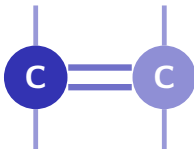


Hydrocarbons

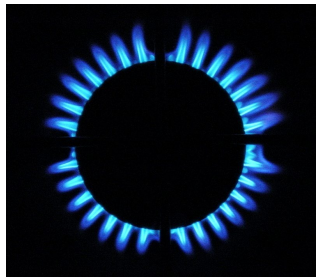
A-Level Chemistry ■ Topic 14

A-Level Chemistry



What we will cover

- 1 Alkanes: making & combustion
- 2 Free-radical substitution
- 3 Alkenes & their reactions
- 4 The bromine test
- 5 Addition polymerisation
- 6 Markovnikov's rule



methane, the simplest alkane

1

Alkanes

Alkanes: making and combustion

complete 完全燃烧

plenty of $\text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$

incomplete 不完全燃烧

too little $\text{O}_2 \rightarrow \text{CO} + \text{soot}$

Alkanes 烷烃 ($\text{C}_n\text{H}_{2n+2}$) are made by **hydrogenation** 氢化 of alkenes or **cracking** 裂化; they are unreactive (strong, non-polar bonds).

Two ways to make an alkane

hydrogenation 氢化

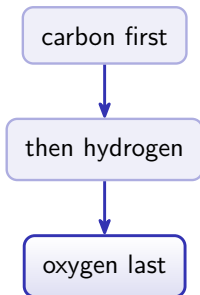
add H_2 across the $\text{C}=\text{C}$ of an **alkene** 烯烃, over a Pt or Ni catalyst with heat

cracking 裂化

break a long-chain alkane into shorter ones by heating over Al_2O_3

Cracking turns heavy fractions of **crude oil** 原油 into lower- M_r alkanes *and* alkenes – a **fraction** 馏分 being molecules of similar boiling point. That is why it is worth doing: the short chains are what is in demand.

Balance a combustion equation in a fixed order



Oxygen goes last because it is the only element that appears **twice** on the right.

C₆H₁₄ burning completely

6 carbons $\Rightarrow$ 6 CO₂;

14 hydrogens $\Rightarrow$ 7 H₂O;

right-hand oxygens = 12 + 7 = 19,

so



Two ways to make an alkene

elimination 消去

remove HX from a **halogenoalkane** 卤代烷 with NaOH dissolved in *ethanol*, and heat

dehydration 脱水

remove water from an **alcohol** 醇 over hot Al_2O_3 , or with concentrated sulfuric acid

NaOH in *ethanol* eliminates to an alkene; NaOH in *water* substitutes to an alcohol. The solvent decides the product.

Reactions of the C=C, reagent by reagent

Reagent and conditions	Product
H ₂ , Ni catalyst, heat	alkane
a hydrogen halide 卤化氢 (HX), room temperature	halogenoalkane
X ₂ (e.g. Br ₂), room temperature	dihalide
steam, H ₃ PO ₄ , high <i>T</i> and <i>p</i>	alcohol
cold, dilute 冷稀 acidified KMnO ₄	a diol 二醇 – two OH added
hot, concentrated 热浓 acidified KMnO ₄	the C=C is broken apart

The last one is how the exam asks you to **locate a double bond**: what each half turns into tells you where it was. Write oxidation with [O].

Reading a broken C=C backwards

What each carbon becomes depends only on **how many hydrogens it had**:

no H

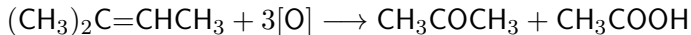
stops at a **ketone** 酮

one H

pushed on to a
carboxylic acid

two H

oxidised all the
way to CO₂



Run it **backwards** – which is how the question is set. Given the products, put the two carbonyl carbons back together with a double bond and you have the original alkene.

Why alkanes are so unreactive

strong bonds

C–H and C–C are strong, so a lot of energy is needed to break either

no polarity

they have almost no **polarity** 极性, so a polar reagent finds nothing to attack

So alkanes react only with something aggressive enough to break a bond **evenly** – **ultra-violet light** 紫外光 making **free radicals** 自由基. That is **homolytic fission** 均裂: one electron to each atom. Break it *unevenly* and you get ions – **heterolytic fission** 异裂.

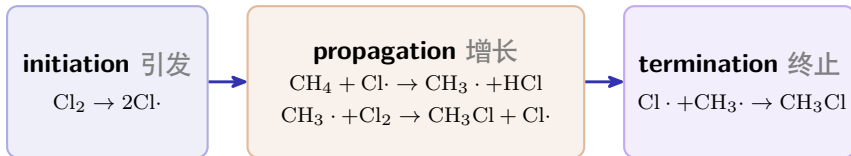
Environmental effects

An internal combustion engine gives off three pollutants; a **catalytic converter** turns them into harmless gases.

Pollutant	Why it forms	Converter gives
carbon monoxide	incomplete combustion	CO_2
oxides of nitrogen	$\text{N}_2 + \text{O}_2$ at engine temperatures	N_2
unburnt hydrocarbons	fuel that did not burn	$\text{CO}_2 + \text{H}_2\text{O}$

Free-radical substitution

Alkanes react with a halogen in **UV light** 紫外线: a chain reaction.



Propagation **regenerates** $\text{Cl}\cdot$, so one initiation step can make many molecules; termination removes two radicals.

Free-radical substitution, in detail



UV light splits Cl-Cl into two radicals



each radical makes a new radical, so the chain continues



two radicals join, ending the chain

Alkanes react with a halogen in **UV light** 紫外线, in three steps:

initiation 引发 – UV splits a halogen into radicals.

propagation 增长 – each step makes another radical, carrying the chain.

termination 终止 – two radicals join and the chain stops.

