Oil Products

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Section 1: Crude Oil and Alkanes

• What is crude oil and how was it formed?

Crude oil is a dark brown, toxic, foul-smelling, flammable liquid, also known as petroleum (literally rock oil). It is found underground in oil-bearing rocks such as shale. Crude oil is a complex mixture of compounds containing hydrogen and carbon, known as hydrocarbons.

There are several different theories, but the most widely accepted idea is that millions of years ago in warm oceans there were vast numbers of microorganisms. When they died, they were buried under thick layers of mud and they slowly changed into crude oil. Crude oil is thus a fossil fuel, because it was made from living organisms. The timescale for the formation of crude oil is infinitely longer than the rate we are consuming it, therefore it will eventually run out; making crude oil a non-renewable resource.

• Suggested Film

- Fractional Distillation

DIAGRAM 01:

Crude Oil and Natural Gas Formation

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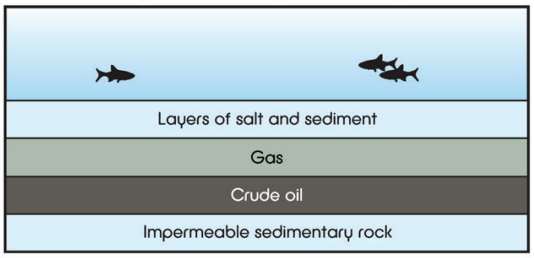
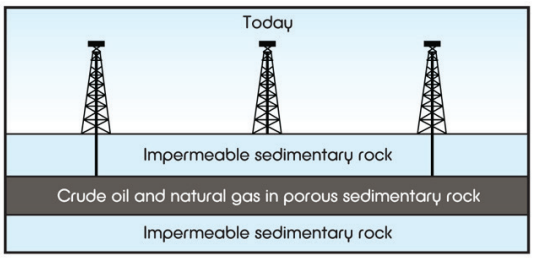
50-100 million years ago tiny microorganisms living in warm seas died and sank to the seabed. Over time they were buried by layers of sediment (sand and mud).



The sea evaporated, leaving layers of salt. Later, more layers of sediment were deposited; heat and pressure turned the microorganisms into crude oil and natural gas.



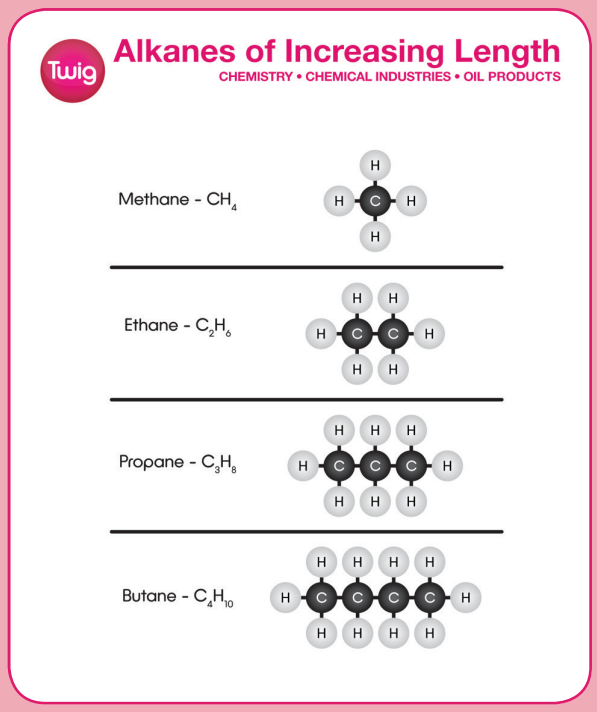
Today, we drill down through layers of impermeable sedimentary rock to reach the reservoirs of crude oil and natural gas trapped in the porous rock beneath.

• What are alkanes?

