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

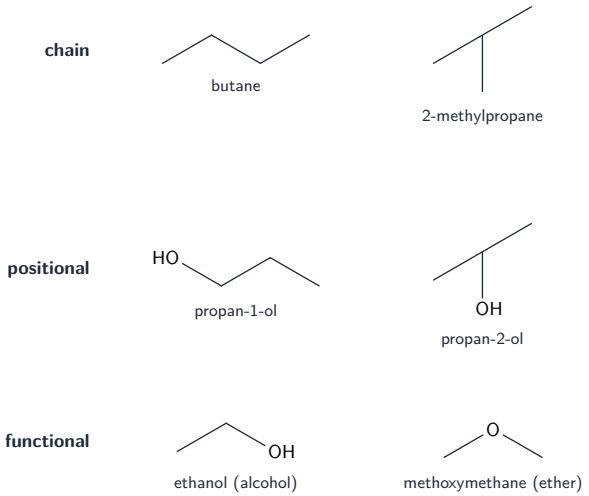
$C_2H_5^{\bullet} + Cl_2 \longrightarrow C_2H_5Cl + Cl^{\bullet}$

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.