Alkanes and Alkenes

Matthew Williams • Chemistry • May 15, 2026

Alkanes and Alkenes

Alkanes and alkenes are both hydrocarbons — compounds of carbon and hydrogen only — but they differ in one fundamental way: alkanes have only single bonds between carbon atoms, while alkenes contain at least one carbon-carbon double bond. This structural difference drives almost every difference in their reactivity.

Alkanes

Alkanes are **saturated** hydrocarbons — every carbon atom forms only single bonds, so no more atoms can be added without breaking existing bonds.

General formula: $\mathrm{C}n\mathrm{H}2n + 2$

Name	Molecular formula	Condensed formula
Methane	CH„	CH„
Ethane	C‚H†	CH₃CH₃
Propane	C„H^	CH₃CH₂CH₃
Butane	C„H•€	CH₃CH₂CH₂CH₃
Pentane	C…H•,	CH₃(CH₂)₃CH₃
Hexane	C†H•„	CH₃(CH₂)₄CH₃

Physical properties change gradually along the series: boiling point, density, and viscosity all increase as chain length grows, because longer molecules have stronger intermolecular forces.

Properties of Alkanes

- Relatively **unreactive** — no functional group and strong C–H and C–C bonds
- **Non-polar** — do not dissolve in water but dissolve in organic solvents
- **Flammable** — the most commercially important reaction is combustion

Combustion of Alkanes

Complete combustion (excess oxygen): produces carbon dioxide and water. The flame is blue.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

Incomplete combustion (limited oxygen): produces carbon monoxide (CO) and/or carbon (soot) instead of CO, The flame is yellow and sooty.

$$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$$

Carbon monoxide is colourless, odourless, and extremely toxic. It binds irreversibly to haemoglobin, preventing oxygen transport in blood. It is a leading cause of accidental poisoning in enclosed spaces with poorly ventilated gas appliances.

Substitution Reactions of Alkanes

In the presence of ultraviolet (UV) light, alkanes undergo **substitution reactions** with halogens. One hydrogen atom is replaced by a halogen atom:

$$CH_4 + Cl_2 \xrightarrow{UV} CH_3Cl + HCl$$

Chloromethane is produced, plus hydrogen chloride. The reaction can continue to give CH_2Cl_2, $CHCl_3$ and CCl_4 if excess chlorine is present. UV light initiates the reaction; it does not occur in the dark.

This is called a substitution reaction because a Cl atom is substituted for an H atom — the number of bonds to carbon does not change.

Alkenes

Alkenes are **unsaturated** hydrocarbons — the C=C double bond means the molecule can add atoms across the double bond without breaking the carbon skeleton.

General formula: C_nH_{2n}

Name	Molecular formula	Condensed formula
Ethene	C_2H_4	$CH_2=CH_2$
Propene	C_3H_6	$CH_3CH=CH_2$
But-1-ene	C_4H_8	$CH_2=CHCH_2CH_3$
But-2-ene	C_4H_8	$CH_3CH=CHCH_3$

Addition Reactions of Alkenes

The C=C double bond opens to allow two new atoms or groups to add — one to each carbon. These are called **addition reactions**.

Hydrogenation (addition of hydrogen)

Alkenes react with hydrogen gas in the presence of a nickel catalyst to form alkanes. This converts liquid unsaturated oils into solid saturated fats (used in margarine manufacture):

$$C_2H_4 + H_2 \xrightarrow{\text{Ni, heat}} C_2H_6$$

Halogenation (addition of a halogen)

Alkenes decolourise bromine water by addition across the double bond:

$$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$$

The orange/brown bromine solution turns **colourless** — this is the standard test for unsaturation.

Hydration (addition of water)

Alkenes react with steam in the presence of a phosphoric acid catalyst to form alcohols. This is the industrial method for making ethanol:

$$C_2H_4 + H_2O \xrightarrow{H_3PO_4\text{, heat, pressure}} C_2H_5OH$$

Addition Polymerisation

Under high pressure and with a catalyst, many alkene monomers link together to form long-chain polymers. The double bond opens and each monomer adds to the chain — covered in detail on the polymers page.

Distinguishing Alkanes from Alkenes

Because alkanes are saturated and alkenes are unsaturated, they can be distinguished using two chemical tests:

Test	Alkane result	Alkene result
Add bromine water	No decolourisation — orange remains	Decolourises — turns colourless
Add acidified potassium manganate(VII)	No change — purple remains	Decolourises — turns colourless

> 📝 **Exam Tip**
> The syllabus states that burning is not an acceptable test to distinguish alkanes from alkenes. Both burn, and although alkenes tend to produce smokier flames, this is not a reliable or acceptable answer. Use the bromine water or acidified KMnO„test.

> 🧠 **Remember**
> **Saturated** means only C–C single bonds — no more atoms can add without breaking. **Unsaturated** means at least one C=C double bond — atoms can add across it. The prefix "un-" signals that the molecule is not full of hydrogen atoms.

Properties, Uses, and Structure

The relationship between structure and reactivity runs through everything in this topic:

Feature	Alkanes	Alkenes
Bonding	Only C–C and C–H single bonds	Contains C=C double bond
Saturation	Saturated	Unsaturated
Typical reaction	Substitution (with halogens, UV light)	Addition (with H, Br, HO)
Reactivity	Relatively low	Higher than alkanes

Main use	Fuels and solvents	Making polymers; feedstocks

Biogas

When organic matter such as animal manure or plant waste decomposes anaerobically (without oxygen), bacteria produce a mixture of gases dominated by methane. This **biogas** can be collected and burned as a fuel. It is a renewable energy source and helps manage agricultural waste.