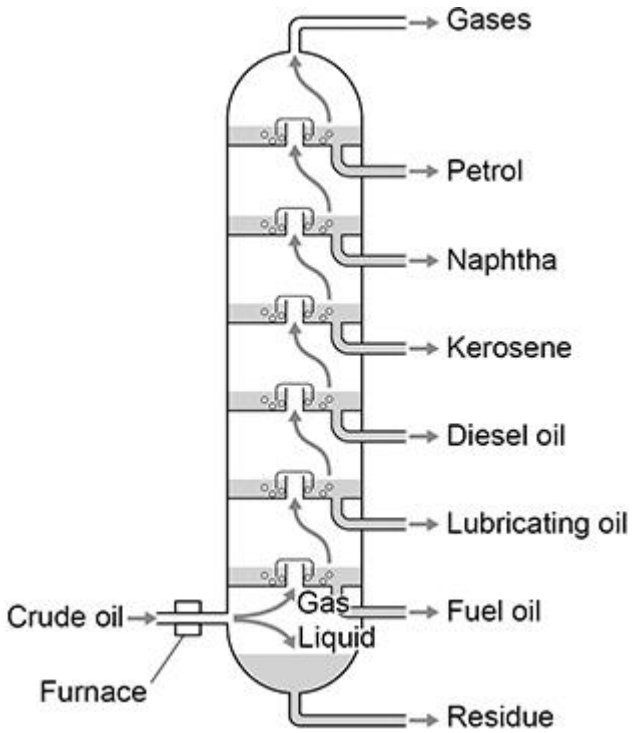
Q1.

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. ⬭

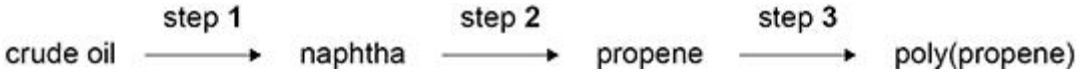
D Kerosene is a mixture of compounds. ⬭

(Total 1 mark)

Q2.

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) 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)

Q3.

This question is about fuels.

(a) The petrol fraction obtained from crude oil can be used as fuel in cars.

State the meaning of fraction, as used in the term petrol fraction.

_____

_____

_____

(1)

(b) Hexadecane ($C_{16}H_{34}$) can be cracked at high temperature to form petrol.

Complete the equation to show the cracking of one molecule of hexadecane to form hexane and cyclopentane only.

Give the name of a catalyst used in this cracking reaction.

$C_{16}H_{34} \rightarrow$ _____ + _____

Catalyst _____

(3)

(c) Carbon dioxide is formed when petrol is burned.
Carbon dioxide acts as a greenhouse gas when it absorbs infrared radiation.

Give a reason why carbon dioxide absorbs infrared radiation.

_____

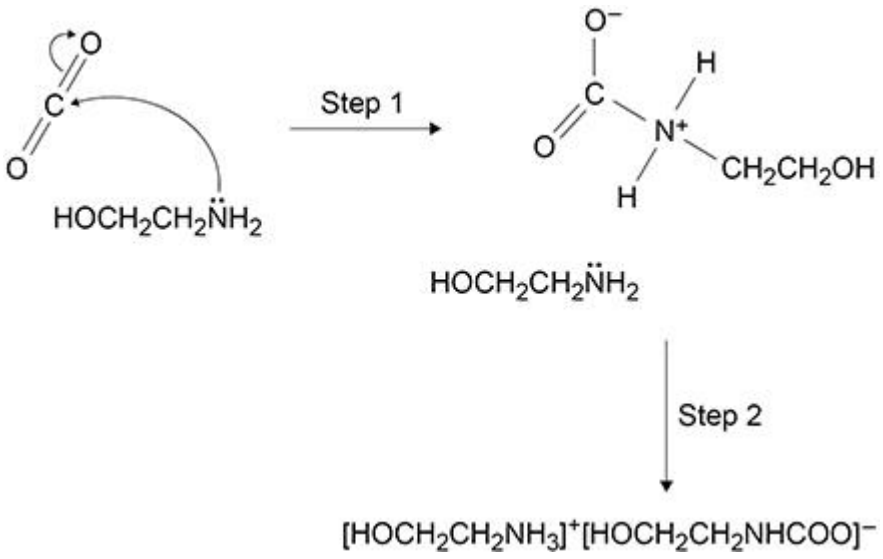
_____

_____

(1)

