Q1.

When hexadecane ($C_{16}H_{34}$) is heated to a high temperature, one molecule of hexadecane decomposes to form an alkane containing eight carbon atoms and two different unsaturated compounds.

Which equation could represent this reaction?

A $C_{16}H_{34} \rightarrow C_8H_{16} + C_5H_{12} + C_3H_6$ ⬭

B $C_{16}H_{34} \rightarrow C_8H_{18} + C_6H_{10} + C_2H_6$ ⬭

C $C_{16}H_{34} \rightarrow C_8H_{18} + 2\ C_2H_4 + C_4H_8$ ⬭

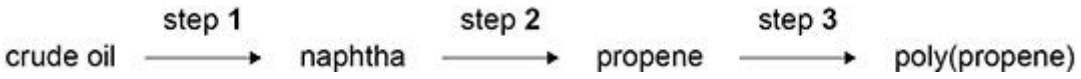
D $C_{16}H_{34} \rightarrow C_8H_{18} + C_6H_{14} + C_2H_2$ ⬭

(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.

_____

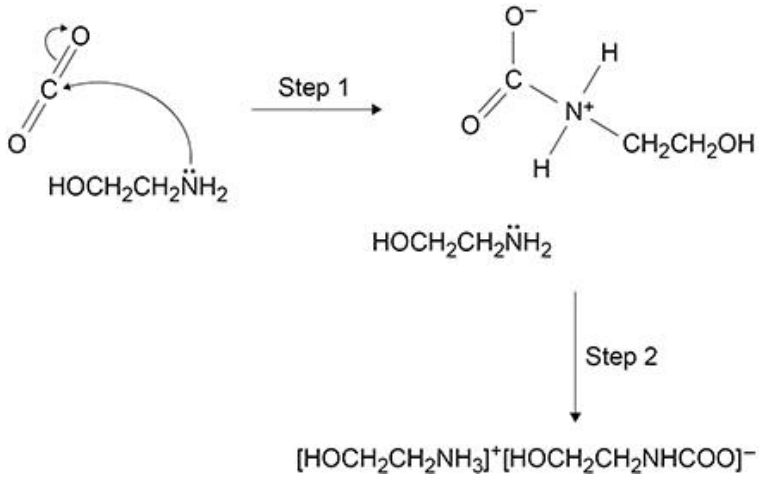
_____

_____

(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 thermal cracking?

A A pressure between 100 and 200 kPa is used. ⬭

B Aromatic hydrocarbons are the major products. ⬭

C C–C bonds are broken. ⬭

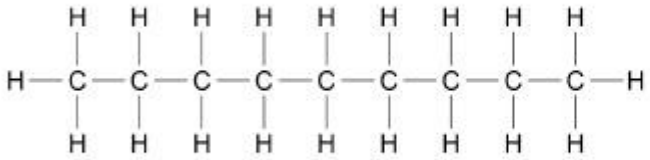
D Zeolite catalysts are used. ⬭

(Total 1 mark)

Q5.

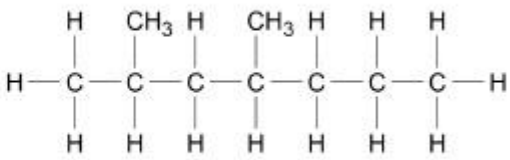
The alkanes nonane and 2,4-dimethylheptane are structural isomers with the molecular formula C_9H_{20}
They are found in crude oil and can be separated by fractional distillation.
Both can be used in fuels or cracked to form other products.

nonane



boiling point 151 °C

2,4-dimethylheptane



boiling point 134 °C

(a) State the general formula of an alkane containing n carbon atoms.
Deduce an expression for the relative molecular mass (M_r) of an alkane in terms of n.

General formula _____

Expression _____

(2)

(b) Explain why nonane has a higher boiling point than 2,4-dimethylheptane.

_____

_____

_____

_____

_____

_____

(2)

(c) Give an equation for the complete combustion of nonane.

_____

(1)

(d) Nonane is often found in fuel for jet engines. Combustion in jet engines produces pollutants including nitrogen monoxide (NO).

Explain how this nitrogen monoxide is formed.

(2)

(e) Nonane can be cracked to form large quantities of propene.

Name the type of cracking used.

(1)

(f) The main use of propene, formed from cracking, is to make poly(propene).

Draw the repeating unit of poly(propene).

(1)
(Total 9 marks)

Q6.

This question is about the reactions of alkanes.

(a) Alkanes can be used as fuels.

Give an equation for the combustion of heptane (C_7H_{16}) in an excess of oxygen.

(1)

(b) Heptane can be obtained from the catalytic cracking of hexadecane ($C_{16}H_{34}$) at a high temperature.

Identify a suitable catalyst for this process.
Give **one** condition other than high temperature.
Give an equation for the catalytic cracking of one molecule of hexadecane to produce one molecule of heptane, one molecule of cyclohexane and one other product.

Catalyst _____

Condition _____

Equation _____

_____

(3)

(c) Alkanes can be used in free-radical substitution reactions to produce halogenoalkanes.

Give equations for the propagation steps in the reaction of butane to form 2-chlorobutane.

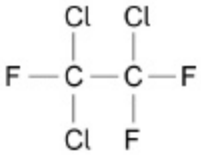
_____

_____

(2)

(d) Chlorofluorocarbons (CFCs) are a group of halogenoalkanes currently banned in many countries. They cannot be used as solvents or refrigerants because of their effect on the environment.

