Week 21

A-Level Chemistry

Homework bundle for this week

本周作业合集

exercises.lol

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14. Hydrocarbons

Starter Quiz · 课前小测

A-Level Chemistry Name: _____ Score: _____

1. Alkanes are:

   ☐ saturated hydrocarbons with general formula C_nH_{2n+2}

   ☐ unsaturated hydrocarbons with a C=C bond

   ☐ compounds containing oxygen

   ☐ ionic compounds

2. Alkanes react with chlorine by free-radical substitution in the presence of:

   ☐ ultraviolet light

   ☐ a nucleophile

   ☐ water

   ☐ an acid catalyst

3. Alkenes are reactive because they have:

   ☐ a C=C double bond (their functional group)

   ☐ only single bonds

   ☐ an –OH group

   ☐ no functional group

4. In addition polymerisation:

   ☐ many alkene molecules join into one long chain, with no other product

   ☐ a small molecule like water is lost

   ☐ a polymer is split apart

   ☐ two different monomers alternate

5. Cracking is used to:

   ☐ break long-chain alkanes into shorter, more useful molecules

   ☐ join short alkanes into long ones

   ☐ add hydrogen to alkenes

   ☐ burn alkanes

6. Alkanes are saturated hydrocarbons containing only single bonds.

   ☐ True ☐ False

7. Alkanes react with halogens in UV light by free-radical _____.

   _____

8. Many ethene molecules join to form the polymer poly(_____).

   _____

9. An alkene decolourises bromine water, while an alkane leaves it orange — that is the standard test for a C=C double bond.

   ☐ True ☐ False

10. The initiation step is:

    ☐ UV light splitting the halogen into two radicals

    ☐ two radicals joining

    ☐ a radical reacting with the alkane

    ☐ the product forming

A-Level Chemistry

1. **saturated hydrocarbons with general formula C_nH_{2n+2}**

   Alkanes have only single C–C bonds (saturated) and follow C_nH_{2n+2}.

2. **ultraviolet light**

   UV light starts the reaction by splitting the halogen into radicals.

3. **a C=C double bond (their functional group)**

   The electron-rich C=C double bond is the reactive functional group of alkenes (C_nH_{2n}).

4. **many alkene molecules join into one long chain, with no other product**

   Alkenes open their double bonds and join into a polymer such as poly(ethene); nothing else is formed.

5. **break long-chain alkanes into shorter, more useful molecules**

   Cracking turns heavy crude-oil fractions into smaller, more useful alkanes and alkenes.

6. **True**

   General formula C_nH_{2n+2}.

7. **substitution**

   Initiation, propagation and termination steps.

8. **ethene**

   Addition polymerisation of the alkene.

9. **True**

   The π electrons of the C=C attack the bromine; alkanes have no double bond, so nothing happens.

10. **UV light splitting the halogen into two radicals**

    Initiation: $Cl_2 \rightarrow 2Cl\cdot$, the homolytic split that starts the chain.

A-LEVEL CHEMISTRY • EXERCISE SHEET

14.1 Alkanes

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS propagation 增长 • initiation 引发 • termination 终止 • carbon monoxide 一氧化碳 • free-radical substitution 自由基取代

Objective

Build the skills to answer exam questions on **alkanes** 烷烃 — making them, **combustion** 燃烧, **free-radical substitution** 自由基取代, and their unreactivity.

You must be able to:

- recall how alkanes are made (hydrogenation, cracking) and describe combustion
- describe the free-radical substitution mechanism (initiation, propagation, termination)
- explain the unreactivity of alkanes and the environmental effects of combustion

1 Worked examples

Making alkanes and combustion

- **hydrogenation:** add H_2 to an alkene (Pt/Ni catalyst, heat).
- **cracking:** break a long alkane into shorter ones (heat, Al_2O_3).
- **complete combustion** → CO_2 + H_2O; **incomplete** (little O_2) → toxic **CO** + soot.

