

Splitting crude oil into alkanes and alkenes

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: Crude oil is a mixture of hydrocarbons separated by fractional distillation into fractions with different chain lengths and boiling points. Long chains can be cracked into shorter alkanes and reactive alkenes. Alkanes (C_nH_{2n+2}) are saturated, while alkenes (C_nH_{2n}) contain $C=C$ and decolourise bromine water.

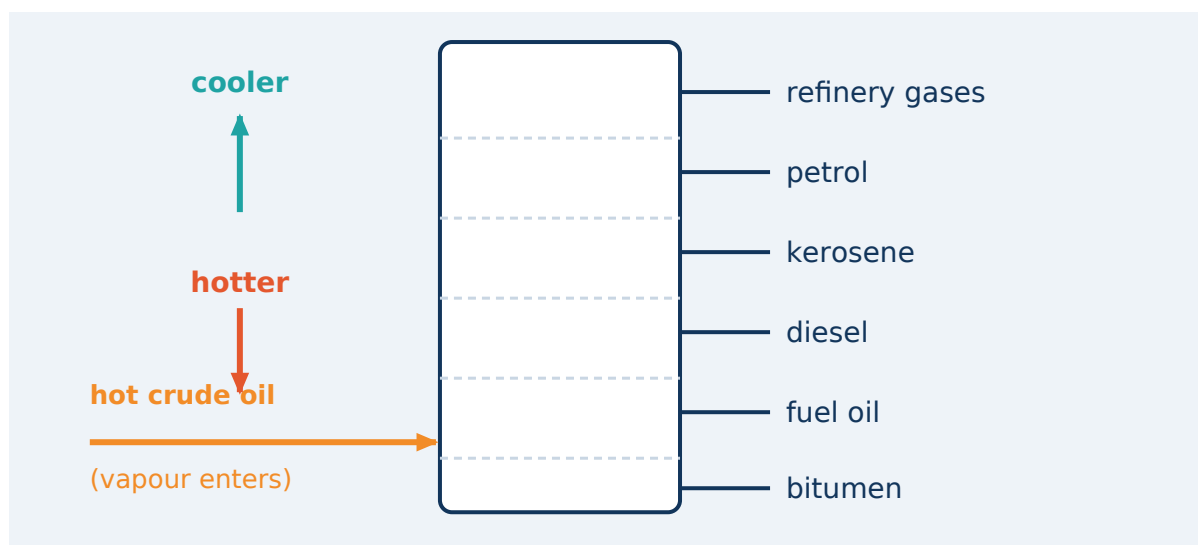
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What is crude oil and how is it separated?

Crude oil is a thick, dark liquid that formed over millions of years from the remains of tiny sea creatures buried under mud and rock. It is a mixture of many hydrocarbons. A hydrocarbon is a compound made of carbon and hydrogen atoms only. Because the molecules differ in size, they have different boiling points, so the mixture can be separated.

Definition **Fractional distillation** separates a mixture of liquids into fractions with different boiling ranges. Each fraction still contains several hydrocarbons of similar chain length.

In a refinery, crude oil is heated until most of it is vapour. The vapour enters a tall column that is hot at the bottom and cooler at the top. As the vapour rises it cools, and each hydrocarbon condenses where the temperature drops below its boiling point. Small molecules reach the top; large molecules condense near the bottom.



Fractional distillation: short chains leave at the cool top, long chains leave at the hot bottom.

Fraction	Carbon atoms (approx.)	Boiling range (approx.)	Typical use
Refinery gases	1 to 4	below 30 °C	heating and cooking gas

Fraction	Carbon atoms (approx.)	Boiling range (approx.)	Typical use
Petrol	5 to 10	40 to 175 °C	car and motorbike fuel
Kerosene	10 to 16	175 to 275 °C	jet fuel, lamps
Diesel	14 to 20	250 to 350 °C	lorries, buses, generators
Fuel oil	20 to 70	350 to 500 °C	ships, power stations
Bitumen	over 70	above 500 °C	road surfaces, roofing

Going down the column, the chains get longer. The boiling point rises, the liquid becomes more viscous (it flows less easily), it becomes harder to ignite and it burns with a smokier flame.

What are alkanes?

Definition

An **alkane** is a saturated hydrocarbon: every carbon-carbon bond is a single bond, so the molecule holds as many hydrogen atoms as possible. The general formula is C_nH_{2n+2} .

The first four alkanes are methane CH_4 , ethane C_2H_6 , propane C_3H_8 and butane C_4H_{10} . Alkanes are fairly unreactive, but they burn well. With plenty of oxygen they undergo complete combustion and form carbon dioxide and water. With too little oxygen they form carbon monoxide or soot (carbon), and carbon monoxide is a toxic gas.

Worked example

Burning 15 g of ethane ($M = 30$ g/mol) completely. Equation: $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$.
Moles of ethane = $15 \div 30 = 0.50$ mol. The ratio ethane : CO_2 is 2 : 4, so $CO_2 = 1.0$ mol.
Mass = $1.0 \times 44 = \mathbf{44 \text{ g of carbon dioxide}}$.

What is cracking and why do refineries do it?

Crude oil contains more long-chain molecules than the market needs, and fewer short, useful ones. **Cracking** breaks long alkane molecules into shorter alkanes and alkenes. It is a thermal decomposition reaction. In catalytic cracking, hot vapour passes over a catalyst such as aluminium oxide or a zeolite at about 550 °C. In steam cracking, the vapour is mixed with steam and heated to a much higher temperature.

