Crude oil and fuels Chemistry Revision materials

Content will be tested in Chemistry Paper 2

Checklist

Key points:	☺	☹
Crude oil and fuels		
What crude oil is made up of		
What are alkenes and how they represented		
How the volatility, viscosity and flammability of hydrocarbons are affected by the size of the chain		
How is crude oil separated into fractions		
Explain the separation of crude oil by separation		
How are the fractions used		
Know the products of combustion		
How to test for the products of combustion		
Explain why carbon monoxide gas is given off when incomplete combustion occurs		
Hoe and why larger, less useful hydrocarbon molecules are cracked into smaller molecules		
Conditions needed for cracking		
What are alkenes and how are they different to alkanes		

Crude oil, hydrocarbons and alkanes

Crude oil is a **finite resource** found in rocks. Crude oil is the remains of an **ancient biomass** consisting mainly of **plankton** that was **buried in mud**.

Crude oil is a mixture of a very large number of compounds.

Most of the compounds in crude oil are **hydrocarbons**, which are **molecules** made up of **hydrogen and carbon only.**

Alkanes

Most of the hydrocarbons in crude oil are hydrocarbons called **alkanes**. The general formula for the homologous series of alkanes is $\mathbf{C_nH_{2n+2}}$.

Alkanes are known as saturared hydrocarbons. All the carbon-carbon bonds are single covalent bonds. This means that they contain as many hydrogen atoms as possible in each molecule.

Task

Draw the covalent bond for Methane (CH_4)

The first four members of the alkanes are methane, ethane, propane and butane after this they follow shape names e.g pentane (pentagon 5 sided shape)

Prefix	Number of carbon atoms
Meth-	1
Eth-	2
Pro-	3
But-	4
Pent-	
Hex-	
Hept	
Oct-	
Non-	
Dec	

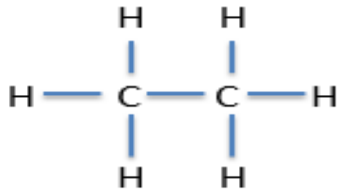
Worked examples

Methane has one carbon atom so it's formula will be $\mathbf{C_1H_{(2x1)+2}}$ this gives $\mathbf{CH_4}$

Butane has four carbon atoms so it's formula will be $\mathbf{C_4H_{(2x4)+2}}$ this gives $\mathbf{C_4H_{10}}$

You will be expected to know the names and formulae of these first four alkanes. You will be expected to calculate the formulae of alkanes with more than four carbons.

Ethane



Task

Draw the following alkanes

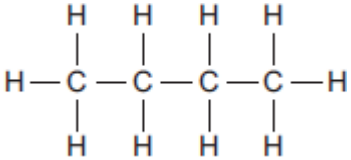
Butane

Octane

Decane

Exam practice 1

Q1. Butane is represented as:



(i) Use the correct answer from the box to complete each sentence.

bond	compound	helium	hydrogen	mixture	oxygen

Butane is a ..... .

Butane contains atoms of carbon and ..... .

Each line between the atoms in butane represents a chemical

..... .

(3)

(ii) Which is the correct formula for butane?

Tick (✓) **one** box.

C_4H_4 ☐

C_4H_8 ☐

C_4H_{10} ☐

(1)

Q2. Octane is a *hydrocarbon.*

(i) What does *hydrocarbon* mean?

.....

.....

(1)

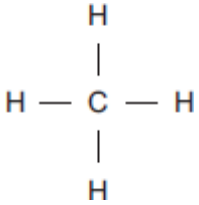
(ii) Give the molecular formula of octane.

.....

(1)

Q3. Methane (CH_4) is used as a fuel.

(a) The displayed structure of methane is:



Draw a ring around a part of the displayed structure that represents a covalent bond.

(1)

(b) Why is methane a compound?

Tick (✓) **one** box.

Methane contains atoms of two elements, combined chemically. ☐

Methane is not in the periodic table. ☐

Methane is a mixture of two different elements. ☐

(1)

Q5. This question is about organic compounds.

Hydrocarbons can be cracked to produce smaller molecules.

The equation shows the reaction for a hydrocarbon, $C_{18}H_{38}$

$$C_{18}H_{38} \rightarrow C_6H_{14} + C_4H_8 + 2\,C_3H_6 + C_2H_4$$

(a) Which product of the reaction shown is an alkane?

Tick **one** box.

C_2H_4 ☐

C_3H_6 ☐

C_4H_8 ☐

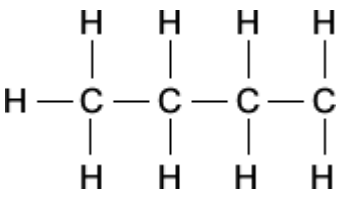
C_6H_{14} ☐

(1)

Q6. Crude oil is a mixture of hydrocarbons. Most of these hydrocarbons are alkanes.

