** to form unsaturated ester **S**.

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

Question 4

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

Question 4

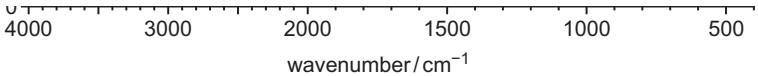


Fig. 4.2

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]

Question 4

[3]

Question 4

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

Question 4

| | | nyaroxy | | 3200–3650 | |

Question 4

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

Table 4.3

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

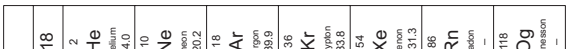
Use Table 4.3 to calculate the number of carbon atoms in **S**.

Question 4

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



		13	14	15	16	17	
							H hy
		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	N n 2
	12	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	A a 3
	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	K kr 8
	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	X xe 1
	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 –	R n
n	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	O oga

	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
	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

Question 4

The Periodic Table of Elements

Group

Key

mic number
ic symbol
name
e atomic mass

			1 H hydrogen 1.0			
5	6	7	8	9	10	11
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
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
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
105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgeniun –

59 Pr aseodymium 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
91 Pa rotactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –

1	2			
3 Li lithium 6.9	4 Be beryllium 9.0		ato atom relativ	
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	pra
actinoids	89 Ac actinium –	90 Th thorium 232.0	p

Solution 4

(a)(i)

Mark scheme

- free-radical substitution
- 1
- 9701/22
- October/November 2025

Solution 4

(a)(ii) Mark scheme

- M1 C3H8 + Cl → CH3CH2CH2 + HCl
- OR C3H8 + Cl → C3H7 + HCl **M2**
- CH3CH2CH2 + Cl2 → CH3CH2CH2Cl + Cl
- OR C3H7 + Cl2 → C3H7Cl + Cl etc **M3**
- CH3CH2CH2 + Cl → CH3CH2CH2Cl
- OR C3H7 + Cl → CH3CH2CH2Cl
- 3

Solution 4

(a)(iii)

Mark scheme

- homolytic
- 1

(a)(iv)

Mark scheme

- 1,2-dichloropropane
- 1

Solution 4

(a)(v)

Mark scheme

- M1 (type of structural isomerism) positional M2
- (type of stereoisomerism) optical
- 2

Solution 4

(b)

Mark scheme

- sodium hydroxide AND water
- 1

Solution 4

(c)(i)

Mark scheme

- orange to green
- 1

(c)(ii)

Mark scheme

- $CH3CH2CH2OH + 2[O] \rightarrow CH3CH2COOH + H2O$
- 1

Solution 4

(d)(i)

Mark scheme

- condensation
- 1

Solution 4

(d)(ii)

Mark scheme

- M1 absorption labelled at approx. 1750 cm–1 identified as C=O M2
- absorption labelled at approx. 1650 cm–1 identified as C=C M3
- absorption labelled at approx. 1170 cm–1 identified as C—O
- 3

Solution 4

(d)(iii)

Mark scheme

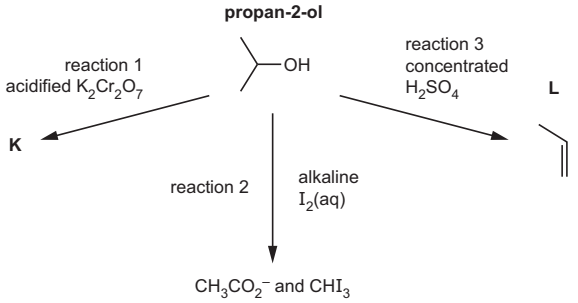
- $(0.31 \,/\, 4.7 \times 100 \,/\, 1.1) = 6$ carbon atoms
- 1

Question 3

9701/24 N25 ▪ Q3 ▪ 11 marks

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.



Question 3

Fig. 3.1

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

Question 3

[1]

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

Question 3

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

Question 3

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

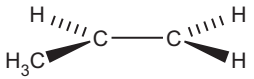
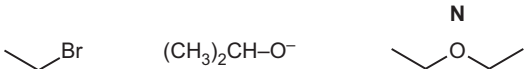


Fig. 3.2

[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.



Question 3

Question 3

Fig. 3.3

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

Question 3

(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.

Question 3

used instead of 2-bromopropane.

Question 3

. .

Explain your answer.

Question 3

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

Construct an equation for the complete combustion of **N**, $C_6H_{14}O$.

Question 3

[Total: 11]

Solution 3

(a)(i)

Mark scheme

- 1

(a)(ii)

Mark scheme

- yellow precipitate
- 1

Solution 3

(a)(iii)

Mark scheme

- elimination
- 1
- 9701/24
- October/November 2025

(a)(iv)

Mark scheme

- 1

Solution 3

(b)(i)

Mark scheme

- $(CH3)2CHOH + Na \rightarrow (CH3)2CHO(-)Na(+) + \ 1/2\ H2$
- 1

Solution 3

(b)(ii)

Mark scheme

- M1 correct dipole on $\delta+$C—Br$\delta-$ AND curly arrow from C—Br bond to Br M2
- intermediate M3
- curly arrow from lone pair of (CH3)2CHO– to C+
- 3

Solution 3

(b)(iii)

Mark scheme

- M1 rate would decrease M2
- C—Br is weaker (than C—Cl, so breaks more easily)
- 2

Solution 3

(b)(iv)

Mark scheme

- $C6H14O + 9O2 \rightarrow 6CO2 + 7H2O$
- 1