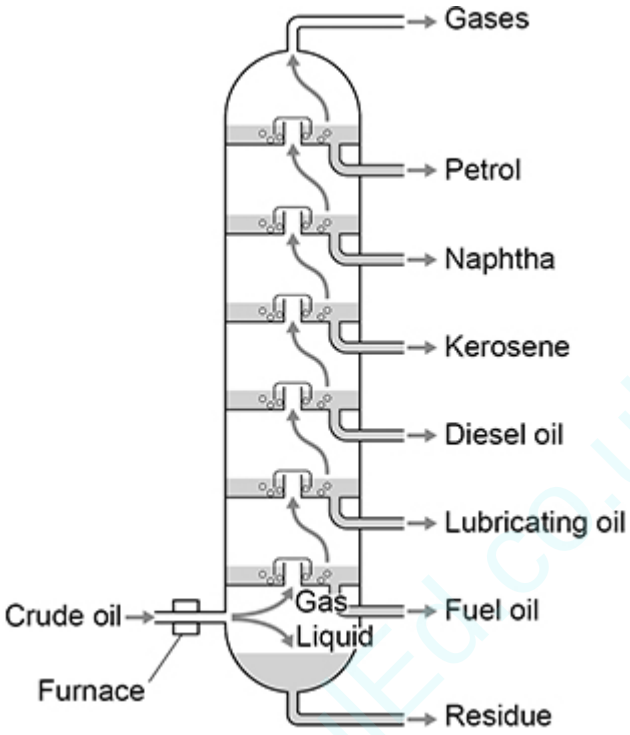
Q1.

The diagram shows a fractionating column used in the industrial fractional distillation of crude oil.



Which statement is correct?

A The most viscous product is fuel oil. ⬭

B The boiling point of naphtha is higher than diesel oil. ⬭

C Molecules in diesel oil are held together by hydrogen bonds. ⬭

D Kerosene is a mixture of compounds. ⬭

(Total 1 mark)

Q2.

Which statement is correct about the fractional distillation of crude oil?

A A zeolite catalyst is used. ⬭

B Each fraction contains a mixture of hydrocarbons. ⬭

C Gaseous fractions are formed by breaking covalent bonds. ⬭

D The fractionating column is hottest at the top. ⬭

(Total 1 mark)

Q3.

Which statement is **not** correct about the pollutant sulfur dioxide?

A It can be removed from car exhaust gases by a catalytic converter. ⬭

B It can be removed from power station flue gases by reaction with calcium oxide. ⬭

C It can cause respiratory problems. ⬭

D It can cause acid rain. ⬭

(Total 1 mark)

Q4.

Alkanes are used as fuels. A student burned some octane (C_8H_{18}) in air and found that the combustion was incomplete.

(a) (i) Write an equation for the incomplete combustion of octane to produce carbon monoxide as the only carbon-containing product.

_____

(1)

(ii) Suggest **one** reason why the combustion was incomplete.

_____

_____

(1)

(b) Catalytic converters are used to remove the toxic gases NO and CO that are produced when alkane fuels are burned in petrol engines.

(i) Write an equation for a reaction between these two toxic gases that occurs in a catalytic converter when these gases are removed.

_____

(1)

(ii) Identify a metal used as a catalyst in a catalytic converter.
Suggest **one** reason, other than cost, why the catalyst is coated on a ceramic honeycomb.

Metal _____

Reason _____

_____

(2)

(c) If a sample of fuel for a power station is contaminated with an organic sulfur compound, a toxic gas is formed by complete combustion of this sulfur compound.

(i) State **one** environmental problem that can be caused by the release of this gas.

_____

_____

(1)

(ii) Identify **one** substance that could be used to remove this gas.
Suggest **one** reason, other than cost, why this substance is used.

Substance _____

Reason why used _____

_____

(2)

(Total 8 marks)

Q5.

(a) (i) Name the process used to separate petroleum into fractions.

_____

(ii) Give the molecular formula for an alkane with nine carbon atoms.

_____

_____

(iii) Write an equation for the complete combustion of the alkane $C_{11}H_{24}$

_____

(iv) Write an equation for the incomplete combustion of $C_{11}H_{24}$ to produce carbon and water only.

_____

(4)

(b) Alkenes can be produced by cracking the naphtha fraction obtained from petroleum.

(i) Write an equation for the thermal cracking of one molecule of $C_{10}H_{22}$ to give one molecule of propene and one molecule of an alkane only.

_____

(ii) Draw the structure of the chain isomer of but-1-ene.

(2)

(c) The alkanes and the alkenes are examples of homologous series of compounds. One feature of an homologous series is the gradual change in physical properties as the relative molecular mass increases. State **two** other general features of an homologous series of compounds.

Feature 1 _____

_____

Feature 2 _____

_____

(2)

(Total 8 marks)

Q6.

Many hydrocarbon compounds burn readily in air.

(i) Write an equation to show the complete combustion of $C_{15}H_{32}$

_____

_____

(ii) One of the gaseous products of the incomplete combustion of methane in gas fires is known to be poisonous. Identify this product and write an equation for the reaction in which it is formed from methane.

Identity of product _____

Equation _____

(Total 4 marks)

Q7.

The fractions obtained from petroleum contain saturated hydrocarbons that belong to the homologous series of alkanes.

(ii) Name the process which is used to obtain the fractions from petroleum.

_____

(iii) State what is meant by the term *saturated*, as applied to hydrocarbons.

_____

_____

(4)

(b) Decane has the molecular formula $C_{10}H_{22}$

(i) State what is meant by the term *molecular formula*.

_____

_____

(ii) Give the molecular formula of the alkane which contains 14 carbon atoms.

_____

(iii) Write an equation for the incomplete combustion of decane, $C_{10}H_{22}$, to produce carbon and water only.

_____

(3)

(c) When petrol is burned in an internal combustion engine, some nitrogen monoxide, NO, is formed. This pollutant is removed from the exhaust gases by means of a reaction in a catalytic converter.

(i) Write an equation for the reaction between nitrogen and oxygen to form nitrogen monoxide.

_____

(ii) Identify a catalyst used in a catalytic converter.

_____

(iii) Write an equation to show how nitrogen monoxide is removed from the exhaust gases as they pass through a catalytic converter.

_____

(3)

(Total 10 marks)

Q8.

(b) Ethanol burns completely in a plentiful supply of air, but incomplete combustion occurs if the air supply is limited.

(i) Identify a **solid** pollutant produced by burning ethanol in a limited supply of air.