Long alkane molecule

Alkanes are one of the types of hydrocarbon molecule found in crude oil. They include methane CH_4, ethane C_2H_6, propane C_3H_8, butane C_4H_{10}, pentane C_5H_{12}, hexane C_6H_{14}, heptane C_7H_{16} and octane C_8H_{18}. Each alkane molecule contains n carbon atoms and (2n+2) hydrogen atoms. The carbon atoms form long chains, with each carbon atom having two hydrogen atoms attached, except for the two carbon atoms at the end of the chain, for instance hexane.

DIAGRAM 02:



The varying length of the alkane chains gives them different properties. For instance, bitumen (a semi-solid tar) contains very large alkane molecules, with hundreds of carbon atoms, while the molecules in petrol (a very volatile liquid) contain between 5 and 8 carbon atoms.

Bitumen molecules thus contain far more electrons per molecule than the molecules in petrol. The intermolecular forces between the molecules in bitumen are much stronger than the intermolecular forces between the molecules in petrol, so much more energy is needed to pull them apart. Bitumen has a much higher boiling point, is much more viscous (treacly), and is much less flammable than petrol.

• Suggested Films

- **FactPack: Hydrocarbons**
- **Fractional Distillation**

Extension Question

Q1. What alkane is used in cooking stoves?

The gas that is set alight in a fuel-burning stove (as opposed to an electric stove) is called natural gas. This is mostly methane, which is the alkane with only one carbon atom, along with a small amount of other hydrocarbons included.

• What can we use crude oil for?

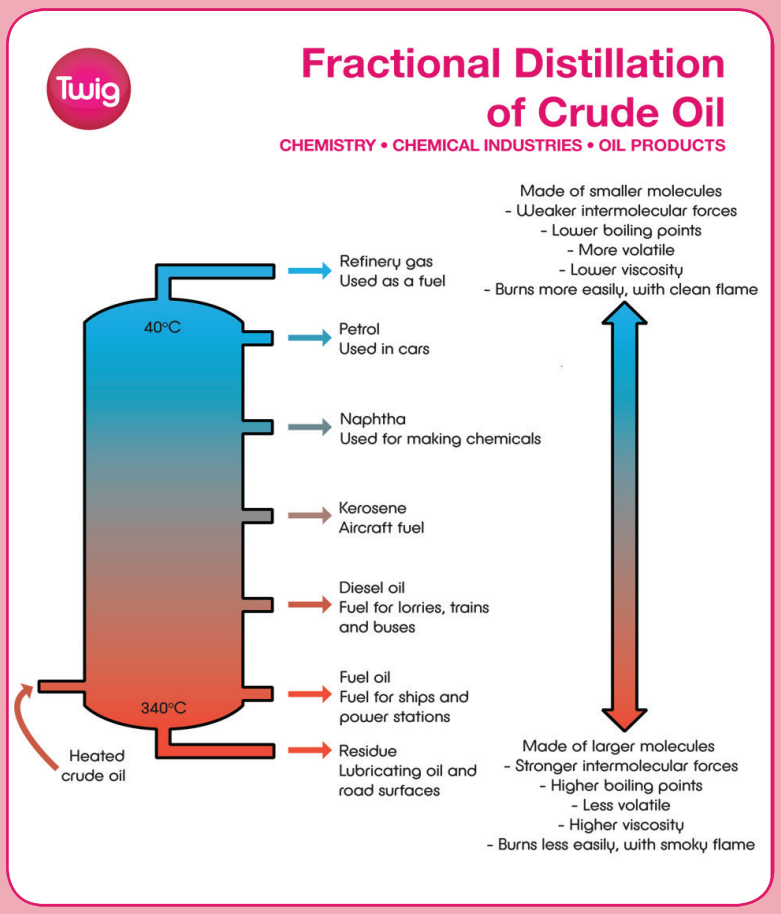
Crude oil itself has no uses, but we can separate it by fractional distillation into 'fractions', liquid mixtures, each with a specific range of boiling points.