(a) The general formula of an alkane is C_nH_{2n+2}

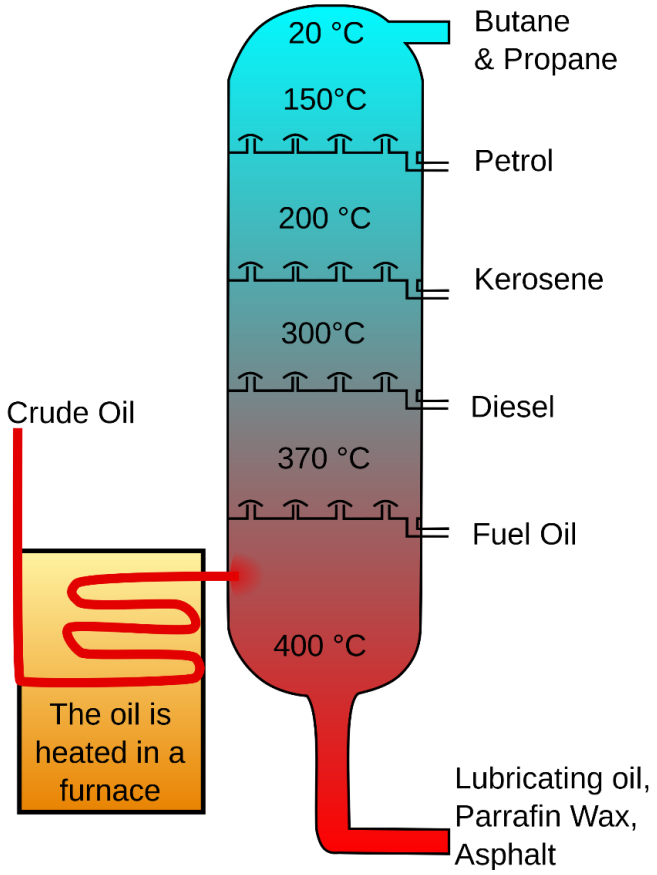
Complete the structural formula for the alkane that has **six** carbon atoms in its molecules.



(1)

Fractional distillation

The many hydrocarbons in crude oil may be separated into **fractions**, each of which contains molecules with a **similar number of carbon atoms** by fractional distillation



Look at the diagram on the above all the hydrocarbon molecules in the highest fraction – **liquefied petroleum gases** will have between **1 and 4 carbons**. All the hydrocarbon molecules in **petrol** will have between **5 and 9 carbons**.

Crude oil is heated up from the bottom and fed in the bottom called a fractionating column as hot vapour. The column is kept hot at the bottom and much cooler at the top, so the temperature decreases going up the column. The gases move up the column and the hydrocarbons condense when they reach the temperature of their boiling points. The different fractions are collected as liquids at different levels. The fractions are collected from the column in a continue process.

Some properties of hydrocarbons depend on the **size of their molecules**, including:

- **Boiling point –** The temperature at which the liquid boils or the gas condenses
- **Volatility –** The tendency to turn to a gas
- **Viscosity –** How easy it flows
- **Flammability -** How easy it burns

These change with increasing molecular size.

Small chain molecules	Long chain molecules
Low boiling point	High melting point
High volatility	Low volatility
Low viscosity	High viscosity
Higher flammability	Higher flammability

The fractions produced in fractional distillation can be processed to produce fuels e.g. petrol, and feedstock (reactants for further chemical reactions) for the petrochemical industry.

Examples of these useful materials are:

- **Solvents** – nail varnish remover
- **Lubricants** – oil for car engines
- **Polymers** – polythene and **p**oly**v**inyl **c**hloride PVC
- **Detergents** – washing up liquid

Exam practice 2

Q1.

Crude oil is a mixture of hydrocarbons.

(a) Name the **two** elements in a hydrocarbon.

1. _____

2. _____

(2)

(b) What was crude oil formed from?

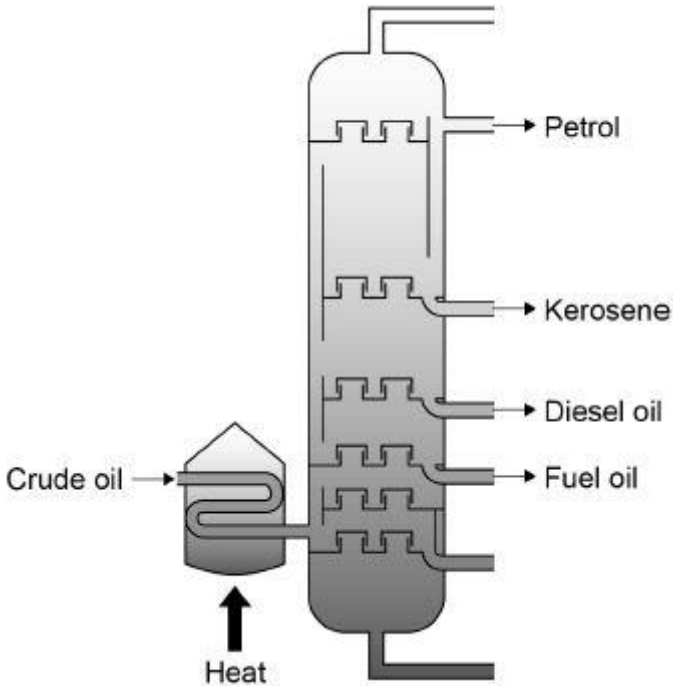
Tick **one** box.

- Acids ☐
- Enzymes ☐
- Metals ☐
- Plankton ☐

(1)

Figure 1 shows how crude oil is separated to produce different fuels.

Figure 1



(c) What is the name of this process?

Tick **one** box.