_____

(ii) Write an equation for the incomplete combustion of ethanol to produce the solid pollutant that you have identified in part (b)(i).

_____

(2)

(Total 5 marks)

Q9.

The alkane butane is used as a fuel.

(a) (i) Write an equation for the complete combustion of butane.

_____

(1)

(ii) State a condition which may cause carbon to be formed as a product in the combustion of butane.

_____

(1)

(b) Butane obtained from crude oil may contain trace amounts of an impurity. When this impurity burns it produces a toxic gas that can be removed by reacting it with calcium oxide coated on a mesh.

(i) Suggest the identity of the toxic gas.

_____

(1)

(ii) (retrieval) Suggest why calcium oxide reacts with the toxic gas.

_____

(1)

(iii) (retrieval) Suggest why the calcium oxide is coated on a mesh.

_____

(1)

(Total 5 marks)

Q10.

A student devised an experiment to investigate the enthalpies of combustion of some alcohols. The student chose the following series of primary alcohols.

Name	Formula
Methanol	CH_3OH
Ethanol	CH_3CH_2OH
Propan-1-ol	$CH_3CH_2CH_2OH$
Butan-1-ol	$CH_3CH_2CH_2CH_2OH$
Pentan-1-ol	$CH_3CH_2CH_2CH_2CH_2OH$
Alcohol **X**	$CH_3CH_2CH_2CH_2CH_2CH_2OH$
Heptan-1-ol	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2OH$

(a) (i) Name alcohol **X**.

_____

(1)

(ii) State the general name of the type of series shown by these primary alcohols.

_____

(1)

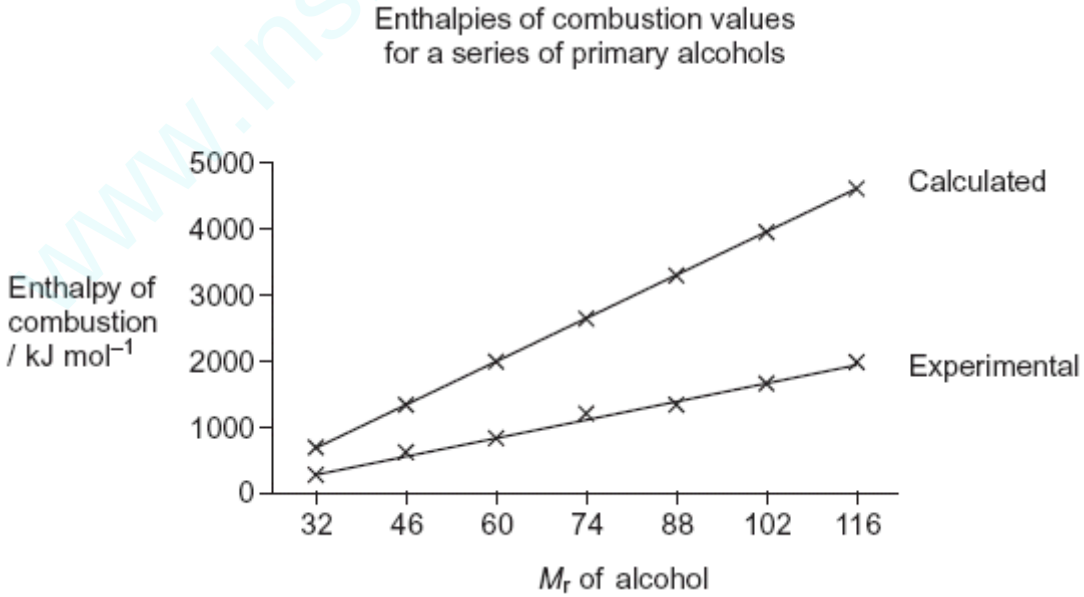
(iii) (retrieval) Draw the displayed formula of the position isomer of butan-1-ol.

(1)

(v) (retrieval) Draw the displayed formula of a functional group isomer of this aldehyde.

(1)

(d) The student repeated the experiment described in part (b) and obtained an experimental value for the enthalpy of combustion for each alcohol in this series. These experimental values were then compared with calculated values from standard enthalpies of formation, as shown in the graph below.



(i) (retrieval) In terms of bonds broken and bonds formed, explain why the calculated values of enthalpies of combustion of these alcohols, when plotted against M_r, follow a straight line.

_____

_____

_____

_____

(2)

(ii) Give **two** reasons why the experimental values obtained by the student are lower than the calculated values using the enthalpy of formation data.

_____

_____

_____

_____

(2)

(Total 18 marks)

Q11.

Cetane ($C_{16}H_{34}$) is a major component of diesel fuel.

(a) Write an equation to show the complete combustion of cetane.

_____

(1)

(b) Cetane has a melting point of 18 °C and a boiling point of 287 °C.
In polar regions vehicles that use diesel fuel may have ignition problems.
Suggest **one** possible cause of this problem with the diesel fuel.

_____

_____

(1)

(c) The pollutant gases NO and NO_2 are sometimes present in the exhaust gases of vehicles that use petrol fuel.

(i) Write an equation to show how NO is formed and give a condition needed for its formation.

Equation _____

Condition _____

(2)

(ii) Write an equation to show how NO is removed from the exhaust gases in a catalytic converter. Identify a catalyst used in the converter.

Equation _____

Catalyst _____

(2)

(iii) Deduce an equation to show how NO_2 reacts with water and oxygen to form nitric acid (HNO_3).

_____

(1)

(d) Cetane ($C_{16}H_{34}$) can be cracked to produce hexane, butene and ethene.

(i) State **one** condition that is used in this cracking reaction.

_____

(1)

(ii) Write an equation to show how one molecule of cetane can be cracked to form hexane, butene and ethene.

_____

(1)

(iii) State **one** type of useful solid material that could be formed from alkenes.

_____

(1)

(Total 10 marks)

Q12.

The burning of fossil fuels can produce atmospheric pollutants.

(a) The combustion of petrol in an internal combustion engine can lead to the formation of carbon monoxide, CO, and nitrogen monoxide, NO.

(i) Write an equation for the incomplete combustion of octane, C_8H_{18}, to produce CO and water only.

_____

(ii) State **one** essential condition for the formation of NO in an engine. Write an equation for the reaction in which NO is formed.

Condition _____

Equation _____

(3)

(b) All new petrol-engined cars must be fitted with a catalytic converter.

(i) Name **one** of the metals used as a catalyst in a catalytic converter.

_____

(ii) Write an equation to show how CO and NO react with each other in a catalytic converter.