Free-radical substitution

1. initiation

$$Cl_2 \xrightarrow{UV} 2\,Cl^{\bullet}$$

UV light splits Cl–Cl into two radicals

2. propagation

$$Cl^{\bullet} + C_2H_6 \longrightarrow C_2H_5^{\bullet} + HCl$$

$$C_2H_5^{\bullet} + Cl_2 \longrightarrow C_2H_5Cl + Cl^{\bullet}$$

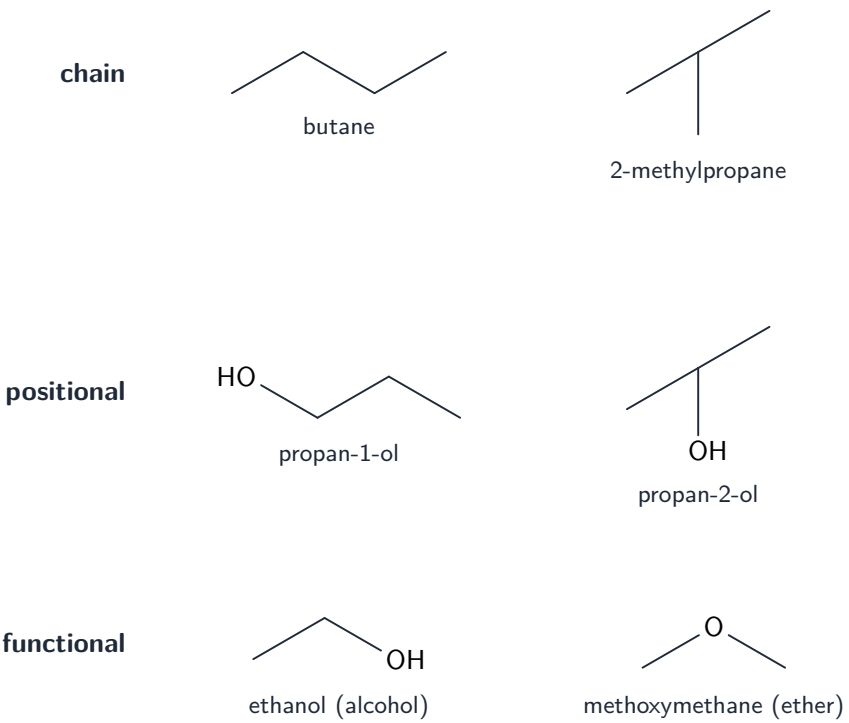
each radical makes a new radical, so the chain continues

3. termination

$$Cl^{\bullet} + C_2H_5^{\bullet} \longrightarrow C_2H_5Cl$$

two radicals join, ending the chain

Free-radical substitution (needs UV light): initiation → propagation → termination



Alkanes show chain and position isomerism

- **initiation:** $Cl_2 \xrightarrow{UV} 2Cl\cdot$
- **propagation:** $Cl\cdot + C_2H_6 \rightarrow C_2H_5\cdot + HCl$; $C_2H_5\cdot + Cl_2 \rightarrow C_2H_5Cl + Cl\cdot$
- **termination:** two radicals join, e.g. $Cl\cdot + C_2H_5\cdot \rightarrow C_2H_5Cl$

Alkanes are unreactive: the C–H and C–C bonds are strong and have little polarity, so nothing attracts a polar reagent.