During fractional distillation the crude oil is heated and vaporised. It then passes into a tower where it condenses and the vapour turns back into a liquid. The different fractions condense over different ranges of temperatures, because some contain long molecules, and others shorter molecules.

Fractional distillation does not involve breaking any of the covalent bonds between atoms of carbon in the chains. The energy supplied during boiling goes into pulling the molecules apart from each other, and thus in overcoming the intermolecular forces.

The tarmac on roads is a fraction of crude oil

DIAGRAM 03:



Each fraction contains a mixture of alkanes and other molecules of different lengths. The fractions include gasoline (used to make petrol), diesel oil (used in trucks and trains) and bitumen (used on roads and flat roofs). For example, the gasoline fraction, used to make petrol, has molecules with between 5 and 10 carbon atoms.

Fractional distillation is a physical process as no new substances are being made; we are simply separating the existing chemicals in the mixture. We can also carry out chemical reactions on the fractions of crude oil, making new chemicals such as fertilisers, pharmaceutical drugs, detergents, and plastics such as polythene and nylon.

• Suggested Films

- **Leaded and Unleaded Petrol**
- **Fractional Distillation**

• Suggested Activity

- **Discuss: How the different properties of the various fractions of crude oil lend themselves to their uses.**

Section 2: Alkenes and Polymerisation

• How do you make alkenes?

Alkenes can be produced from longer alkanes by the process of cracking. Cracking involves breaking the strong covalent bonds in long alkane molecules. It is carried out at a high temperature with a catalyst. Long alkane molecules are not very useful, but the shorter alkanes can be sold and used as fuels. During cracking, the long alkane molecule breaks into a shorter alkane molecule and an alkene, for example:

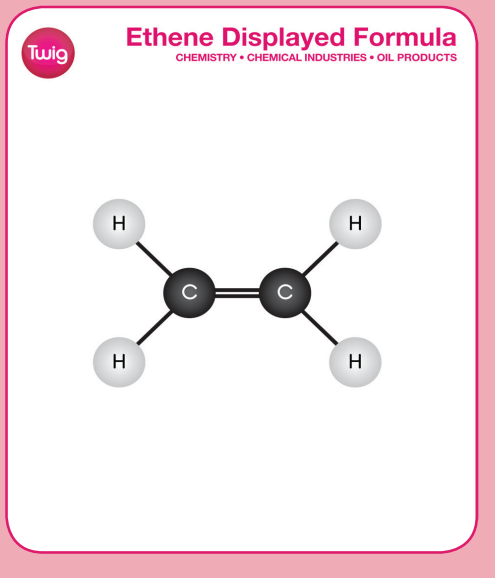
$$C_{20}H_{42} \rightarrow C_2H_4 + C_{18}H_{38}$$

The alkene in this case is ethene C_2H_4, which has a carbon-carbon double bond. Alkene molecules can be made to join together to make very useful materials called addition polymers.

• Suggested Films

- **FactPack: Hydrocarbons**
- **Esters and Perfumes**

DIAGRAM 04:



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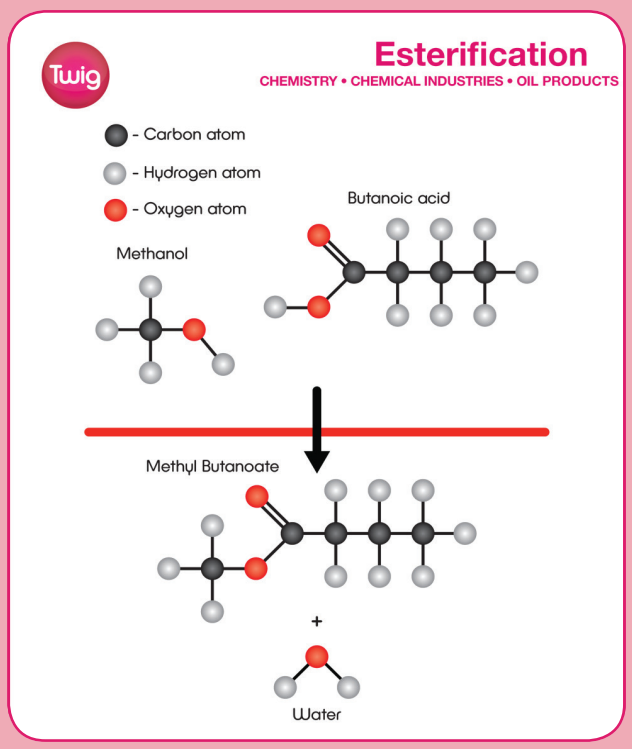