_____

(2)

(c) State why sulphur dioxide gas is sometimes found in the exhaust gases of petrol-engined cars. Give **one** adverse effect of sulphur dioxide on the environment.

Reason for SO_2 in exhaust gases _____

_____

Environmental effect of SO_2 _____

_____

(2)

(Total 7 marks)

Q13.

Some oil-fired heaters use paraffin as a fuel.
One of the compounds in paraffin is the straight-chain alkane, dodecane ($C_{12}H_{26}$).

(a) Give the name of the substance from which paraffin is obtained.
State the name of the process used to obtain paraffin from this substance.

Substance _____

Process _____

(2)

(b) The combustion of dodecane produces several products.

Write an equation for the **incomplete** combustion of dodecane to produce gaseous products only.

_____

(1)

(c) Oxides of nitrogen are also produced during the combustion of paraffin in air.

(i) Explain how these oxides of nitrogen are formed.

_____

_____

_____

_____

(2)

(ii) Write an equation to show how nitrogen monoxide in the air is converted into nitrogen dioxide.

_____

(1)

(iii) Nitric acid (HNO_3) contributes to acidity in rainwater.

Deduce an equation to show how nitrogen dioxide reacts with oxygen and water to form nitric acid.

_____

(1)

(d) Dodecane ($C_{12}H_{26}$) can be cracked to form other compounds.

(i) Give the general formula for the homologous series that contains dodecane.

_____

(1)

(ii) Write an equation for the cracking of one molecule of dodecane into equal amounts of two different molecules each containing the same number of carbon atoms.
State the empirical formula of the straight-chain alkane that is formed.
Name the catalyst used in this reaction.

Equation _____

Empirical formula of alkane _____

Catalyst _____

_____

(3)

(iii) Explain why the melting point of dodecane is higher than the melting point of the straight-chain alkane produced by cracking dodecane.

_____

_____

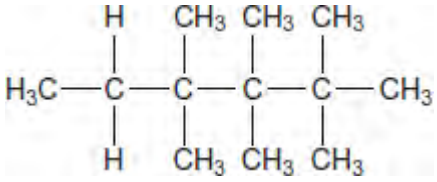
_____

_____

_____

(2)

(e) (retrieval) Give the IUPAC name for the following compound and state the type of structural isomerism shown by this compound and dodecane.



IUPAC name _____

Type of structural isomerism _____

(2)

(f) Dodecane can be converted into halododecanes.

Deduce the formula of a substance that could be reacted with dodecane to produce 1-chlorododecane and hydrogen chloride only.

_____

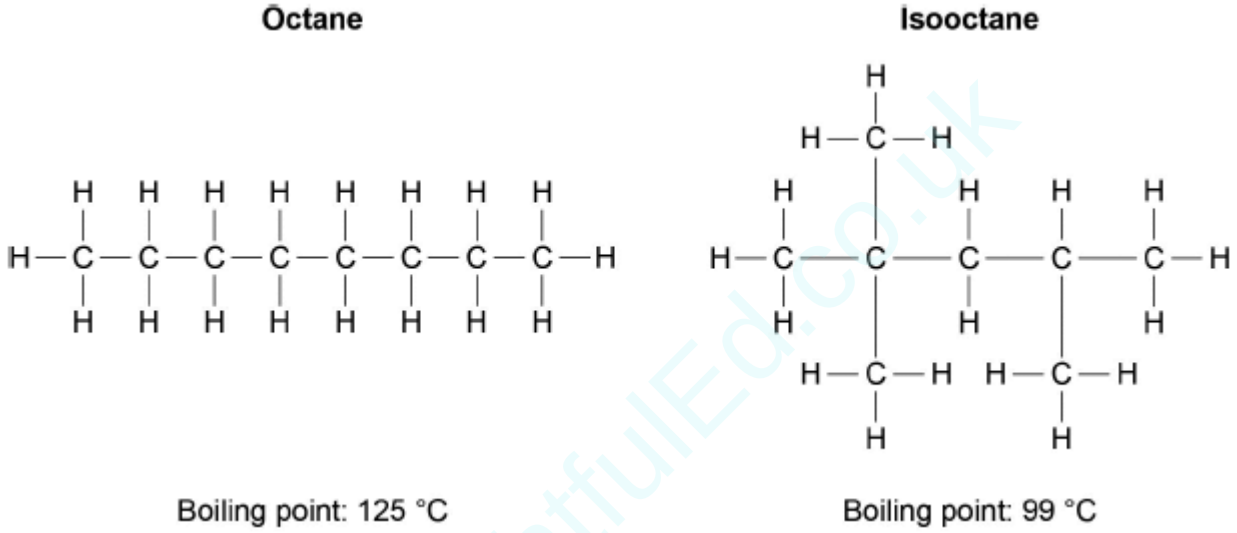
(1)

(Total 16 marks)

Q14.

Octane and isooctane are structural isomers with the molecular formula C_8H_{18}.
The displayed formulas and boiling points of octane and isooctane are shown in **Figure 1**.

Figure 1



(a) Give the IUPAC name for isooctane.

_____

(1)

(b) Octane and isooctane can be separated in the laboratory.

Name a laboratory technique that could be used to separate isooctane from a mixture of octane and isooctane.

Outline how this technique separates isooctane from octane.

Name _____

Outline _____

_____

_____

_____

_____

(3)

(c) Isooctane is added to petrol to increase its octane rating. Some

high-performance engines require fuel with a higher octane rating.

Write an equation for the complete combustion of isooctane. Use the molecular formula (C_8H_{18}) of isooctane in your equation.

_____

(1)

(d) Explain, in general terms, how a catalyst works.

_____

_____

_____

(2)

(e) Carbon monoxide is produced when incomplete combustion takes place in engines. Nitrogen monoxide is another pollutant produced in car engines.

Write an equation to show how these pollutants react together in a catalytic converter.

_____

(1)

(f) Platinum, palladium and rhodium are metals used inside catalytic converters. A very thin layer of the metals is used on a honeycomb ceramic support.

Explain why a thin layer is used in this way.