- Combustion ☐
- Fractional distillation ☐

Phytomining ☐

Steam cracking ☐

(1)

(d) Why is the crude oil heated?

_____

_____

(1)

The table below shows some properties of the fuels produced by the process.

Fuel	**Number of carbon atoms in chain**	**Lowest boiling point in °C**	**Highest boiling point in °C**
Petrol	5−10	20	200
Kerosene	10−16	180	260
Diesel oil	14−20	260	340
Fuel oil	20−70	370	600

(e) Which of the fuels has the largest boiling point range?

Tick **one** box.

Petrol ☐

Kerosene ☐

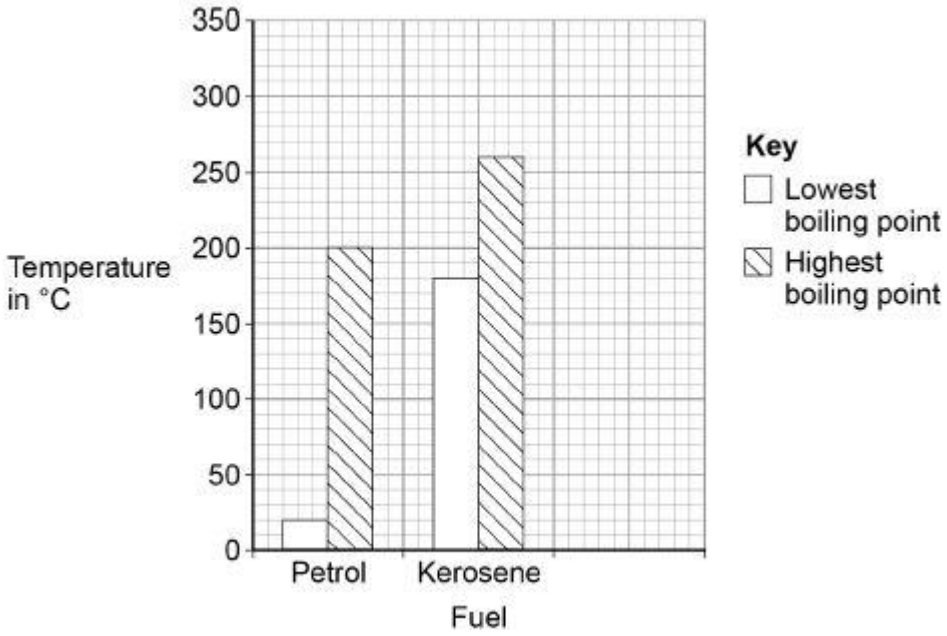
Diesel oil ☐

Fuel oil ☐

(1)

(f) Plot the data for diesel oil from the table on **Figure 2**.

Figure 2



(3)

(Total 9 marks)

Q2.

Crude oil is a fossil fuel.

(a) To make crude oil more useful it is separated into fractions.

Use the correct word from the box to complete each sentence.

boiling	**compound**	**decomposition**	**distillation**
	filtration	**mixture**	**molecule**

(i) Crude oil is a _____ of different substances.

(1)

(ii) The substances in crude oil have different

_____ points.

(1)

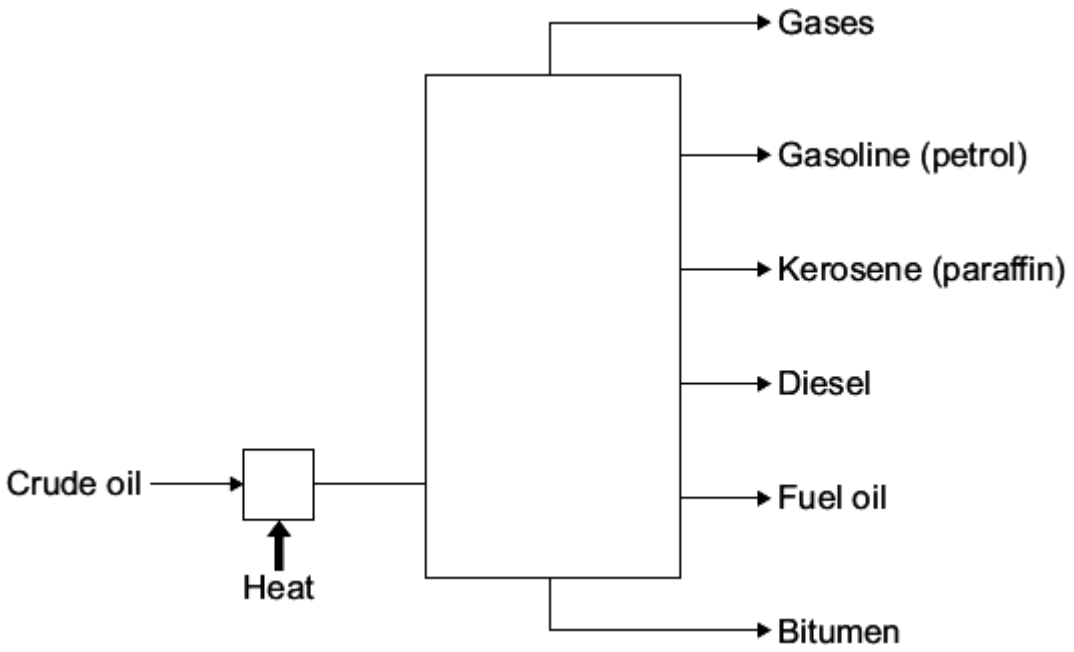
(iii) Crude oil is separated by fractional _____ .