2 Practice

2.1 State the reagent and condition for making an alkane from an alkene. [2]

2.2 Give the products of the **incomplete** combustion of an alkane. [2]

3 Exam-style questions

3.1 What condition is needed for the free-radical substitution of an alkane by chlorine? [1]

- **A** a nickel catalyst
- **B** ultraviolet light
- **C** concentrated sulfuric acid
- **D** aqueous sodium hydroxide

3.2 Why are alkanes generally unreactive towards polar reagents? [1]

- **A** they are ionic
- **B** the C–H and C–C bonds are strong and non-polar
- **C** they contain a double bond
- **D** they are very volatile

3.3 Ethane reacts with chlorine in UV light.

(a) Write equations for the initiation step and **one** propagation step. [3]

(b) Write an equation for a termination step that forms chloroethane. [1]

3.4 Explain why incomplete combustion of a fuel is dangerous. [2]

3.5 Methane reacts with chlorine in the presence of ultraviolet light.

(a) Write equations for the initiation step, **two** propagation steps and one termination step, labelling each. [5]

(b) Explain why no reaction occurs in the dark, and state what the ultraviolet light does. [2]

(c) Explain why a mixture of organic products is obtained, and name **two** organic products other than chloromethane. [3]

(d) Alkanes are described as unreactive. Explain this in terms of bond enthalpy and bond polarity. [3]

Solutions

2.1 hydrogen (H_2) with a Pt or Ni catalyst; and heat.

2.2 carbon monoxide (and/or carbon/soot); water.

3.1 B. Free-radical substitution needs ultraviolet light.

3.2 B. Strong, non-polar C–H and C–C bonds offer no site for a polar reagent.

3.3 (a) initiation: $Cl_2 \rightarrow 2Cl\cdot$; propagation: $Cl\cdot + C_2H_6 \rightarrow C_2H_5\cdot + HCl$ and $C_2H_5\cdot + Cl_2 \rightarrow C_2H_5Cl + Cl\cdot$.
(b) $C_2H_5\cdot + Cl\cdot \rightarrow C_2H_5Cl$.

3.4 it produces carbon monoxide, a toxic gas that binds to haemoglobin and prevents oxygen transport.

3.5 (a) Initiation: $Cl_2 \xrightarrow{uv} 2Cl\bullet$. Propagation: $Cl\bullet + CH_4 \rightarrow \bullet CH_3 + HCl$ and $\bullet CH_3 + Cl_2 \rightarrow CH_3Cl + Cl\bullet$. Termination: any two radicals combining, e.g. $\bullet CH_3 + Cl\bullet \rightarrow CH_3Cl$. Each step correctly labelled.
(b) Ultraviolet light supplies the energy to break the Cl–Cl bond **homolytically**; without it no radicals are produced, so the chain can never start.
(c) Chloromethane still contains C–H bonds, so a chlorine radical can attack it in turn and substitution continues; dichloromethane, CH_2Cl_2, and trichloromethane, $CHCl_3$. (Ethane, from two methyl radicals combining, is also acceptable.)
(d) C–C and C–H bonds are strong, so a large energy input is needed to break them; carbon and hydrogen have very similar electronegativities, so the bonds are essentially non-polar; there is therefore no $\delta+$ carbon for a nucleophile to attack.

28 Two hydrocarbons, R–CH_3 and R'–CH_3, react separately with bromine in the presence of ultraviolet light. One of these hydrocarbons is unsaturated.

In each case, free radical substitution reactions occur.

R is $CH_3CHC(CH_3)$.

R' is $CH_3CH(CH_3)CH_2$.

Which row is correct?

	a propagation stage for the saturated hydrocarbon	a termination stage for the unsaturated hydrocarbon
A	$R–CH_2• + Br• \rightarrow R–CH_2Br$	$R'–CH_2• + Br• \rightarrow R'–CH_2Br$
B	$R–CH_2• + Br_2 \rightarrow R–CH_2Br + Br•$	$R'–CH_2• + Br_2 \rightarrow R'–CH_2Br + Br•$
C	$R'–CH_3 + Br• \rightarrow R'–CH_2• + HBr$	$2R–CH_2• \rightarrow R–CH_2CH_2–R$
D	$2R'–CH_2• \rightarrow R'–CH_2CH_2–R'$	$R–CH_3 + Br• \rightarrow R–CH_2• + HBr$

29 The fumes from the exhausts of petrol-burning cars contain the following pollutants.

1 unburnt hydrocarbons

2 nitrogen dioxide

3 carbon monoxide

Which pollutants are removed by oxidation in a catalytic converter?