_____

_____

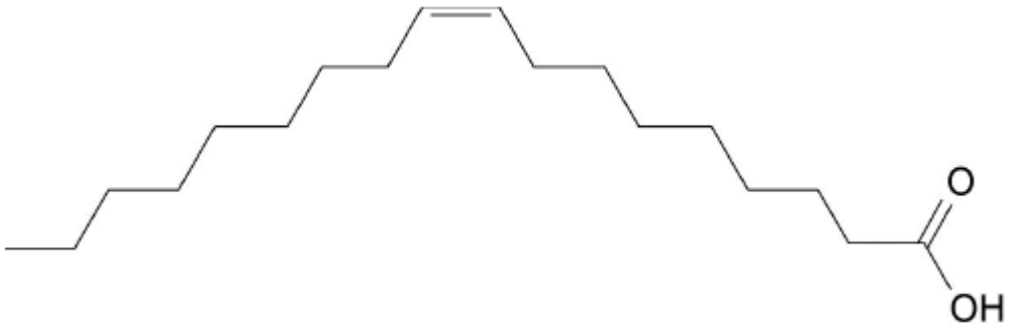
_____

_____

(2)

(g) (retrieval) Oleic acid ($C_{18}H_{34}O_2$) is a straight-chain fatty acid obtained from plant oils. Isooctane can be made from oleic acid. The skeletal formula of oleic acid is shown in **Figure 2**.

Figure 2



Identify a reagent that could be used in a chemical test to show that oleic acid is

unsaturated.

State what would be observed in this test.

Reagent _____

Observation _____

_____

(2)

(Total 12 marks)

Q15.

An engineer was trying to develop a new fuel for a motorboat by blending mixtures of different alcohols in order to find out which mixture released the most energy when used in the engine.

The engineer had a number of alcohols in unlabelled bottles. It was decided to identify the alcohols by determining their enthalpies of combustion and comparing these values with those from a data book.

(d) The filter in the air intake for the engine in the motorboat may become partially blocked by dust and debris.

Explain with the aid of an equation why combustion of methylpropan-2-ol under these circumstances would be of economic and environmental concern to the engineer.

_____

_____

_____

_____

_____

_____

(3)

Q16.

This question is about fossil fuels.

(a) The petrol fraction from crude oil contains octane (C_8H_{18}).

Give an equation for the complete combustion of octane.

_____

(1)

(b) The combustion of petrol in car engines produces the pollutant nitrogen monoxide.

Give an equation for a reaction that removes nitrogen monoxide in a catalytic converter.

_____

(1)

(c) (retrieval) Sulfur dioxide is produced in the combustion of fossil fuels. The total emissions of sulfur dioxide in the UK have fallen dramatically since 1970.

Sulfur dioxide is now removed from the flue gases in power stations by reaction with calcium oxide.

$$CaO + SO_2 \rightarrow CaSO_3$$

In 1970, the total UK emissions of sulfur dioxide were 6.49 million tonnes (1 tonne = 1000 kg).

Calculate the mass, in kilograms, of calcium oxide needed to react with this mass of sulfur dioxide.

Give your answer in standard form.

Mass of calcium oxide _____ kg

(2)

(Total 4 marks)

Q17.

(a) Gas oil (diesel), kerosine (paraffin), mineral oil (lubricating oil) and petrol (gasoline) are four of the five fractions obtained by the fractional distillation of crude oil within the temperature range 40–400 °C.

Identify the missing fraction and state the order in which the five fractions are removed as the fractionating column is ascended. Give **two** reasons why the fractions collect at different levels in the fractionating column.

(4)

(b) Thermal cracking of large hydrocarbon molecules is used to produce alkenes. State the type of mechanism involved in this process. Write an equation for the thermal cracking of $C_{21}H_{44}$ in which ethene and propene are produced in a 3:2 molar ratio together with one other product.

(3)

(c) Write equations, where appropriate, to illustrate your answers to the questions below.

(i) Explain why it is desirable that none of the sulphur-containing impurities naturally found in crude oil are present in petroleum fractions.

(2)

(ii) The pollutant gas NO is found in the exhaust gases from petrol engines. Explain why NO is formed in petrol engines but is not readily formed when petrol burns in the open air.

(3)

(iii) The pollutant gas CO is also found in the exhaust gases from petrol engines. Explain how CO and NO are removed from the exhaust gases and why the removal of each of them is desirable.

(5)

(Total 17 marks)

Q18.

(a) Alite must be made at temperatures above 1250 ºC. This means that Portland cement manufacture is a very energy-intensive process.

In the 1950s, heavy fuel oil was used. A typical heavy fuel oil contains compounds with the molecular formula $C_{20}H_{42}$. This kind of fuel requires pre-heating before it can be burned. The equation for the complete combustion of $C_{20}H_{42}$ is

$$2C_{20}H_{42}(g) + 61O_2(g) \longrightarrow 40CO_2(g) + 42H_2O(g)$$

(i) Suggest why combustion of the fuel oil is likely to be incomplete.

_____

(1)

(ii) The large volume of exhaust gases can cause dust to be blown out of the kiln. The amount of dust can be decreased by passing the exhaust gases through electrostatic precipitators. These can produce sparks because of the high voltage.

Identify a gas that may be present because of incomplete combustion. Suggest why the use of electrostatic precipitators could be a hazard if this gas were present.

Identity of gas _____

Reason _____

(2)

(iii) Cold air is blown over the alite at the end of the process so that it is cooled as quickly as possible.

Suggest how the resulting air can be used to improve the economy of the whole process.

_____

_____

(1)

(b) Cement kilns were once one of the largest contributors to global pollution by nitrogen oxides.

(i) State how nitrogen oxides could be formed during the manufacture of Portland cement.

_____

_____

(1)

(ii) Sulfur dioxide is formed by the oxidation of sulfur compounds in the fuel used to heat the kiln. Sulfur dioxide can be removed by the minerals in the kiln. Suggest why a kiln with a very fast air flow is likely to emit more sulfur dioxide than one with a slower air flow but otherwise operating under the same conditions.

_____

_____

(1)

(Total 6 marks)

Q19.

Petrol contains saturated hydrocarbons. Some of the molecules in petrol have the molecular formula C_8H_{18} and are referred to as octanes. These octanes can be obtained from crude oil by fractional distillation and by cracking suitable heavier fractions.

Petrol burns completely in a plentiful supply of air but can undergo incomplete combustion in a car engine.

(a) State the meaning of both the words *saturated* and *hydrocarbon* as applied to the term *saturated hydrocarbon*.

Name the homologous series to which C_8H_{18} belongs.

(3)

(b) Outline the essential features of the fractional distillation of crude oil that enable the crude oil to be separated into fractions.

(4)

(c) C_8H_{18} is obtained by the catalytic cracking of suitable heavy fractions.
State what is meant by the term *cracking* and name the catalyst used in catalytic cracking.

Write an equation to show how one molecule of $C_{14}H_{30}$ is cracked to form one molecule of C_8H_{18} and one molecule of another hydrocarbon.

Explain why oil companies need to crack 'suitable heavy fractions'.