Worked example

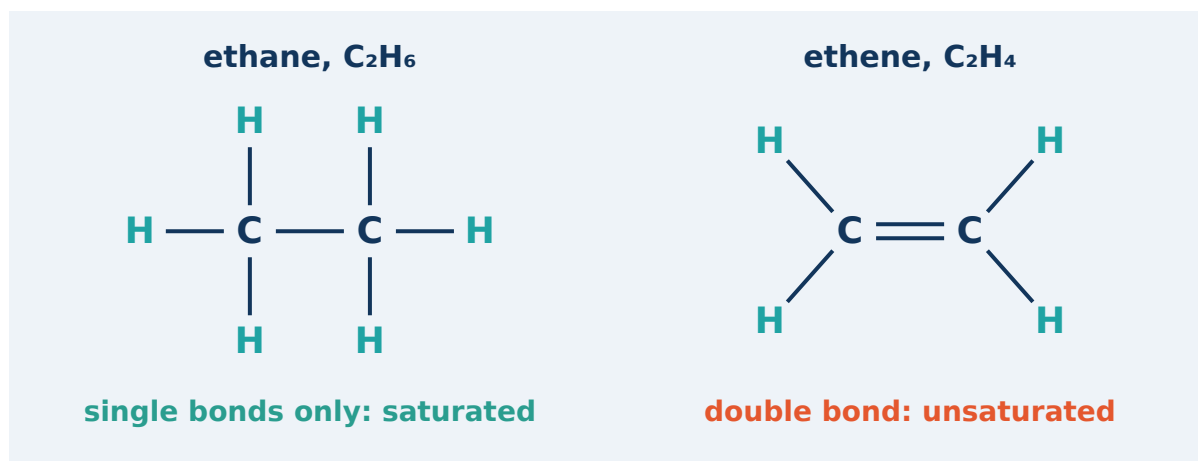
Balance the cracking equation $C_{12}H_{26} \rightarrow C_8H_{18} + ?C_2H_4$. Carbon: $12 - 8 = 4$ carbon atoms left, so two ethene molecules. Check hydrogen: $18 + 2 \times 4 = 26$. The equation is $C_{12}H_{26} \rightarrow C_8H_{18} + \mathbf{2C_2H_4}$.

The shorter alkane is a better fuel. The alkene is a valuable starting material, because alkene molecules can join together to make plastics.

What are alkenes and how do we test for them?

Definition

An **alkene** is an unsaturated hydrocarbon that contains one carbon-carbon double bond (C=C). The general formula is C_nH_{2n} .



Ethane has only single bonds; ethene has a C=C double bond and two fewer hydrogen atoms.

Property	Alkanes	Alkenes
General formula	C_nH_{2n+2}	C_nH_{2n}
Bonding	single bonds only	one C=C double bond
Example	propane C_3H_8	propene C_3H_6
Reactivity	low	higher, because of C=C
Flame	mostly clean	smoky, yellow

To tell them apart, shake the liquid or gas with orange bromine water. An alkene adds the bromine across the double bond, so the orange colour disappears at once. An alkane does not react, so the water stays orange. For ethene: $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$.



Bromine water test: only the alkene decolourises the orange solution.

Common mistake

Alkenes are unsaturated, not saturated: they hold fewer hydrogen atoms than the alkane with the same number of carbons. Do not confuse the two processes either. Fractional distillation is a physical separation and breaks no bonds, but cracking breaks carbon-carbon bonds.

Lina's tip

To get the alkane formula, double the carbon number and add 2. For an alkene, just double the carbon number. Seven carbons: alkane C_7H_{16} , alkene C_7H_{14} .

Key points to remember

- Fractional distillation separates crude oil by boiling point: short chains at the top, long chains at the bottom.
- Alkanes: C_nH_{2n+2} , saturated, single bonds only; alkenes: C_nH_{2n} , one $C=C$ bond.
- Longer chain: higher boiling point, higher viscosity, lower flammability.
- Cracking turns long alkanes into shorter alkanes plus alkenes, using heat and a catalyst or steam.
- Bromine water changes from orange to colourless with an alkene but not with an alkane.

Splitting crude oil into alkanes and alkenes: frequently asked questions

Why can crude oil be separated by fractional distillation?

Crude oil contains molecules of many different sizes, and each size boils at a different temperature. In the column each hydrocarbon condenses at the height where it is cooler than its boiling point, so similar chain lengths collect together.

What is the difference between saturated and unsaturated hydrocarbons?

A saturated hydrocarbon has only single carbon-carbon bonds and the most hydrogen atoms possible. An unsaturated hydrocarbon has at least one $C=C$ double bond, so it holds fewer hydrogen atoms and is more reactive.

Why are long hydrocarbons cracked?

Demand for short fuels such as petrol is higher than the supply from crude oil. Cracking converts surplus long chains into useful shorter alkanes and alkenes, which are raw materials for plastics.

What is the general formula of the alkenes?

It is C_nH_{2n} , so an alkene has twice as many hydrogen atoms as carbon atoms. Ethene is C_2H_4 and butene is C_4H_8 .

Why does a smoky flame show incomplete combustion?

A smoky flame means carbon particles formed because there was not enough oxygen.

Incomplete combustion may also make carbon monoxide, which is toxic and has no smell.