(d) Compound **Z** ($HOCH_2CH_2NH_2$) can be used to remove carbon dioxide from the mixture of waste gases produced in some power stations.

The figure below shows part of a suggested mechanism for the reaction of **Z** with carbon dioxide.



Draw **two** curly arrows to complete the mechanism in the figure above.

Name compound **Z** ($HOCH_2CH_2NH_2$)

Deduce the role of **Z** in step **2** of the mechanism.

Name _____

Role _____

_____

(4)

(e) $HOCH_2CH_2NH_2$ can be represented as XNH_2
$[HOCH_2CH_2NH_3]^+$ can be represented as $[XNH_3]^+$

Draw the shape of XNH_2 and of $[XNH_3]^+$

State whether the H–N–H bond angle in XNH_2 is greater than, the same as, or smaller than that in $[XNH_3]^+$

Explain your answer.

Shape of XNH_2 Shape of $[XNH_3]^+$

Bond angle _____

Explanation _____

_____

(4)

(f) Bioethanol is used as an alternative to fossil fuels.

This statement appeared on a website.

"The fact that bioethanol is a carbon-neutral fuel outweighs the environmental disadvantages of producing bioethanol."

Evaluate this statement.

In your answer you should include:
- an outline of how bioethanol is produced
- relevant equations
- analysis of the environmental impacts.

(6)

(Total 19 marks)

Q4.

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. ⬭

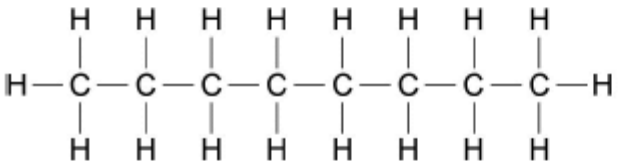
(Total 1 mark)

Q5.

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**.

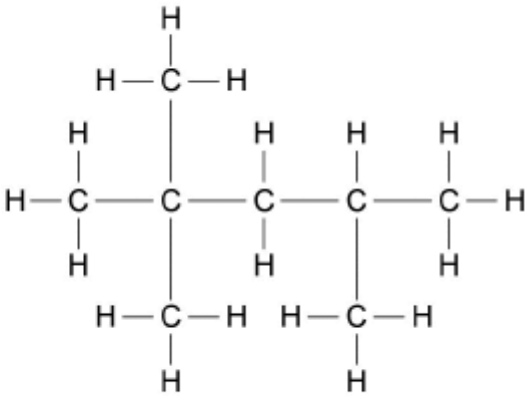
Figure 1

Octane



Boiling point: 125 °C

Isooctane



Boiling point: 99 °C

(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.

_____

_____

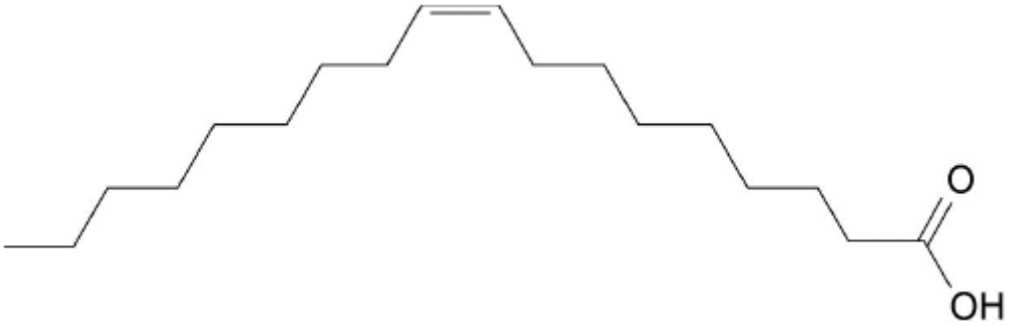
_____

_____

(2)

(g) 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)

Q6.