(4)

(d) Write an equation for the incomplete combustion of C_8H_{18} to form carbon monoxide and water only.

A catalytic converter is used to remove carbon monoxide from the exhaust gases in a car. Identify a catalyst used in the catalytic converter.

Write an equation to show how carbon monoxide is removed in a catalytic converter.

State why the water produced in the exhaust gases may contribute to global warming.

(4)

(e) When some petrol was accidentally contaminated in 2007, the sensors in the affected cars caused a decrease in the supply of petrol to the engine.

Suggest the effect that the contaminated fuel would have on the performance of the cars.

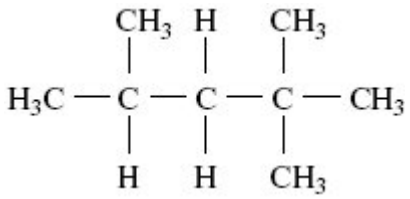
State how the oil company might have recognised the problem before the petrol was sold.

(2)

(f) (retrieval) The molecular formula C_8H_{18} represents several structural isomers.

State what is meant by the term *structural isomers*.

Name the following structural isomer of C_8H_{18}



(3)

(Total 20 marks)

Q20.

(a) Crude oil is separated into fractions by fractional distillation. Outline how different fractions are obtained by this process.

(3)

(b) The table below gives details of the supply of, and demand for, some crude oil fractions.

Fractions	Approximate %	
	Typical supply from crude oil	**Global demand**
Gases	2	4
Petrol and naphtha	16	27
Kerosine	13	8

Gas oil	19	23
Fuel oil and bitumen	50	38

(i) Use the data given above to explain why catalytic cracking of crude oil fractions is commercially important.

_____

_____

_____

(ii) Give the two main types of product obtained by catalytic cracking.

Type 1 _____

Type 2 _____

(4)

(c) Name a catalyst used in catalytic cracking. State the type of mechanism involved and outline the industrial conditions used in the process.

Catalyst _____

Conditions _____

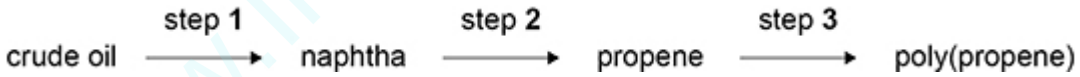
(4)

(Total 11 marks)

Q21.

This question is about poly(propene).

(a) The three key steps in the manufacture of poly(propene) from crude oil are shown.



Naphtha is a mixture of alkanes with 6 to 12 carbon atoms per molecule.

For each step, name the process and state briefly the purpose of the process that leads to the formation of poly(propene).

Step **1**

Name _____

Purpose _____

_____

_____

Step **2**

Name _____

Purpose _____

_____

_____

Step **3**

Name _____

Purpose _____

_____

_____

(6)

(b) (retrieval) Poly(propene) is not biodegradable because it is unreactive.

Explain why poly(propene) is unreactive.

_____

_____

_____

(1)

(c) Scientists are developing new polymers, including some that are biodegradable.

Suggest why it is beneficial for some polymers to be biodegradable.

_____

_____

_____

(1)

(Total 8 marks)

Q1.

D

Kerosene is a mixture of compounds

[1]

Q2.

B

[1]

Q3.

A

It can be removed from car exhaust gases by a catalytic converter.

[1]

Q4.

(a) (i) $C_8H_{18} + 8\frac{1}{2} O_2 \rightarrow 8CO + 9H_2O$

Accept multiples

1

(ii) Not enough oxygen or air (available for complete combustion) / lack of oxygen or air / too much octane

Ignore poor ventilation, low temp, poor mixing, incomplete combustion

1

(b) (i) $2CO + 2NO \rightarrow 2CO_2 + N_2$

Allow multiples

1

(ii) Pt / Pd / Rh / Ir or names

Apply list principle

1

Big(ger) surface area / increased reaction rate / removes more of the gases / ensures complete reaction

Allow (ceramic) withstands high temperatures

1

(c) (i) Acid rain

Allow consequence of acid rain

Ignore greenhouse gas / global warming / ozone

1

(ii) CaO/ lime / $CaCO_3$ /limestone

Allow chemical names

1

Neutralises the gas or words to that effect/it is basic/ SO_2 is acidic

Allow 'reacts with it' or 'it is alkaline'

Ignore 'absorb'

1

[8]

Q5.

(a) (i) fractional distillation or fractionation

1

(ii) C_9H_{20} only

1

(iii) $C_{11}H_{24} + 17O_2 \rightarrow 11CO_2 + 12H_2O$

1

(iv) $C_{11}H_{24} + 6O_2 \rightarrow 11C + 12H_2O$

1

(b) (i) $C_{10}H_{22} \rightarrow C_3H_6 + C_7H_{16}$

1

(ii) correctly drawn structure of methylpropene

(insist on clearly drawn C-C and C=C bonds)

1

(c) Any two from

- chemically similar or chemically the same or react in the same way
- same functional group
- same general formula
- differ by CH_2

(penalise same molecular formula or same empirical formula)

2

[8]

Q6.

(i) $C_{15}H_{32} + 23\ O_2 \rightarrow 15\ CO_2 + 16\ H_2O$

Products (1)
Balance (1)
If wrong reactant C.E

(ii) Identity of product: CO or carbon monoxide **(1)**

Equation: $CH_4 + \frac{3}{2}\ O_2 \rightarrow CO + 2\ H_2O$ (1)

Any balanced equation using CH_4, producing CO could also make C + CO_2

[4]

Q7.

(a)

(ii) fractional distillation or fractionation

1

(iii) contains only single bonds or has no double bonds

(credit 'every carbon is bonded to four other atoms' provided it does not contradict by suggesting that this will always be H)

1

(b) (i) the molecular formula gives the actual number of atoms of each element/type in a molecule/hydrocarbon/compound/formula

(penalise 'amount of atoms')

(penalise 'ratio of atoms')

1

(ii) $C_{14}H_{30}$ only

(penalise as a contradiction if correct answer is accompanied by other structural formulae)

1

(iii) $C_{10}H_{22} + 5½O_2 \rightarrow 10C + 11H_2O$

(or double this equation)

1

(c) (i) $½N_2 + ½O_2 \rightarrow NO$

(or double this equation)

1

(ii) Platinum or palladium or rhodium

1

(iii) $2CO + 2NO \rightarrow 2CO_2 + N_2$ or

$2NO \rightarrow N_2 + O_2$ or

(ignore extra O_2 molecules provided the equation balances)

$C + 2NO \rightarrow CO_2 + N_2$

(or half of each of these equations)

$C_8H_{18} + 25NO \rightarrow 8CO_2 + 12½N_2 + 9H_2O$

(or double this equation)

1

[10]

Q8.