(1)

Q3.

Crude oil is used to produce many useful materials.

(a) The diagram shows some of the fractions produced from crude oil by fractional distillation.



Use the diagram to help you to explain how crude oil is separated into fractions.

You should use the words evaporated and condensed in your answer.

(3)

(b) The table shows some information about four of the fractions from crude oil that are used as fuels.

Fraction	Boiling point in °C	Number of carbon atoms found in the molecules
Gasoline (petrol)	20 - 200	5 - 10
Kerosene (paraffin)	180 - 260	10 - 16
Diesel	260 - 340	14 - 20
Fuel oil	370 - 600	20 - 70

Use the information in the table to help you to answer these questions.

(i) How can you tell that each of the fractions is a mixture?

_____

_____

(1)

(ii) How does the number of carbon atoms in a molecule affect its boiling point?

_____

_____

(1)

(Total 8 marks)

Q4.

Crude oil is a mixture of hydrocarbons.

Hydrocarbons can be used as fuels.

(a) One alkane hydrocarbon contains 34 hydrogen atoms.

What is the formula of the hydrocarbon?

Tick **one** box.

$C_{15}H_{34}$ ☐

$C_{16}H_{34}$ ☐

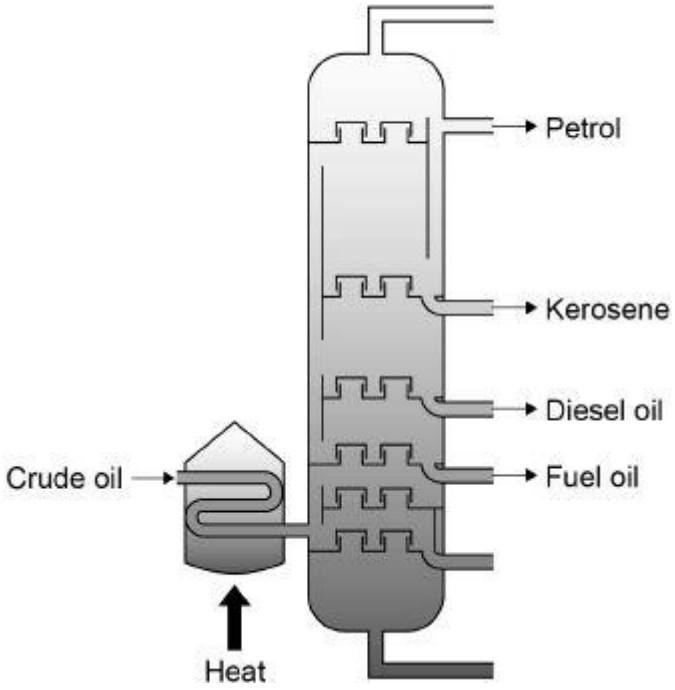
$C_{17}H_{34}$ ☐

$C_{18}H_{34}$ ☐

(1)

(b) **Figure 1** represents a fractionating column used to separate crude oil.

Figure 1



Describe how crude oil is separated using fractional distillation.

(4)

(d) Some fuels are obtained from plants.

Evaluate the environmental impact of fuels obtained from plants and from crude oil.

_____

_____

_____

(4)

Q5.

Crude oil is a mixture of many different chemical compounds.

The table shows information about four compounds that can be obtained from crude oil.

Compound	**Chemical formula**	**Melting point in °C**	**Boiling point in °C**
Decane	$C_{10}H_{22}$	–30	+174
Ethene	C_2H_4	–169	–104
Icosane	$C_{20}H_{42}$	+37	+343
Methane	CH_4	–183	–164

(a) Which compound in the table is a liquid at room temperature (20 °C)?

Tick **one** box.

Decane ☐

Ethene ☐

Icosane ☐

Methane ☐

(1)

(b) Which compound in the table has the highest viscosity?

Tick **one** box.

Decane ☐

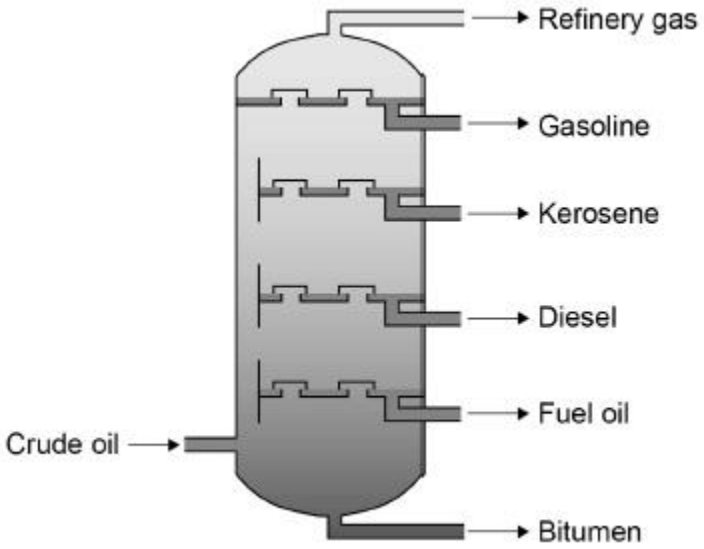
Ethene ☐

Icosane ☐

Methane ☐

(1)

(d) The diagram shows the separation of crude oil in a fractionating column.