Extension Question

Q2. What are esters?

Esters are another type of hydrocarbon. They are compounds made by reacting an alcohol with a carboxylic acid. For example, methanol and butanoic acid react to make methyl butanoate and water.

Note that in the middle of the molecule there is the O-(C=O) - ester linkage, which joins the alcohol to the acid. Esters always have two names: the first comes from the alcohol ('methyl' from 'methanol'); the second comes from the acid ('butanoate' from 'butanoic acid').

• How are these alkenes useful in making other molecules?

Alkenes can be joined together to make long molecules in a process called addition polymerisation. In addition polymerisation, small alkene molecules, or monomers with carbon-carbon double bonds, are forced to link together to form very long chains called polymers. These can have tens of thousands of carbon atoms in the chains. For example, ethene can be made into poly(ethene), better known as polythene. The polymer molecules can be tens of thousands of atoms long, which is why polymers are solids whereas monomers are gases.

• Suggested Film

- Plastics and Polymers

• Suggested Activity

- Ask students to create ball and stick models to show how the double bond in an alkene can break to form two single bonds in polymerisation.

The plastics used to make these bottles are made up of many, many long polymer molecules

DIAGRAM 06:

Polymerisation of Ethene

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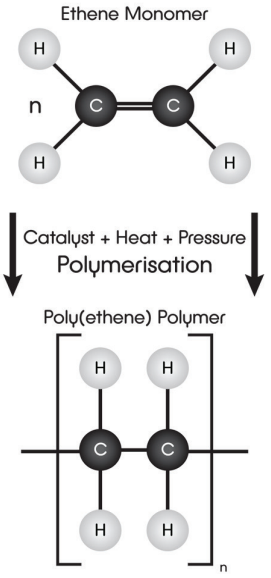

DIAGRAM 07:

Common Polymers

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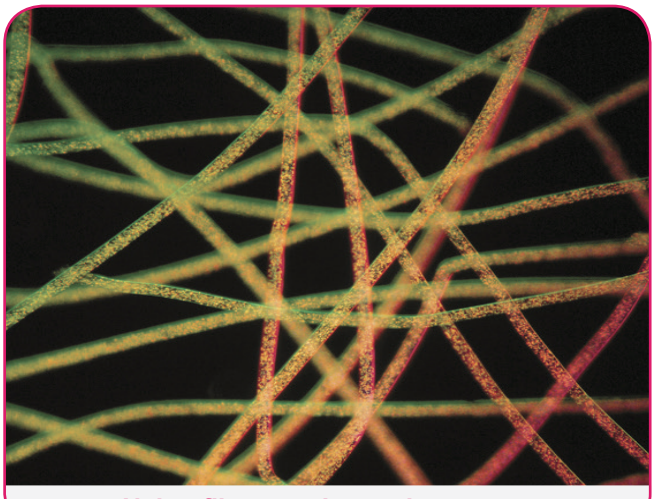
No.	Monomer	Polymer	Uses
(1)	$CH_2=CH_2$ Ethene	$-(CH_2-CH_2)_n-$ Poly(ethene)	Toys, plastic bags, milk bottles
(2)	 Chloroethene (Vinyl Chloride)	 Poly(chloroethene) Polyvinyl Chloride (PVC)	Flooring tiles, raincoats, handbags, drainpipes, window frames
(3)	$CF_2=CF_2$ Tetrafluoroethene	$-(CF_2-CF_2)_n-$ Poly(tetrafluoroethene) Teflon	Non-stick cooking vessels, corrosion-resistant tubing, low-friction bearings, electrical insulation

• What is nylon?