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

25 Two hydrocarbons, $CH_3CHC(CH_3)CH_3$ and $CH_3CH(CH_3)CH_2CH_3$, react separately with chlorine in the presence of ultraviolet light.

In each reaction, free-radical substitution occurs.

Which row is correct?

	identity of the hydrocarbon that can also undergo electrophilic addition	a termination stage of the free-radical substitution of the saturated hydrocarbon
A	$CH_3CHC(CH_3)CH_3$	$CH_3CH(CH_3)CH_2CH_2• + Cl• \rightarrow CH_3CH(CH_3)CH_2CH_2Cl$
B	$CH_3CHC(CH_3)CH_3$	$CH_3CHC(CH_3)CH_2• + Cl• \rightarrow CH_3CHC(CH_3)CH_2Cl$
C	$CH_3CH(CH_3)CH_2CH_3$	$CH_3CH(CH_3)CH_2CH_2• + Cl• \rightarrow CH_3CH(CH_3)CH_2CH_2Cl$
D	$CH_3CH(CH_3)CH_2CH_3$	$CH_3CHC(CH_3)CH_2• + Cl• \rightarrow CH_2CHC(CH_3)CH_2Cl$

3 The alkanes are a homologous series of organic molecules. Alkanes are generally unreactive and are commonly used as fuels.

(a) Define homologous series.

.....

..... [2]

(b) Give two reasons to explain the general unreactivity of alkanes.

1 .....

2 .....
[2]

(c) Alkanes with low relative molecular mass, M_r, are more useful than those found in heavier crude oil fractions.

Name the process that is used to obtain alkanes with low M_r from heavier crude oil fractions.

..... [1]

(d) Hexane, C_6H_{14}, has four structural isomers.

Fig. 3.1 shows hexane and two of its structural isomers.

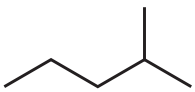
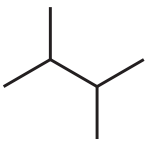
hexane	**A**	**B**	**C**	**D**
				

Fig. 3.1

(i) Complete Fig. 3.1 by drawing structures for **C** and **D**, the other two structural isomers of hexane. [2]

(ii) **A**, **B** and hexane have different boiling points.

Arrange **A**, **B** and hexane in order of increasing boiling point.

Explain your answer.

lowest ..... < ..... < ..... highest

.....

.....

.....
[3]

(e) Hexane can be converted into compounds **E** and **F** at high temperature and pressure. Fig. 3.2 shows the reaction scheme involving hexane, **E** and **F**.

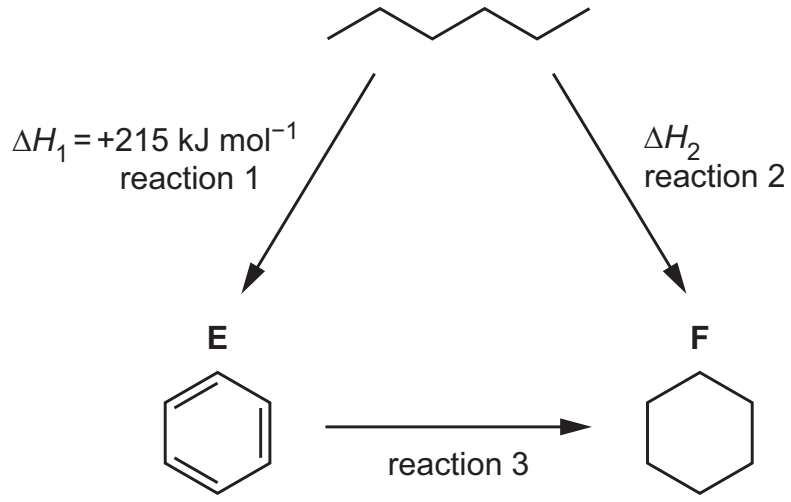


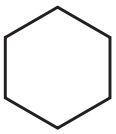
Fig. 3.2

(i) Identify a suitable reagent for reaction 3.