(b) (i) Carbon OR C

(credit "soot" or "sooty")

(penalise "coke" or "coal")

(credit "carbon + carbon monoxide" provided it is clear that carbon is solid; penalise "carbon + carbon dioxide")

1

(ii) $CH_3CH_2OH + O_2 \rightarrow 2C + 3H_2O$
OR
$CH_3CH_2OH + 1½O_2 \rightarrow C + CO + 3H_2O$

(credit multiples of these equations)

(credit use of C_2H_5OH for ethanol)

(penalise use of C_2H_6O for ethanol, but note a possible repeat error from part (a) above)

1

[5]

Q9.

(a) (i) $C_4H_{10} + 6\frac{1}{2} O_2 \rightarrow 4CO_2 + 5H_2O$

Allow multiples

1

(ii) insufficient oxygen/low temperature/poor mixing of butane and air

Allow insufficient air
Allow lack or oxygen/air
Do not allow no oxygen
Not incomplete combustion

1

(b) (i) Sulfur dioxide/SO_2

Allow sulfur trioxide/SO_3

(allow spelling of sulphur to be sulphur)

1

(ii) It is basic/the gas (SO_2) is acidic

Idea of neutralisation
It = calcium oxide

1

(iii) bigger surface area to react

Do not allow cheaper

1

[5]

Q10.

(a) (i) Hexan-1-ol1

ONLY

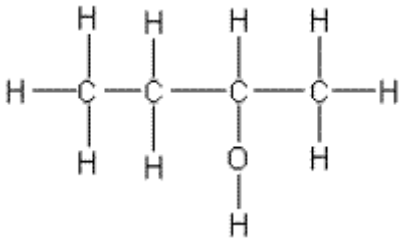
1

(ii) Homologous (series)

ONLY

1

(iii) <u>Displayed formula</u> for butan-2-ol



All bonds must be drawn out including the O–H bond
Ignore bond angles

1

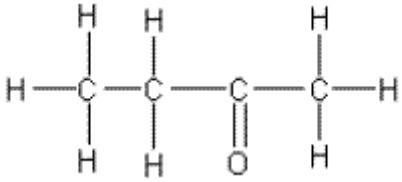
(iv) $CH_3CH_2CH_2CH_2OH + [O] \longrightarrow CH_3CH_2CH_2CHO + H_2O$

Require this whole equation as written or formulae drawn out
Penalise "sticks"

1

(v) Displayed formula for butanone

(credit possible enols, ethers and cyclic structures for C_4H_8O)



All bonds must be drawn out
Ignore bond angles

1

(d) (i) **M1 This is about the change in formula up the series**

Each alcohol in the series (compared with the previous one)

increases by/has an extra CH_2

OR

has one more C-C and two more C-H

M2 This is about the reaction and bond breaking/making

Combustion of each alcohol in the series breaks one

more C-C and two more C-H compared with the previous one AND forms one more mol CO_2 and one more mol H_2O

OR

A statement in which there is the idea that the extra OR additional OR difference in number of bonds broken and formed (as the series increases) is the same OR has the same difference in energy

N.B. If the first statement here for M2 is given, both marks score

2

(ii) **For the two marks M1 and M2**

heat loss or heat absorbed by the apparatus

OR

incomplete combustion/not completely burned

OR

The idea that the water may end up in the gaseous state (rather than liquid) OR reactants and/or products may not be in standard states.

2

[18]

Q11.

(a) $C_{16}H_{34} + 24.5O_2 \rightarrow 16CO_2 + 17H_2O$

Allow multiples

Ignore state symbols in equation

1

(b) Solidifies/freezes/goes viscous/waxing occurs

Allow does not vapourise/less volatile

Lack of Oxygen = 0

Apply list principle

1

(c) (i) $N_2 + O_2 \rightarrow 2NO$

Allow multiples/Ignore state symbols in equation

1

Spark/(very) high temp/2500 °C – 4000 °C

Ignore pressure/catalyst/low % of oxygen

Not just heat/hot

Apply list principle eg if high temp 150 °C = 0

1

(ii) $2CO + 2NO \rightarrow 2CO_2 + N_2$

Allow multiples/Ignore state symbols in equation

OR

$C_8H_{18} + 25NO \rightarrow 8CO_2 + 12.5\ N_2 + 9H_2O$

Allow other alkane reacting with NO in correctly balanced equation

OR

$C + 2NO \rightarrow CO_2 + N_2$

OR

$2NO \rightarrow N_2 + O_2$

1

Pt/Pd/Rh/Ir

Penalise contradiction of name and symbol

1

(iii) $4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$

Allow multiples/Ignore state symbols in equation

1

(d) (i) High temp/

anywhere in range 400 °C – 900 °C/

anywhere in range 670-1200K/high pressure/anywhere in range 5000 kPa up to 8000 kPa/

Not catalyst/heat

1

(ii) $C_{16}H_{34} \rightarrow C_6H_{14} + 2C_4H_8 + C_2H_4$

Or $C_{16}H_{34} \rightarrow C_6H_{14} + C_4H_8 + 3C_2H_4$

Do not allow multiples

Ignore state symbols in equation

1

(iii) Polymers/plastics/named polymer

Allow polyesters or polyamides

Ignore object made from polymer

1

[10]

Q12.

(a) (i) $C_8H_{18} + 8½O_2 \rightarrow 8CO + 9H_2O$ **(1)**

OR double this equation

(ii) *Condition*: Spark OR high T OR T = 2500 – 4000 °C **(1)**

Equation: $N_2 + O_2 \rightarrow 2NO$ **(1)**

OR half this equation

3

(b) (i) platinum OR rhodium OR palladium **(1)**

(ii) $2CO + 2NO \rightarrow N_2 + 2CO_2$ **(1)**

OR half this equation

2

(c) *Reason for SO_2 in exhaust gases*: fraction / petrol / fuels contain sulphur or sulphur-containing impurities (which burn to give SO_2) **(1)**

Environmental effect SO_2: acid rain OR a specific effect **(1)**

NOT greenhouse effect

NOT damages ozone layer

2

[7]

Q13.

(a) Crude oil **OR** petroleum

Not petrol.

1

Fractional distillation / fractionation

Not distillation alone.

1

(b) $C_{12}H_{26} + 12.5O_2 \longrightarrow 12CO + 13H_2O$

Allow balanced equations that produce CO_2 in addition to CO.

