Week 21

A-Level Chemistry

Homework bundle for this week

本周作业合集

exercises.lol

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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

14. Hydrocarbons

Answers · 答案

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

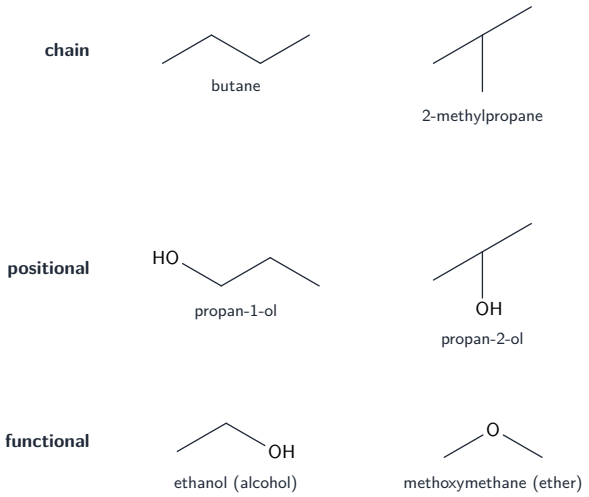
$C_2H_5^{\bullet} + Cl_2 \longrightarrow C_2H_5Cl + Cl^{\bullet}$

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	$R–CH_2\bullet + Br\bullet \rightarrow R–CH_2Br$	$R'–CH_2\bullet + Br\bullet \rightarrow R'–CH_2Br$
B	$R–CH_2\bullet + Br_2 \rightarrow R–CH_2Br + Br\bullet$	$R'–CH_2\bullet + Br_2 \rightarrow R'–CH_2Br + Br\bullet$
C	$R'–CH_3 + Br\bullet \rightarrow R'–CH_2\bullet + HBr$	$2R–CH_2\bullet \rightarrow R–CH_2CH_2–R$
D	$2R'–CH_2\bullet \rightarrow R'–CH_2CH_2–R'$	$R–CH_3 + Br\bullet \rightarrow R–CH_2\bullet + HBr$

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	$CH_3CHC(CH_3)CH_3$	$CH_3CH(CH_3)CH_2CH_2\bullet + Cl\bullet \rightarrow CH_3CH(CH_3)CH_2CH_2Cl$
B	$CH_3CHC(CH_3)CH_3$	$CH_3CHC(CH_3)CH_2\bullet + Cl\bullet \rightarrow CH_3CHC(CH_3)CH_2Cl$
C	$CH_3CH(CH_3)CH_2CH_3$	$CH_3CH(CH_3)CH_2CH_2\bullet + Cl\bullet \rightarrow CH_3CH(CH_3)CH_2CH_2Cl$
D	$CH_3CH(CH_3)CH_2CH_3$	$CH_3CHC(CH_3)CH_2\bullet + Cl\bullet \rightarrow CH_2CHC(CH_3)CH_2Cl$

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.

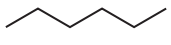
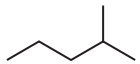
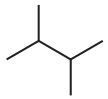
hexane	A	B	C	D
				

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**.

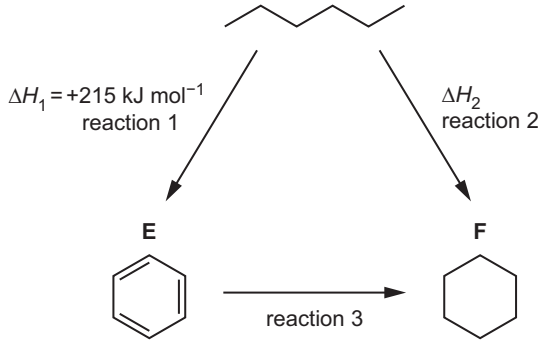


Fig. 3.2

(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]

A-LEVEL CHEMISTRY • EXERCISE SHEET

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.

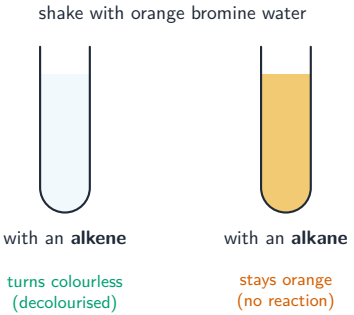
You must be able to:

- 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

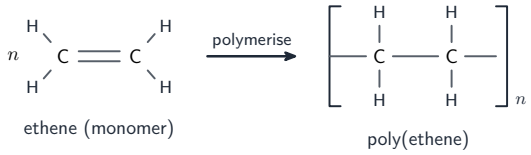
1 Worked examples

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.