..... [1]

(ii) Use the data in Fig. 3.2 and in Table 3.1 to calculate the enthalpy change of reaction 2, ΔH_2.

Table 3.1

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
	−156
	+48

ΔH_2 = ... kJ mol^{-1} [2]

(iii) Write an equation for the complete combustion of hexane.

..... [1]

[Total: 14]

14.2 Alkenes

Name: _____ Class: _____ Date: _____ **Total: 13 marks**

KEY WORDS electrophilic addition 亲电加成 • addition polymerisation 加成聚合 • bromine 溴 • alkenes 烯烃 • polymer 聚合物

Objective

Build the skills to answer exam questions on **alkenes** 烯烃 — making them, **electrophilic addition** 亲电加成, the **bromine** 溴 test, **addition polymerisation** 加成聚合, and **Markovnikov's rule** 马氏规则.

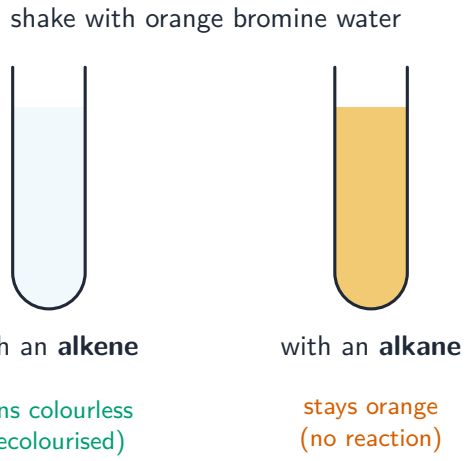
You must be able to:

- recall how alkenes are made and describe their addition reactions
- describe the electrophilic addition mechanism and use the bromine test
- explain carbocation stability and Markovnikov addition

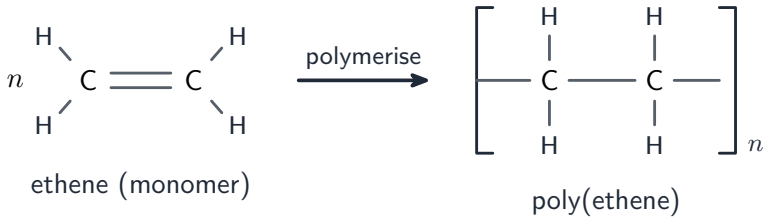
1 Worked examples

■ Reactions of alkenes

The C=C bond reacts by **electrophilic addition**: with H_2 (Pt/Ni) → alkane; steam (H_3PO_4) → alcohol; HX → halogenoalkane; X_2 → dihalide. Cold dilute $KMnO_4$ → diol; hot conc. $KMnO_4$ breaks the C=C.