Central heating fuel, obtained by the fractional distillation of crude oil, contains saturated hydrocarbons with the molecular formula $C_{16}H_{34}$

(a) Give the meaning of the terms **saturated** and **hydrocarbon** as applied to saturated hydrocarbons.

Saturated _____

_____

Hydrocarbon _____

_____

(2)

(b) If the boiler for a central heating system is faulty, a poisonous gas may be produced during the combustion of $C_{16}H_{34}$

Write an equation for the reaction that forms this poisonous gas and one other product only.

_____

(1)

(c) Explain why the sulfur compounds found in crude oil should be removed from the fractions before they are used for central heating fuel.

_____

_____

_____

_____

_____

(2)

(d) A hydrocarbon $C_{16}H_{34}$ can be cracked to form C_8H_{18}, ethene and propene.

(i) Write an equation to show this cracking reaction.

_____

(1)

(ii) Suggest **one** important substance manufactured on a large scale from propene.

_____

(1)

(iii) Draw the **displayed formula** of the functional group isomer of propene.

(1)

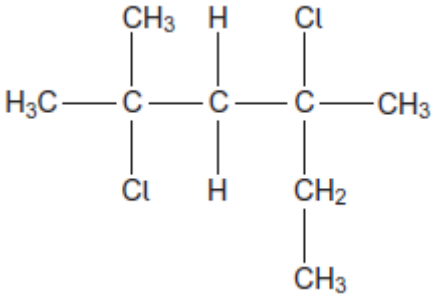
(e) There are many structural isomers with the molecular formula C_8H_{18}

Draw the structure of 2,3,3-trimethylpentane.

(1)

(f) A compound C_8H_{18} reacts with chlorine to give several haloalkanes.

Give the IUPAC name of the following haloalkane.



_____

(1)

(Total 10 marks)

Q7.

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.

_____

_____

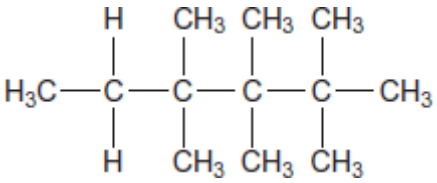
_____

_____

_____

(2)

(e) 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)

Mark schemes

Q1.

D

Kerosene is a mixture of compounds

[1]

Q2.

(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 ***I*** 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]

Q3.

(a) A group of (hydrocarbons/compounds) with similar boiling points

Allow compounds that boil in a similar range of temperatures

Compounds with similar (carbon) chain length with C5-C12 range

or within range

1

(b) zeolite

Allow Aluminosilicate or aluminium oxide

M1

All formulae correct

M2

Balanced equation $C_{16}H_{34} \rightarrow C_6H_{14} + 2\ C_5H_{10}$

M3

(c) C=O bonds vibrate at the same frequency as IR

The difference in energy between the ground and first excited vibrational state of CO_2 is equal to the energy of the infrared radiation.

Allow

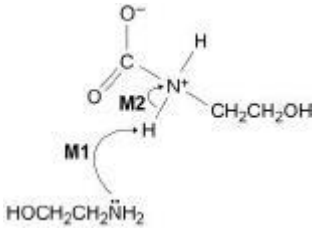
Bond vibrations match frequency of IR radiation

C=O bonds vibrate in range 1680-1750cm^{-1}

C=O bonds are polar

1

(d)