Explain how crude oil is separated into different fractions by fractional distillation.

(6)

(Total 9 marks)

Combustion

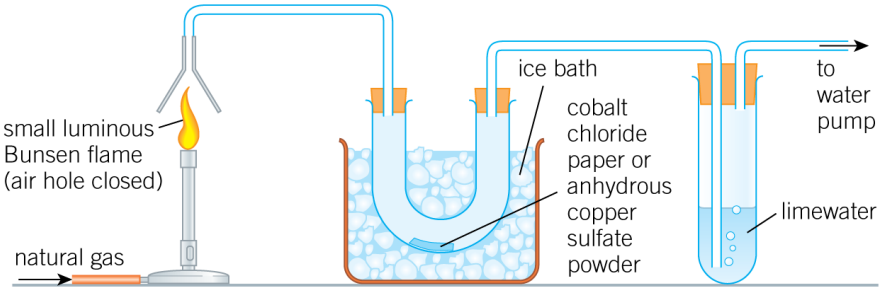
Complete combustion

The **combustion** of hydrocarbon fuels releases energy. During combustion, the carbon and hydrogen in the fuels are **oxidised**. The **complete combustion** of a hydrocarbon produces **carbon dioxide** and **water** e.g.

Methane + oxygen → carbon dioxide + water

$$\mathbf{CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + H_2O(l)}$$

To make carbon dioxide and water all of the carbon and hydrogen bonds must break, these will then make carbon and oxygen bonds for carbon dioxide i.e. the **carbon is oxidised** and hydrogen and oxygen bonds for the water i.e. the **hydrogen is oxidised**.



You must be able to write **balanced equations** for the complete combustion of hydrocarbons with a given formula.

Worked Example

What is the balanced symbol equation for the combustion of C_9H_{20}

$$\mathbf{C_{11}H_{24} + 17O_2 \rightarrow 11CO_2 + 12H_2O}$$

The number in front of **CO_2 is always the subscript from the alkane for carbon** e.g. 11

The number in front of **H_20 is always half the subscript from the alkane for hydrogen** e.g. 12

We then **add up the number of oxygen atoms** we now have as products e.g. 22 from CO_2 and 12 from H_2O which gives 34, we then **put half this number in front of O_2** e.g. $17O_2$

Task

Nonane C_9H_{20} was combusted in oxygen to produce carbon dioxide and water. Write the balanced symbol equation for this reaction

Incomplete combustion

Occurs when fuel is burnt in limited oxygen

The products made are carbon monoxide and water and particulates (soot):

Methane + limited supply of oxygen → carbon monoxide + water

Carbon monoxide (CO) is produced instead of Carbon dioxide ($C0_2$).

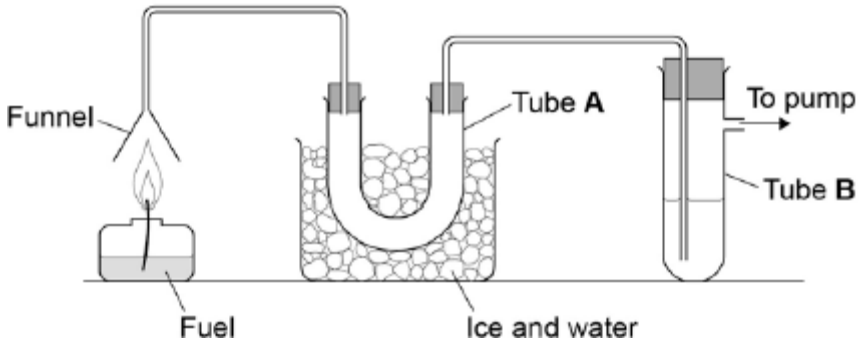
Carbon monoxide is toxic gas. It is colour less and odourless. Your red blood cells pick up this gas and carry it around your body rather than oxygen.

Exam practice 3

Q1.

A student investigated the substances produced when fuels burn.

The figure below shows the apparatus the student used.



(a) The complete combustion of a hydrocarbon produces carbon dioxide and one other substance.

Look at the figure above. What would the student see in tube **A**?

_____

_____

(1)

(b) When the student burned the fuel she saw soot in the funnel.

Explain why soot forms.

_____

_____

_____

_____

(2)

Q2.

Petrol is a hydrocarbon fuel.