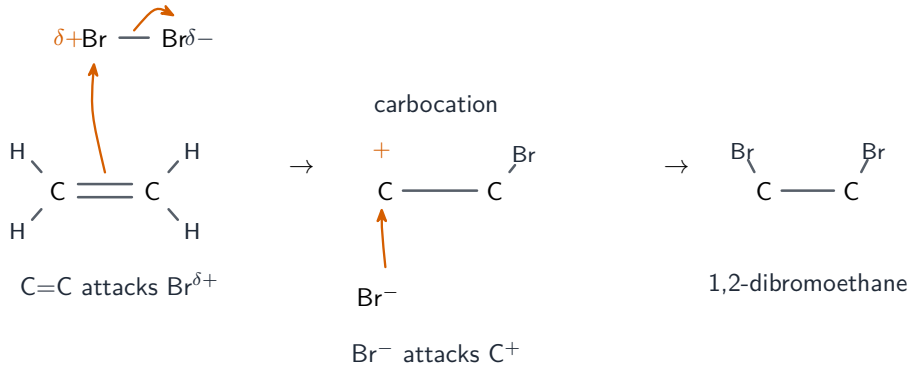


Test for C=C: an alkene decolourises orange bromine water; an alkane does not

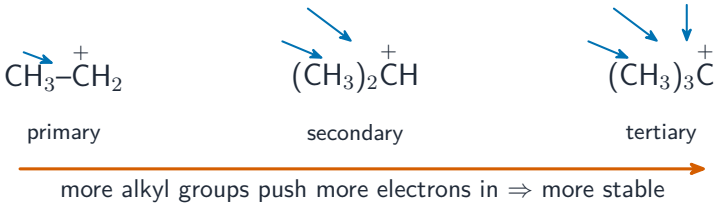


Addition polymerisation: many ethene molecules join into poly(ethene), with no other product

Mechanism and Markovnikov



Electrophilic addition: the electron-rich C=C attacks the electrophile, forming a carbocation, then the nucleophile attacks



Markovnikov: HBr adds so the *more stable* carbocation forms

Alkyl groups push electrons in (inductive effect), so tertiary > secondary > primary — the basis of Markovnikov's rule

2 Practice

2.1 State the reagent and condition for making an alcohol from an alkene. [2]

2.2 Describe the test for a C=C double bond and the positive result. [2]

3 Exam-style questions

3.1 Which reagent converts ethene into a halogenoalkane? [1]

- **A** H_2 / Ni
- **B** steam / H_3PO_4
- **C** HBr at room temperature
- **D** hot $KMnO_4$

3.2 During electrophilic addition, the positive intermediate formed is a: [1]

- **A** free radical
- **B** carbocation
- **C** nucleophile
- **D** diol

3.3 (a) Describe the mechanism of the electrophilic addition of bromine to ethene (use curly arrows or words). [3]

(b) Write the equation for the addition polymerisation of ethene to poly(ethene). [1]

3.4 When HBr adds to propene, 2-bromopropane is the major product. Explain why, using carbocation stability. [3]

Solutions

2.1 steam (H_2O gas) with a phosphoric acid (H_3PO_4) catalyst.

2.2 shake with (orange) bromine water; an alkene decolourises it / turns it colourless.

3.1 C. HBr at room temperature gives a halogenoalkane.

3.2 B. The intermediate is a carbocation.

3.3 (a) the C=C double bond attacks the $\delta+$ bromine, with a curly arrow from the double bond; the Br–Br bond breaks heterolytically, forming a carbocation and a Br^-; the Br^- then attacks the carbocation to give 1,2-dibromoethane.
(b) $n\,CH_2{=}CH_2 \rightarrow -(CH_2CH_2)_n-$.

3.4 adding H^+ to propene can form a secondary or a primary carbocation; the secondary carbocation is more stable, because two alkyl groups push electrons towards the positive carbon; the more stable (secondary) carbocation forms preferentially, giving 2-bromopropane.

27 Which intermediate ion forms in the greatest amount during the addition of HBr to propene?

A $CH_3CH^+CH_3$

B $CH_3CH_2CH_2^+$

C $CH_3CH^-CH_2Br$

D $CH_3CHBrCH_2^-$

27 What is the major product when 2-methylpent-2-ene reacts with hydrogen bromide?

A 1-bromo-2-methylpentane

B 2-bromo-2-methylpentane

C 3-bromo-2-methylpentane

D 4-bromo-2-methylpentane

28 Pent-2-ene is reacted with cold, dilute, acidified manganate(VII) ions.

What is the major product?