Accept multiples.

1

(c) (i) M1 Nitrogen and oxygen (from air) react / combine / allow a correct equation

If nitrogen from petrol / paraffin / impurities CE = 0 / 2.

1

M2 at high temperatures

Allow temperatures above 1000 °C or spark.

Not just heat or hot.

M2 dependent on M1.

But allow 1 mark for nitrogen and oxygen together at high temperatures.

1

(ii) $2NO + O_2 \longrightarrow 2NO_2$

Allow multiples.

1

(iii) $4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$

Allow multiples.

1

(d) (i) C_nH_{2n+2}

Allow C_xH_{2x+2}

CnH2n+2

Allow CxH2x+2

1

(ii) $C_{12}H_{26} \longrightarrow C_6H_{14} + C_6H_{12}$

Only.

1

C_3H_7

Only.

1

Zeolite / aluminosilicate(s)

Ignore aluminium oxide.

1

(iii) Larger molecule / longer carbon chain / more electrons / larger surface area

1

More / stronger <u>van der Waals' forces between molecules</u>

Allow dispersion forces / London forces / temporary induced dipole-dipole forces <u>between molecules.</u>

If breaking bonds, CE = 0 / 2.

1

(e) 2,2,3,3,4,4-hexamethylhexane

Only.

Ignore punctuation.

1

Chain

Ignore branch(ed).

1

(f) Cl_2

Only.

Cl–Cl

Not CL_2 or Cl2 or CL2 or Cl^2 or CL^2.

Ignore Chlorine.

1

[16]

Q14.

(a) 2,2,4-trimethylpentane

This answer only but ignore punctuation

1

(b) M1 (fractional or simple) distillation

Incorrect process in M1 CE=0

If M1 blank, mark on for M2 and M3 (ignore boiling, condensing)

1

M2 idea that isooctane / the one with the lower boiling point boils (first) (or reaches top of column first)

Ignore reference to octane boiling and being collected at higher temperature

If temperature referred to, should be between 99 and 124°C

"it" refers to isooctane

M2 – allow vaporises/evaporates first

1

M3 idea that isooctane <u>condenses / liquefies</u> and <u>collected</u>

Penalise M2 and M3 if octane boils first

In M2 and M3 – if no specific reference to individual alkanes, could score one mark for M2 + M3 combined if M2 and M3 both otherwise correct

M2 and M3 must refer to a laboratory apparatus (not to an industrial process)

1

(c) $C_8H_{18} + 12½O_2 \longrightarrow 8CO_2 + 9H_2O$

Accept multiples; ignore state symbols

Accept any correct structural representation of isooctane

1

(d) M1 Alternative route/mechanism/pathway

1

M2 With lower <u>activation energy</u>

Accept E_a for activation energy

1

(e) $2CO + 2NO \longrightarrow 2CO_2 + N_2$

Accept multiples; ignore state symbols

1

(f) M1 to reduce amount of metals needed / small amount of metal needed

Relates to low amount of metal

1

M2 Increase / maximise / produce large surface area or to give catalyst a larger surface area: volume ratio or so that high(er) proportion of atoms/metal is on surface

Is related to large surface area

1

(g) M1 bromine (water or in organic solvent or CCl_4) / Br_2 (aq) / Br_2

No reagent or an incorrect reagent (e.g. bromide), CE=0;

Penalise Br (or incorrect formula of other correct reagent) but mark on for M2

It must be a whole reagent and/or correct formula

If oxidation state given in name, it must be correct

If 'manganate' or 'manganate(IV)' or incorrect formula, penalise M1 but mark on

Ignore 'acidified'

1

M2 (orange/yellow to) colourless / decolourised / loses its colour

Ignore goes clear

Ignore brown/red, but penalise other incorrect colours

1

Alternatives:

M1 = potassium manganate(VII), M2 = colourless

M1 = <u>conc</u> sulfuric acid, M2 = brown

M1 = iodine, M2 = colourless

[12]

Q15.

(d) $C_4H_9OH + 2O_2 \rightarrow 4C + 5H_2O$

OR

$C_4H_9OH + 4O_2 \rightarrow 4CO + 5H_2O$

Allow any correct balanced equations which include combinations of C, CO and/or CO_2 in the products but must be incomplete combustion.

1

Engine would not run as efficiently / would need to use more fuel / would release less energy

Allow build-up of carbon in engine costly to remove

1

CO / Particulates of carbon toxic

Allow global dimming if carbon given as product

1

[13]

Q16.

(a) $C_8H_{18} + 12.5\ O_2 \rightarrow 8\ CO_2 + 9\ H_2O$

Allow multiples

Ignore state symbols

1

(b) $2\ NO + 2\ CO \rightarrow N_2 + 2\ CO_2$ ***or***

$25\ NO + C_8H_{18} \rightarrow 12.5\ N_2 + 9\ H_2O + 8\ CO_2$

Allow multiples

Ignore state symbols

Allow $2NO \rightarrow N_2 + O_2$ (or multiples)

1

(c)

M1 moles $SO_2 = \frac{6\,490\,000 \times 10^6}{64.1}$ $\left(= \frac{6.49 \times 10^{12}}{64.1} = 1.012 \times 10^{11} \right)$

1

M2 mass CaO $= \left(\frac{1.012 \times 10^{11} \times 56.1}{1000} \right) = 5.68 \times 10^9$ (kg)

1

M2 *must be in standard form*

Correct answer in standard form scores 2 marks (allow 5.6 – 5.7 × 10^9). Answer to at least 2sf.

Correct answer in non-standard form scores 1 mark

Answers that are 5.6 – 5.7 × 10^n score 1 mark

For other answers, allow ECF from ***M1*** *to* ***M2*** *(but answer must be in standard form for* ***M2*** *to score)*

Alternative

M1 mass CaO $= \frac{6\,490\,000 \times 10^6}{64.1} \times 56.1$

= 5.68 million tonnes

M2 *5.68 × 10^9 (kg)*

(7.4.. × 10^9 would score 1 mark due to use of $\frac{64.1}{56.1}$)

[4]

Q17.