Curly arrow from N lp to H

Curly arrow from N-H bond to N$^+$

M1
M2

2-aminoethanol

Allow 2-hydroxyethylamine 2-hydroxyethanamine ethanolamine

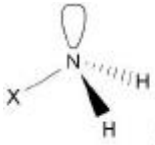
M3

Base

Allow proton acceptor / removes H$^+$ / electron pair donor M1

M4

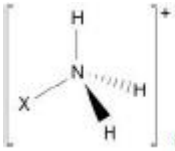
(e)



allow with/without lone pair

Allow these shapes with lines instead of wedges and dashed lines

M1



allow with/without charge

M2

Smaller

Allow comparison of correct numbers

M3

lone (or non-bonding) pair repulsion greater than bond pair repulsion

M4

(f)

This question is marked using Levels of Response. Refer to the Mark Scheme Instructions for Examiners for guidance.	
Level 3 **5-6 marks**	All stages are covered and each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from Stage 1 to Stages 2 and 3 Covers at least 2 points for stage 1, 2 for stage 2 and 3 for stage 3.
Level 2 **3-4 marks**	All stages are covered but stage(s) may be incomplete or may contain inaccuracies **OR** two stages are covered and are generally correct and virtually complete. Answer is communicated mainly coherently and shows a logical progression from Stage 1 to Stages 2 and 3. Covers at least 1 point for stage 1 to stages 2 and 3.
Level 1 **1-2 marks**	Two stages are covered but stage(s) may be incomplete or may contain inaccuracies **OR** only one stage is covered but is generally correct and virtually complete. Answer includes isolated statements but these are not presented in a logical order.
Level 0	Insufficient correct chemistry to gain a mark

Indicative Chemistry content

Stage 1 names of processes

1a Photosynthesis (is the natural process in plants that takes CO_2 from the air)

1b Fermentation (is the process used to make bioethanol releasing some CO_2)

1c Combustion (is the process where bioethanol is burned and releases CO_2)

Stage 2 Equations

2a $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

2b $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

2c $2C_2H_5OH + 6O_2 \rightarrow 6H_2O + 4CO_2$

Stage 3 Carbon neutrality and environmental issues

3a Deforestation / Sacrifice land that could be used for food

3b Loss of biodiversity / habitat

3c $6CO_2$ in and $6CO_2$ out but it isn't actually C neutral as fuel is used in production, distribution, etc

6

[19]

Q4.

B

[1]

Q5.

(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]

Q6.

(a) Saturated − single bonds only / no double bonds

1

Hydrocarbon − contains carbon and hydrogen (atoms) <u>only</u>

1

(b) $C_{16}H_{34} + 16.5O_2 \longrightarrow 16CO + 17H_2O$

Allow multiples

1

(c) (On combustion) SO_2 produced

Allow equation to produce SO_2. Ignore sulfur oxides.

1

Which causes acid rain

If formula shown it must be correct

M2 is dependent on M1. But if M1 is sulfur oxides, allow M2.

For M2 allow consequence of acid rain or SO_2.

Ignore greenhouse effect and toxic

1

(d) (i) $C_{16}H_{34} \longrightarrow C_8H_{18} + C_2H_4 + 2C_3H_6$

Allow multiples

1

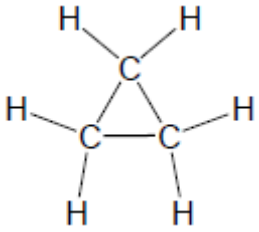
(ii) polypropene / propan(-1 or 2-)ol / propane(-1,2-)diol / isopropanol / propanone / propanal

Accept alternative names

Ignore plastic and polymer

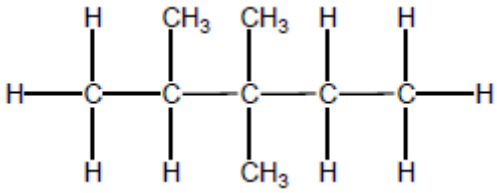
1

(iii)



1

(e)



Allow any unambiguous representation

1

(f) 2,4-dichloro-2,4-dimethylhexane

Only but ignore punctuation

1

[10]

Q7.

(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 van der Waals' forces between molecules

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

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]