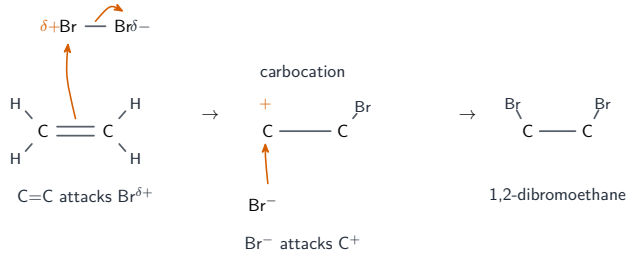


Test for C=C: an alkene decolourises orange bromine water; an alkane does not

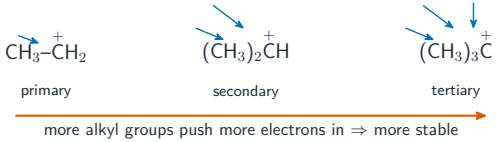


Addition polymerisation: many ethene molecules join into poly(ethene), with no other product

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.

Name: A-Level Chemistry: **w25 11**

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 $CH_3CHBrCH_2^-$

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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 $CH_3CH_2CH(OH)CH(OH)CH_3$

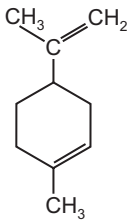
B $CH_3CH_2COCOCH_3$

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

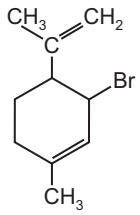
29 Limonene is an oil formed in the peel of citrus fruits.

limonene

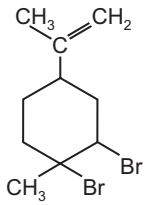


Which product is formed when an excess of bromine, $Br_2(l)$, reacts with limonene at room temperature in the dark?

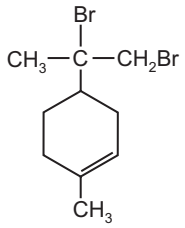
A



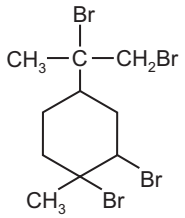
B



C

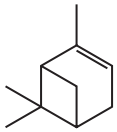


D

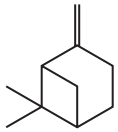


29 Pinenes are unsaturated compounds. The structures of two pinenes are shown.

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.

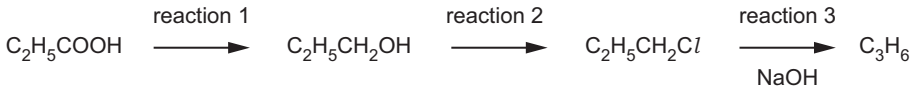


Fig. 4.1

(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).

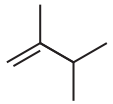
1 .....

2 .....

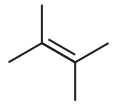
[2]

(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**.

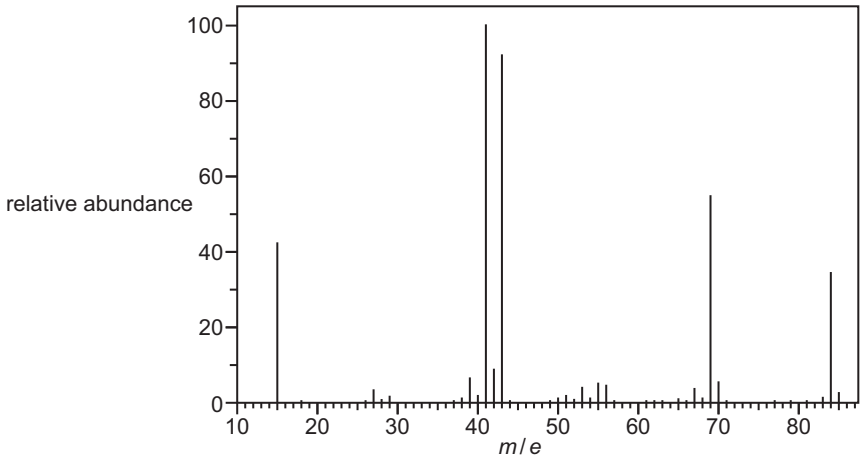


Fig. 4.2

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