(a) Missing fraction = naphtha *(allow naphtha from list if not quoted separately*) **(1)** Order = mineral oil (lubricating oil), gas oil (diesel),

kerosene (paraffin),
naphtha, petrol (gasoline) **(1)**

Mark order consequential on M1 (if no missing fraction given, M2 = 0) Accept correct reversed order

Negative temperature gradient on the column
or temperature of column decreases upwards **(1)**

Larger molecules **or** heavier fractions condense at higher temperatures **or** lower down the column **or** reference to different boiling points

(ignore mp) ***(1)***

4

(b) Type of mechanism = (free) radical / homolytic fission - **used in complete sentence/phrase (1)**

$C_{21}H_{44} \rightarrow 3\ C_2H_4 + 2\ C_3H_6 + C_9H_{20}$ *correct alkenes* ***(1)***

Accept CH_2CH_2 & CH_2CHCH_3 all correct ***(1)***

3

(c) (i) Sulphur (containing impurities) burn to form **or** forms SO_2 **or** oxides of sulphur *(if oxide identified, must be correct)* **(1)**
OR equation: e.g. $S + O_2 \rightarrow SO_2$ **or** $H_2S + 1½O_2 \rightarrow SO_2 + H_2O$

Leading to acid rain (*must have specified oxides of S* ***or burning***)
or toxic product **or** respiratory problems **(1)**

(ii) NO formed by reaction between N_2 and O_2 from the air **(1)**
OR $N_2 + O_2 \rightarrow 2NO$
High combustion temperature **or** spark in engine **(1)**
provides E_A **or** sufficient heat / energy to break $N \equiv N$ **(1)**

(iii) Need to remove NO as forms acid rain **or** toxic product **or** causes respiratory problems **(1)**
$2NO + O_2 \rightarrow 2NO_2$ **(1)**
$4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$ **(1)**

Need to remove CO as it is poisonous **(1)**

Catalytic converter **(1)**
uses Pt / Rh / Pd / Ir (*wrong answer cancels a correct one*) **(1)**
Provides active sites / reduces E_A **(1)**
Forms $N_2 + CO_2$ **(1)**
$2NO + 2CO \rightarrow N_2 + 2CO_2$ (*correct equation worth last 2 marks*) **(1)**

Max 10

[17]

Q18.

(a) (i) Difficult to supply sufficient air / oxygen (for complete combustion)

Accept ratio of oxygen to fuel is very high.

Ignore any references to temperature factors.

1

(ii) Carbon monoxide (or unburned fuel)

1

Flammable / explosion

1

(iii) Used to pre-heat fuel or air in the kiln

Raise steam to generate electricity used in the process.

1

(b) (i) Nitrogen reacts with oxygen at <u>high temperature</u>

1

(ii) Less chance of reaction of SO_2 if the flow is fast

Increased oxygen supply so more sulfur (compounds) oxidized. Allow less contact time between SO2 and the minerals.

1

[6]

Q19.

(a) Single bonds <u>only</u> /no double or multiple bonds;

1

Contains carbon and hydrogen <u>only</u>;

C and H <u>only</u>
not C and H molecules

1

Alkanes;

1

(b) (1) Fractions or hydrocarbons or compounds have different boiling points/ separation depends on bp;

Ignore mp and vdw

1

(2) bp depends on size/ M_r/ chain length;

If refer to bond breaking/cracking/ blast furnace/oxygen/air 2 max

1

(3) Temp gradient in <u>tower or column</u> / cooler at top of <u>column</u> or vice versa;

QWC

1

(4) Higher bp / larger or heavier molecules at bottom (of column) or vice versa;

Not increasing size of fraction

Not gases at top

1

(c) Large molecules or compounds or long chain hydrocarbons (broken) into smaller molecules or compounds or smaller chain hydrocarbons;

QWC

1

Zeolite or aluminosilicate (catalyst);

1

$C_{14}H_{30} \rightarrow C_8H_{18} + C_6H_{12}$;

Only

1

Smaller chain molecules are in more demand or have higher value or vice versa;

Insufficient to say more useful/have more uses

1

(d) $C_8H_{18} + 8½\ O_2 \rightarrow 8CO + 9H_2O$;

Allow multiples

1

Rh/ Pd/Pt/Ir or in words;

Penalise contradiction of name and symbol

1

$2CO + 2NO \rightarrow 2CO_2 + N_2$ / $2CO + O_2 \rightarrow 2CO_2$;

Allow multiples

1

Greenhouse gas/ absorbs infrared radiation;

1

(e) car less powerful/ car stops/ reduced performance/ won't run smoothly/ can't accelerate;

Not incomplete combustion or bad effect on engine
Not doesn't go as far.

1

Test it (before sale) /Quality control etc;

1

(f) (compounds with) same molecular formula / same no and type of atoms;

Not atoms/elements with same molecular formula.
If same chemical formula, can allow M2

1

And different structure/ structural formula;

M2 consequential on M1
Allow displayed formula for M2

1

2,2,4-trimethylpentane;

Only (but allow numbers in any order)

1

[20]

Q20.

(a) Crude oil is heated to vaporise it / **oil vaporised (1)**
(Vapour passed into fractionating) tower / column **(1)**
Top of tower cooler than bottom
or **negative temperature gradient (1)**
fractions separated by b.p
OR condensed at different temperatures OR levels
OR low boiling fractions at the top
OR at the top small molecules or light components (1)

max 3

(b) (i) Identify shortfall in supply - e.g. petrol / small molecules **(1)**
Higher value products **OR more useful products (1)**

OR cracking produces more of material (problem solving)

(ii) Motor fuels
Aromatic hydrocarbons
Branched alkanes / hydrocarbons
Cycloalkanes

Any two (2)
Ignore specific fractions, alkanes, shorter alkanes, penalise alkenes, and hydrogen

4

(c) *Catalyst*: Zeolite / aluminosilicate **(1)**
Type of mechanism: Carbocation / heterolytic fission **(1)**
Conditions: High temp OR around 450 °C [300 – 600] °C **NOT heat / warm (1)**
Slight pressure [> 1 atm $\leq$ 10 atm **OR 1 megaPa, 1000 kPa] (1)**

NOT high pressure

4

[11]

Q21.

(a) **Step 1**

M1 fractional distillation

1

M2 separated into mixtures of compounds with similar boiling points / similar sized molecules

***M2** to separate naphtha from other compounds; to separate compounds by chain length / size / boiling point*

1

Step 2

M3 (thermal) cracking

***M3** not catalytic cracking*

1

M4 to make alkenes / propene **/** shorter molecules

1

Step 3

M5 (addition) polymerisation

M5 *not condensation polymerisation 1*

1

M6 molecules joined together or to produce long chain molecule

For each step the two marks are independent

1

(b) no polar bonds (in chain) / non-polar

Do not allow if only C-H bonds mentioned as non polar

1

(c) to prevent build-up of waste (in landfill) OR they can be broken down by natural processes

1

[8]