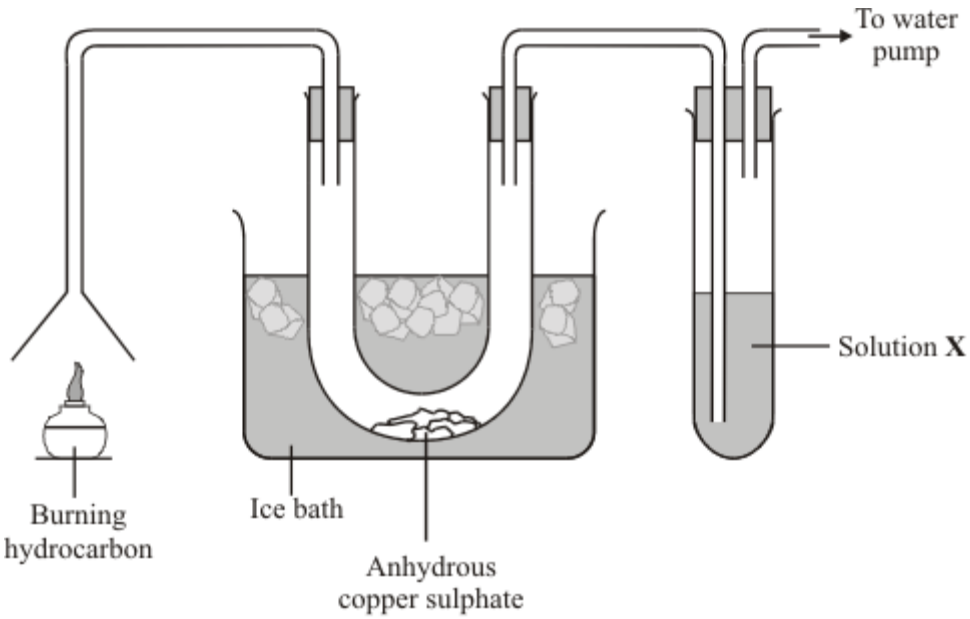
(a) Complete this sentence.

Hydrocarbons are compounds which are made from the elements _____

and _____ only.

(2)

(b) This apparatus was used to study the combustion of a hydrocarbon fuel.



(i) Name the substance which changed the anhydrous copper sulphate from white to blue.

_____

(1)

(ii) Carbon dioxide is also produced when the hydrocarbon fuel is burned.
Name the solution, labelled **X** on the diagram, which tests for carbon dioxide.

_____

(1)

(iii) Complete this sentence.

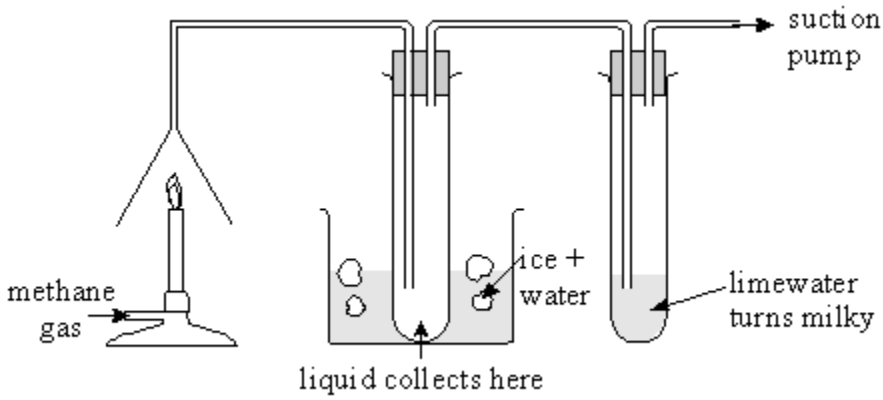
Carbon dioxide turns solution **X**

_____ .

(1)

Q3.

Methane CH_4 contains the elements carbon and hydrogen only. A student wanted to find out which new substances are produced when methane is burned. The student set up the apparatus shown below.



(a) Which gas in the air reacts with methane when it burns?

_____

(1)

(b) Name the liquid collected.

_____

(1)

(c) Name the gas which turns limewater milky.

_____

(1)

(d) When methane burns an exothermic reaction takes place. What is meant by an exothermic reaction?

_____

_____

(2)

(Total 5 marks)

Q4.

A burning torch is carried by a runner.

The fuel in the torch is a mixture of propane and butane.

Propane and butane are alkanes.

Alkanes have the general formula C_nH_{2n+2}

(c) Complete the word equation for the complete combustion of butane.

butane + oxygen → _____ + _____

(1)

(d) In earlier designs of the torch, propene (C_3H_6) was used as the fuel.

Smoke is produced when propene is burned.

Explain why smoke is produced.

_____

_____

_____

_____

(2)

(Total 5 marks)

Q5.

b) Propane is a fuel because it burns in air releasing heat energy.

(i) Complete the balancing of the two chemical equations for propane burning in air.

$2C_3H_8$ + _____ O_2 → _____ CO_2 + _____ H_2O

$2C_3H_8$ + _____ O_2 → _____ CO + _____ H_2O

(2)

(ii) The products of the two chemical reactions in (b)(i) are different.

Explain why.

_____

_____

_____

_____

_____

(2)

Cracking and alkenes

Alkenes

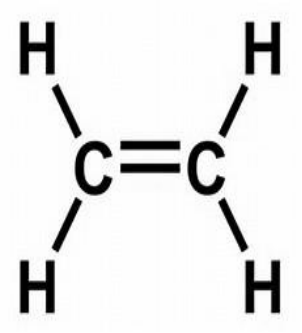
We already know that alk**anes** have the general formulae C_nH_{2n+2}

Alk**enes** are hydrocarbons with a **double carbon-carbon bond**. Unsaturated compounds contain at least one double bond. The general formula for the homologous series of alkenes is C_nH_{2n}

The first four members of the alkanes are ethene, propene, butene and pentene.

There is no chemical called methene, as the double bond must be between two carbons. Any hydrocarbon starting with meth- can only have one carbon.