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Alkenes

Alkenes and their reactions



Alkenes 烯烃 (C_nH_{2n}) have a reactive $C=C$, attacked by **electrophilic addition** 亲电加成:

- $H_2/Ni \rightarrow$ alkane; steam $\rightarrow$ alcohol
- $HX \rightarrow$ halogenoalkane; $X_2 \rightarrow$ dihalide

The bromine test

shake with orange bromine water



with an **alkene**

turns colourless
(decolourised)



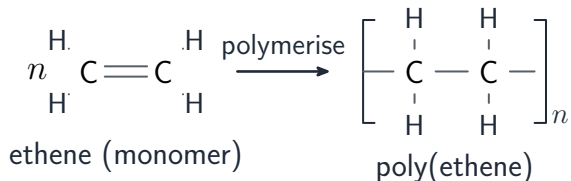
with an **alkane**

stays orange
(no reaction)

Shake with orange **bromine water** 溴水:

An alkene **decolourises** it (electrophilic addition); an alkane leaves it orange.

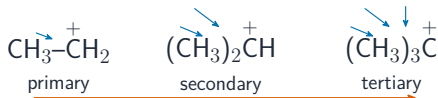
Addition polymerisation



In **addition**

polymerisation 加成聚合, many alkene molecules open their C=C and join into one long chain – with **no other product**. Ethene → poly(ethene), a **polymer** 聚合物.

Mechanism and Markovnikov's rule



more alkyl groups push more electrons in $\Rightarrow$ more stable

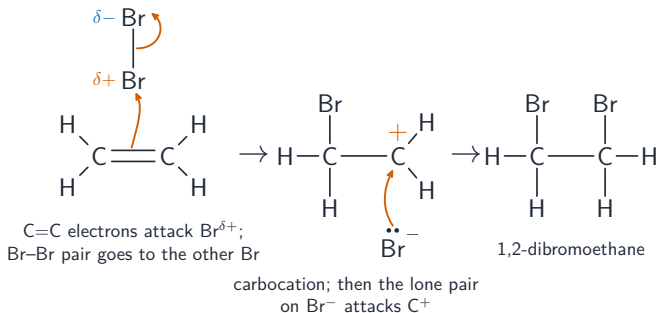
Markovnikov: HBr adds so the *more stable* carbocation forms

A **carbocation** 碳正离子 forms in electrophilic addition.

Alkyl groups push electrons in (the **inductive effect** 诱导效应), so tertiary > secondary > primary – the more stable one forms (**Markovnikov's rule** 马氏规则).

The mechanism: bromine and ethene

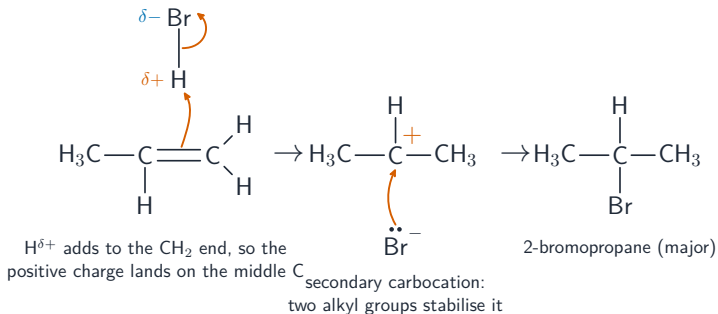
Bromine + ethene



Electrophilic addition of bromine to ethene: the $\text{C}=\text{C}$ attacks $\text{Br}^{\delta+}$, a carbocation forms, then Br^- attacks it

The mechanism: hydrogen bromide and propene

Hydrogen bromide + propene



H^+ adds to the CH_2 end, so the positive charge sits on the middle C: the secondary carbocation is more stable, and 2-bromopropane is the major product

Combustion

complete: $\text{alkane} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$

incomplete: $\text{alkane} + \text{less O}_2 \rightarrow \text{CO} + \text{soot} + \text{H}_2\text{O}$

Complete combustion gives CO_2 and water; incomplete also gives CO and soot

Exam tips

- **Alkanes:** free-radical substitution needs **UV light** – show initiation, propagation and termination with the radical dots.
- **Alkenes:** electrophilic addition via a **carbocation**; draw curly arrows from the $C = C$.
- **Markovnikov:** H adds to the carbon with more H's, via the **more stable carbocation** (alkyl groups are electron-releasing).
- Test for $C = C$: **bromine water decolourises** (orange $\rightarrow$ colourless) – state the observation.

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Recap

Worked example – which product is major?

But-1-ene reacts with HBr. Name the major product and explain why.

- The C=C π electrons attack the $\delta+$ H of H-Br: **electrophilic addition**.
- Two **carbocations** 碳正离子 are possible: a **secondary** one or a **primary** one.
- Alkyl groups **push electron density in**, spreading the charge, so the secondary is more stable.
- Br^- attacks it: major product **2-bromobutane**.

Always route through the **more stable carbocation**.
Stability: tertiary > secondary > primary.

Topic 14 – key takeaways

1

Alkanes

combustion; free-radical
substitution in UV

2

Alkenes

electrophilic addition across $C=C$

3

Bromine test

alkene decolourises bromine water

4

Markovnikov

the more stable carbocation forms

Check yourself

- 1 What two products does incomplete combustion add?
- 2 What light is needed for free-radical substitution?
- 3 What does an alkene do to bromine water?
- 4 Which carbocation is most stable: 1° , 2° or 3° ?



Answers 1. carbon monoxide and soot 2. ultraviolet 3. decolourises it 4. tertiary (3°)