Nylon is a polymer made by reacting two monomer molecules **A** and **B** together. This is not the same as addition polymerisation, as the molecules do not have double bonds. Each of these molecules has reactive groups at BOTH ends, and when they react they make a long chain of repeating units, **ABABABAB**….. Nylon is a remarkably strong, lightweight material. It can be drawn into threads and used to make many useful products such as fabrics and ropes.

• Suggested Films

- **Plastics and Polymers**
- **Invention of Nylon**



Nylon fibres under a microscope

Section 3: Hydrocarbons and the Environment

• How easy is it to recycle plastics?

Crushed plastics ready for recycling

Ideally we should recycle all our plastic waste, but in practice it is quite difficult to do so. Firstly, all plastics may look similar, but poly(ethene), poly(propene) and poly(chloroethene) or PVC are very different chemically, and we cannot melt them all down into a single substance called 'plastic'. Separating them is therefore quite costly as it needs considerable expertise. Secondly, the plastics have to be washed, which can cause water pollution. Even if the plastics are separated and melted down, heating them can cause them to decompose, and they may even release toxic gases as they do so.

An alternative to recycling is to burn the plastics, and use the heat to generate electricity. The problems with this are that burning makes the greenhouse gas carbon dioxide. Toxic gases such as carbon monoxide, hydrogen chloride (from PVC) and hydrogen cyanide (from nylon) may also be generated.

• Suggested Film

- Recycling Plastics

• Are vegetable oils an alternative to petrol as a fuel?

Vegetable oils have several useful properties. They are a renewable resource (we can always grow more oil producing plants, so it should not run out). Their use as fuels is, in theory, carbon neutral, as the plant takes in carbon dioxide during photosynthesis, and this offsets the carbon dioxide that is made when the oil burns.

However, when vegetable oil burns, it still makes some carbon dioxide. Moreover, if we use land to grow vegetable oil plants there will be less land to grow food crops. Forests may be cut down to grow the oil-producing crop, and this will increase greenhouse gases released into the air. Finally, the use of vegetable oil as a fuel may push up its price, making it harder for poor people to buy cooking oil. So the overall balance must be considered.

• Suggested Film

- Vegetable Oils As Fuels

• Quizzes

Fractional Distillation

Basic

• The colour of crude oil is

A – clear
B – yellow
C – brown
D – green

• Crude oil is a mixture consisting mainly of

A – acids
B – alcohols
C – hydrocarbons
D – esters

• Fractional distillation is able to separate the fractions because

A – they have different colours
B – they have different smells
C – they have different boiling points
D – they have different uses

• The fractionating column is

A – hot at the bottom, cool at the top
B – cool at the bottom, hot at the top
C – cool at the top and bottom, hot in the middle
D – hot at the top and bottom, cool in the middle

Advanced

• Distillation involves

A – heating a liquid, then cooling a vapour
B – heating a vapour, then cooling a liquid
C – cooling a liquid, then heating a vapour
D – cooling a vapour, then heating a liquid

• The longer the chain of carbon atoms in the molecule

A – the lower the melting point
B – the higher the boiling point
C – the lighter the colour of the fraction
D – the more easily the fraction evaporates

• Decane boils at a higher temperature than methane because it

A – has more bonds than methane
B – has a darker colour than methane
C – has a longer chain of carbon atoms than methane
D – has a higher percentage of carbon than methane

• Which of these compounds is the most likely to condense near the BOTTOM of the fractionating column?

A – CH_4
B – C_3H_8
C – $C_{10}H_{22}$
D – $C_{30}H_{62}$

• Answers

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