

Exercise walk-through

14.1

Alkanes

A-Level Chemistry

Alkanes: making and combustion

complete

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

incomplete

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

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

Two ways to make an alkane

hydrogenation

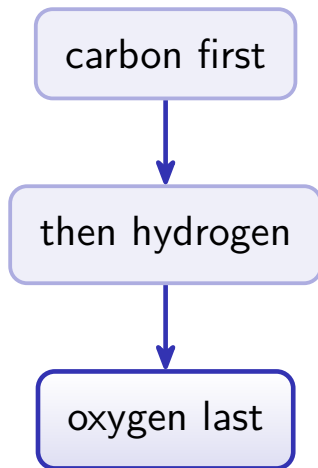
add H_2 across the $\text{C}=\text{C}$ of an **alkene**, over a Pt or Ni catalyst with heat

cracking

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

Cracking turns heavy fractions of **crude oil** into lower- M_r alkanes *and* alkenes – a **fraction** 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



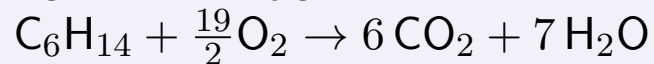
Oxygen goes last because it is the only element that appears **twice** on the right.

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

remove HX from a **halogenoalkane**
solved in *ethanol*, and heat

with NaOH dis-

dehydration

remove water from an **alcohol**
concentrated sulfuric acid

over hot Al_2O_3 , or with

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 (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 acidified KMnO ₄	a diol – two OH added
hot, concentrated 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].

Exercises 2.1-3.1

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]

3.1 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

Exercises 2.1·3.1

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

2.1

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

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

2.2

- carbon monoxide (and/or carbon/soot); water
-

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

3.1 B

- Free-radical substitution needs ultraviolet light

Exercise 3.2

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

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3.2 B

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

Exercise 3.3 (a)

3.3 Ethane reacts with chlorine in UV light.

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

[3]

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(a)

- initiation: $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$; propagation: $\text{Cl}\cdot + \text{C}_2\text{H}_6 \rightarrow \text{C}_2\text{H}_5\cdot + \text{HCl}$ and $\text{C}_2\text{H}_5\cdot + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_5\text{Cl} + \text{Cl}\cdot$

Exercise 3.3 (b)

3.3 Ethane reacts with chlorine in UV light.

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

[1]

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(b)



Exercise 3.4

3.4 Explain why incomplete combustion of a fuel is dangerous.

[2]

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3.4

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

Exercise 3.5 (a)

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]

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(a)

- Initiation: $\text{Cl}_2 \xrightarrow{\text{uv}} 2\text{Cl}\bullet$. Propagation: $\text{Cl}\bullet + \text{CH}_4 \rightarrow \bullet\text{CH}_3 + \text{HCl}$ and $\bullet\text{CH}_3 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{Cl}\bullet$. Termination: any two radicals combining, e.g. $\bullet\text{CH}_3 + \text{Cl}\bullet \rightarrow \text{CH}_3\text{Cl}$. Each step correctly labelled

Exercise 3.5 (b)

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

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

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- Ultraviolet light supplies the energy to break the Cl–Cl bond **homolytically**; without it no radicals are produced, so the chain can never start

Exercise 3.5 (c)

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

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(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.)

Exercise 3.5 (d)

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(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