A $CH_3CH_2CH(OH)CH(OH)CH_3$

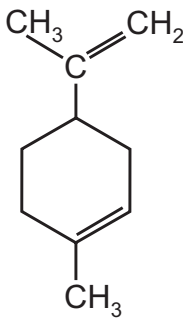
B $CH_3CH_2COCOCH_3$

C a mixture of $CH_3CH_2CH(OH)CH_2CH_3$ and $CH_3CH_2CH_2CH(OH)CH_3$

D CH_3CH_2COOH and CH_3COOH

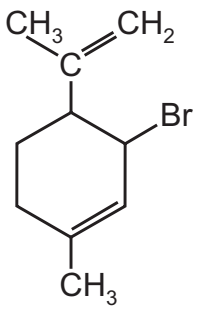
29 Limonene is an oil formed in the peel of citrus fruits.

limonene

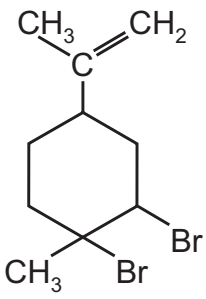


Which product is formed when an excess of bromine, $Br_2(l)$, reacts with limonene at room temperature in the dark?

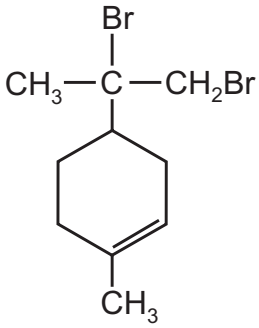
A



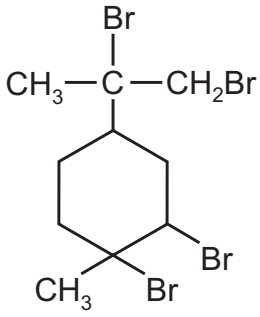
B



C

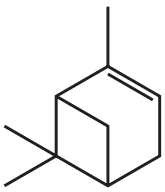


D

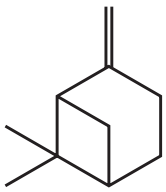


29 Pinenes are unsaturated compounds. The structures of two pinenes are shown.

α-pinene



β-pinene



A mixture of these two pinenes reacts with hot concentrated acidified $KMnO_4$.

What are the molecular formulae of the organic products?

A $C_9H_{14}O$ and $C_{10}H_{16}O_3$

B $C_9H_{14}O$ and $C_{10}H_{14}O_4$

C $C_9H_{16}O_2$ and $C_{10}H_{16}O_3$

D $C_9H_{16}O_2$ and $C_{10}H_{14}O_4$

4 Fig. 4.1 shows a possible synthesis of propene, C_3H_6.

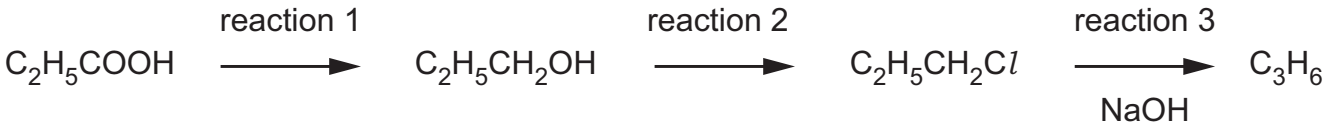


Fig. 4.1

(a) (i) Identify the type of reaction that occurs in reaction 1.

..... [1]

(ii) Suggest a suitable reagent for reaction 2.

..... [1]

(iii) Reaction 3 is an elimination reaction.

Write an equation for this reaction and identify the solvent and conditions used.

equation .....

solvent and conditions .....
[2]

(iv) $C_2H_5CH_2OH$ can be directly converted to C_3H_6.

Suggest the reagent and conditions for this conversion.

..... [1]

(b) Under suitable conditions, propene polymerises to form poly(propene).

Poly(propene) exhibits stereoisomerism.

(i) Identify the type of polymerisation that forms poly(propene) from propene.

..... [1]

(ii) Define stereoisomerism.

.....

..... [2]

(iii) Draw a section of poly(propene), showing **two** repeat units.