Ethene



Task

Complete the table below

Name	Formula	Structure
Propene		
Butene		
Pentene		

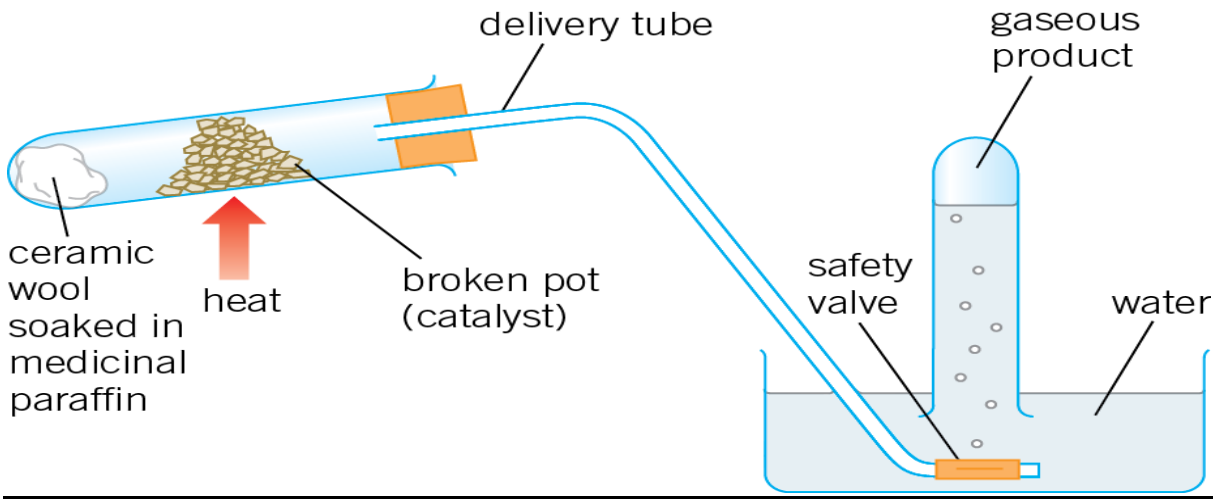
Cracking

Hydrocarbons can be broken down (cracked) to produce smaller **more useful** molecules.

- **Cracking** is the **breaking down** of **long chain hydrocarbons** to **shorter** more **useful hydrocarbons chains**.
- There is a **higher demand** for **short** chain hydrocarbons as they make **good fuel** whereas long chain hydrocarbons aren't very useful.
- Cracking produces **two products**, **alkanes** and **alkenes**.
- Alkenes are also hydrocarbons.

$C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$

The two products made are both more useful than the starting hydrocarbon, but notice that there are always the **same number** of carbons and hydrogens on the left hand side of the equation and on the right hand side.



Two types of cracking

Cracking is a **thermal decomposition** reactions – breaking down using thermal energy.

A catalyst speeds up the rate of chemical reaction, but is not used up itself during the reaction. It remains chemically unchanged.

Catalytic cracking

1. **Heat** long chain hydrocarbons to **vaporise** them.
2. **Vapour** is passed over **hot** powdered aluminium oxide **catalyst**.
3. Long chain hydrocarbons **split apart** on the **surface** of the catalyst.

Steam cracking

1. **Heat** long chain hydrocarbons to **vaporise** them.

2. **Mix** the vapours with **steam**
3. **Heat** to a very high temperature.

<u>Distinguishing between alkanes and alkenes using a simple chemical test.</u>

Alkanes and alkenes can be distinguished using a simple chemical test.

Bromine water is a dilute solution of bromine that is normally orange-brown in colour, but becomes colourless when shaken with an alkene. Alkenes can decolourise bromine water, while alkanes cannot.

Exam practice 4

Q1.

(a) The hydrocarbon $C_{16}H_{34}$ can be cracked.

Balance the equation for cracking $C_{16}H_{34}$

$C_{16}H_{34} \rightarrow$ _____ $C_2H_4 + C_8H_{18}$

(1)

(b) Describe the differences between cracking and distillation.

_____

_____

_____

_____

(2)

(c) What type of reaction is cracking?

Tick **one** box.

Combustion ☐

Decomposition ☐

Neutralisation ☐

Precipitation ☐

(1)

Q2.

This question is about hydrocarbons.

(a) Most of the hydrocarbons in crude oil are alkanes.

(i) Large alkane molecules can be cracked to produce more useful molecules.

The equation shows the cracking of dodecane.

$$\underset{\text{dodecane}}{C_{12}H_{26}} \longrightarrow \underset{\text{butane}}{C_4H_{10}} + \underset{\text{hexene}}{C_6H_{12}} + \underset{\text{ethene}}{C_2H_4}$$

Give **two** conditions used to crack large alkane molecules.

1. _____

2. _____

(2)

(ii) The products hexene and ethene are alkenes.

Complete the sentence.

