Petroleum and Cracking

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Petroleum is the raw material from which most fuels and organic chemicals are made. Understanding how it is separated into useful fractions and how those fractions are further processed by cracking connects directly to the properties of alkanes and alkenes studied in the pages that follow.

Sources of Hydrocarbons

Hydrocarbons are compounds that contain only carbon and hydrogen. The two main natural sources are:

Petroleum (crude oil): a complex mixture of hydrocarbons formed over millions of years from the remains of marine organisms under high pressure and temperature. It is the primary source of fuels and petrochemicals worldwide.

Natural gas: consists mainly of methane (CH)„, with smaller amounts of ethane, propane, and butane. Used directly as a fuel and as a source of hydrogen for the Haber process.

Both are **non-renewable** — once used, they cannot be replaced on a human timescale.

Fractional Distillation of Petroleum

Crude oil is a mixture of hundreds of hydrocarbons with different chain lengths and boiling points, so it must be separated before it can be used. Fractional distillation does this continuously.

Crude oil is separated into useful fractions by **fractional distillation**. The crude oil is heated and vapourised; the fractionating column is hotter at the bottom and cooler at the top. As the vapour rises, different fractions condense at different heights according to their boiling points.

Fraction	Approx. boiling point	Carbons	Main uses
Refinery gases	Below 25 °C	C•C„	LPG, cooking fuel, heating
Petrol / gasoline	25–75 °C	C‥C•€	Fuel for motor vehicles

Naphtha	75–120 °C	C–C•€	Feedstock for petrochemicals
Kerosene	120–250 °C	C••C•…	Jet fuel, paraffin heaters
Diesel	250–350 °C	C•–C•‰	Fuel for diesel engines
Fuel oil	350–400 °C	C,€	Ships, power stations
Bitumen	Above 400 °C	C„€	Road surfacing, roofing

Moving from top to bottom of the fractionating column: boiling point increases, carbon chain length increases, viscosity increases, colour darkens, and volatility and flammability decrease.

> 🧠 **Remember**
> The most volatile (easiest to vapourise) fractions collect at the top of the column. The least volatile collect at the bottom. Boiling point correlates with chain length because longer molecules have stronger intermolecular forces.

Cracking

Distillation gives fractions in proportions fixed by the oil's composition, but that composition does not match what is actually needed. There is too much of the heavy fractions and not enough petrol. Cracking corrects this imbalance.

Petroleum contains more long-chain, heavy fractions than the market demands, and fewer short-chain fuels. The heavier fractions are broken apart in a process called **cracking**.

Cracking is the thermal decomposition of large hydrocarbon molecules into smaller, more useful ones. One product is always an **alkene** (which has a C=C double bond and is used in polymer manufacture); the other product is a shorter alkane.

Example:

$$C_{10}H_{22} \rightarrow C_5H_{12} + C_5H_{10}$$

(decane ’pentane + pentene)

Method	Conditions	Notes
Thermal cracking	Very high temperature (~800 °C) and pressure	Produces mainly alkenes
Catalytic cracking	Lower temperature (~500 °C), zeolite catalyst	More selective, more efficient; used industrially

The alkenes produced by cracking are the starting materials for making plastics (polymers) and many other organic chemicals.

Bonding Patterns of Carbon

The reason cracking produces so many different products, and the reason organic chemistry is so vast in general, comes down to something fundamental about carbon itself.

Carbon (Group IV) forms four covalent bonds. This versatility allows it to build:

- **Straight chains:** C–C–C–C–...
- **Branched chains:** chains with side branches
- **Rings:** cyclic structures (e.g. benzene, cyclohexane)
- **Multiple bonds:** single (C–C), double (C=C), triple (C≡C)

The ability of carbon to bond to itself (called **catenation**) and to hydrogen, nitrogen, oxygen, and halogens means millions of distinct organic compounds are possible.