Use your diagram to identify the type of stereoisomerism shown by poly(propene). Explain your answer.

section of poly(propene)

.....

.....

.....

.....

[3]

(iv) State **two** difficulties associated with the disposal of poly(propene).

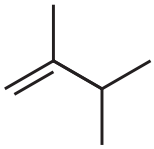
1 .....

2 .....

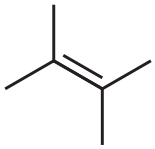
[2]

(c) Under different conditions, two molecules of propene can combine to form compounds **X** and **Y**.

X



Y



(i) Name **X**.

..... [1]

(ii) Fig. 4.2 shows the mass spectrum of either compound **X** or compound **Y**.

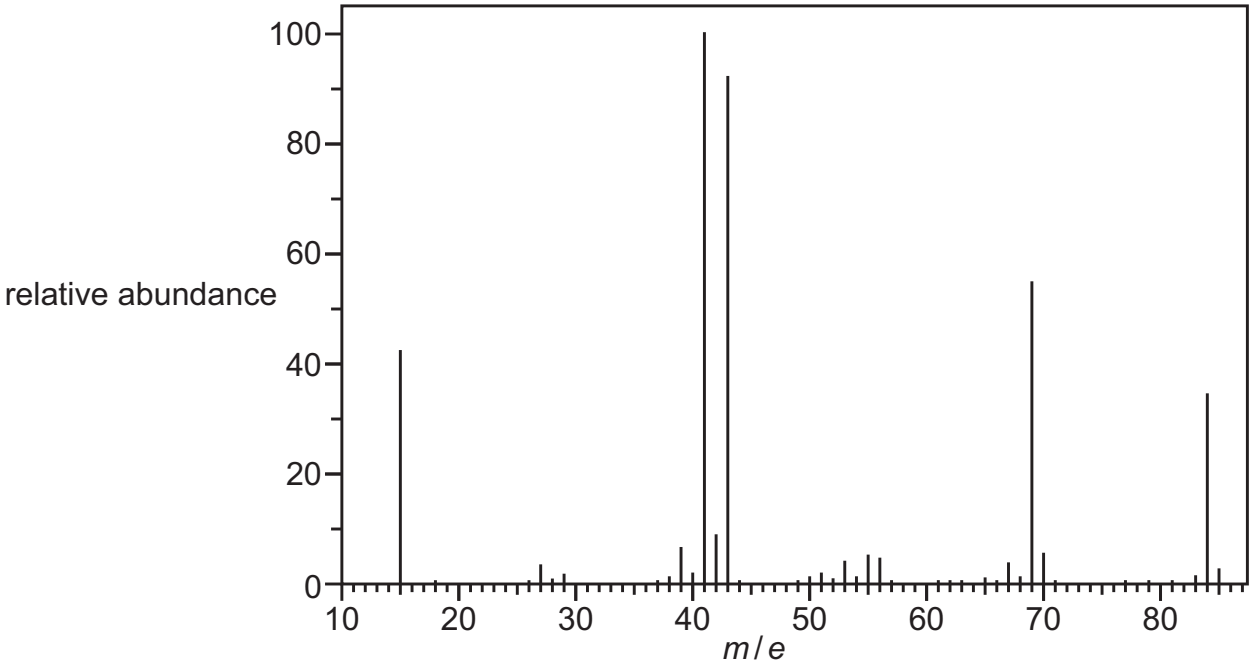


Fig. 4.2

Identify which of **X** and **Y** gives this mass spectrum.

Give **one** reason for your answer, referring to the fragmentation pattern.

.....

.....

..... [1]

(iii) The molecular ion peak in the spectrum in Fig. 4.2 has relative abundance 34.7.

Calculate the relative abundance of the $[M+1]^+$ peak in this spectrum.

relative abundance of $[M+1]^+$ peak = ... [1]

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	3	4	5	6	7	8	9	10	11	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	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 –