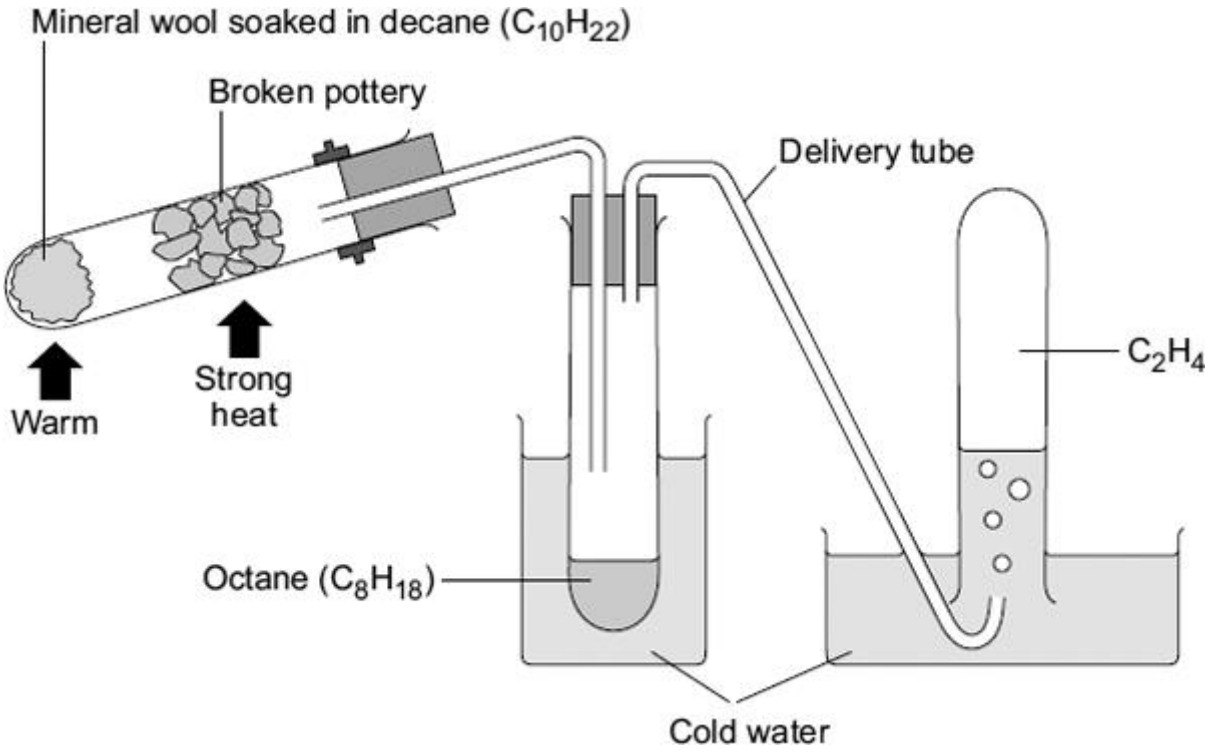
When alkenes react with bromine water the colour changes from orange to _____ .

(1)

Q3.

Hydrocarbons are cracked to produce smaller molecules.

The diagram shows an experiment to demonstrate cracking.



Describe the process of cracking shown in the diagram.

_____

_____

_____

_____

_____

_____

_____

(Total 4 marks)

Q4.

This question is about crude oil.

(a) The table shows information about crude oil fractions.

Crude oil fraction	Number of carbon atoms	Approximate percentage (%) in crude oil	Approximate percentage (%) demand
Gas	1–4	3	4
Petrol	5–10	9	23
Naphtha	8–12	10	5
Kerosene	9–16	14	8
Diesel	15–25	16	22
Residue	20–30+	48	38

Explain the advantage of cracking hydrocarbons.

Give **one** example from the table.

_____

_____

_____

_____

_____

_____

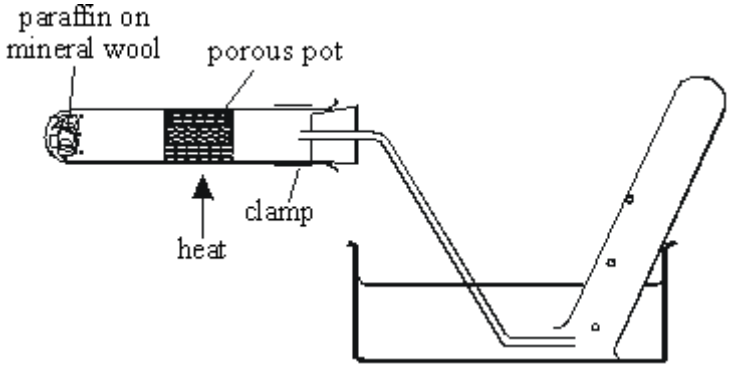
(3)

Q5.

Crude oil is a mixture of a large number of compounds most of which are hydrocarbons

(c) The cracking of large molecules obtained from crude oil is one of the important processes in an oil refinery. Cracking involves the thermal decomposition of large molecules. The diagram below shows an apparatus

that can be used to demonstrate cracking in the laboratory. The porous pot acts as a catalyst in the reaction.



(i) What happens during thermal decomposition?

_____

_____

_____

(2)

(ii) What effect does the porous pot catalyst have on the reaction?

_____

_____

(1)

(iii) Complete the equation below for the cracking of the molecule. $C_{20}H_{42}$.

$C_{20}H_{42} \rightarrow C_{12}H_{26}$ + _____

(1)

(Total 6 marks)

Q6.

(c) Dodecane ($C_{12}H_{26}$) from crude oil is cracked to produce ethene (C_2H_4).

(i) Complete the equation for this reaction.

$C_{12}H_{26} \longrightarrow 2\ C_2H_4$ + _____

(1)

(ii) Give **two** conditions needed for cracking.

1._____

2. _____

(2)

(Total 9 marks)