The structure of a CFC is shown.



Identify the radical produced from this CFC that is responsible for the depletion of ozone in the atmosphere.

Explain, with the aid of equations, why a single radical can cause the decomposition of many molecules of ozone.

Radical _____

Explanation _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 10 marks)

Q7.

The table shows possible conditions and products for the cracking of alkanes.

Which row is correct?

	Type of cracking	Conditions	Products	
A	Thermal	High pressure High temperature	Mainly alkanes	⬭
B	Thermal	Slight pressure High temperature	Mainly alkenes	⬭
C	Catalytic	Slight pressure High temperature	Mainly branched alkanes and aromatics	⬭
D	Catalytic	High pressure High temperature	Mainly branched alkanes and aromatics	⬭

(Total 1 mark)

Q8.

Which catalyst is used in the catalytic cracking of alkanes?

A Concentrated phosphoric acid ⬭

B Iron ⬭

C Nickel ⬭

D Zeolite ⬭

(Total 1 mark)

Q9.

Dodecane ($C_{12}H_{26}$) is a hydrocarbon found in the naphtha fraction of crude oil. Dodecane can be used as a starting material to produce a wide variety of useful products. The scheme below shows how one such product, polymer **Y**, can be produced from dodecane.

Reaction **1**

$$C_{12}H_{26} \longrightarrow C_2H_4 + C_4H_8 + \mathbf{X}$$

Reaction **2**

$$nC_4H_8 \rightleftharpoons \left(\begin{array}{cc} H & CH_3 \\ | & | \\ C & C \\ | & | \\ CH_3 & H \end{array} \right)_n$$

Polymer **Y**

(a) Name the homologous series that both C_2H_4 and C_4H_8 belong to.
Draw a functional group isomer of C_4H_8 that does **not** belong to this homologous series.

Name _____

Functional group isomer

(2)

(b) Identify compound **X**.

_____

(1)

(c) Name polymer **Y**.

_____

(1)

(d) Reaction **1** is an example of thermal cracking and is carried out at a temperature of 750 °C.

State **one other** reaction condition needed.

_____

(1)

(e) Reaction **2** is exothermic. A typical compromise temperature of 200 °C is used industrially for this reaction.

Explain the effect of a change of temperature on both the position of equilibrium and the rate of reaction, and justify why a compromise temperature is used industrially.

(6)

(Total 11 marks)

Mark schemes

Q1.

C

$C_{16}H_{34} \rightarrow C_8H_{18} + 2C_2H_4 + C_4H_8$

[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

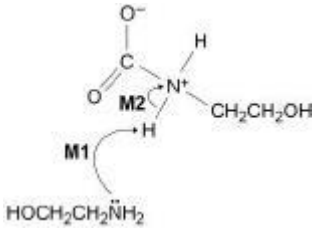
Bond vibrations match frequency of IR radiation

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

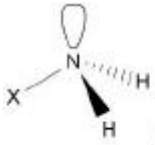
M3

Base

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

M4

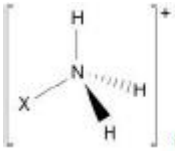
(e)



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.

C

C-C bonds are broken

[1]

Q5.

(a) **M1** C_nH_{2n+2}

1

M2 14.0*n* + 2.0 or 14n + 2

or 2(7.0n + 1.0) or 2.0(7n + 1) or 2(7n + 1)

1

(b) **M1** nonane has stronger / greater / more van der Waals' forces between molecules

or converse arguments for 2,4-dimethylbutane having lower boiling point

question refers to nonane if not expressly stated by candidate

intermolecular forces = forces between molecules

***M1** ignore abbreviations vdW and/or imf*

1

M2 nonane molecules pack closer together / more (surface) contact

***M2** ignore reference to surface area alone*

CE=0 reference to breaking (covalent) bonds / breaking chain

1

(c) $C_9H_{20} + 14O_2 \rightarrow 9CO_2 + 10H_2O$

allow multiples; ignore any state symbols; correct structures rather than formulae are fine

1

(d) **M1** nitrogen and oxygen from air react

***M1** must be at least one reference to air and no reference to nitrogen/oxygen coming from the fuel*

1

M2 at high temperature

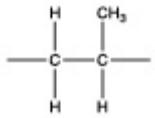
ignore reference to pressure, heat, hot, incomplete combustion

if temperature is stated, must be over 1000°C

1

(e) thermal (cracking)

1

(f) 

allow any correct structural representation

ignore any n or brackets

1

[9]

Q6.

(a) $C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$

Ignore state symbols

Allow multiples

M1

(b) Zeolite OR aluminosilicate

Allow porous pot / aluminium oxide / alumina / silica / silicon dioxide

M1

Slight/moderate pressure

Slightly above atmospheric – allow 1-5 atmospheres / 100-500kPa

M2

$C_{16}H_{34} \rightarrow C_7H_{16} + C_6H_{12} + C_3H_6$

M3

(c) $Cl\bullet + CH_3CH_2CH_2CH_3 \longrightarrow CH_3CH_2\dot{C}HCH_3 + HCl$

*If incorrect radical or ambiguous radical lose **M1** but can award **M2** for ecf in each equation.*

M1

$CH_3CH_2\dot{C}HCH_3 + Cl_2 \longrightarrow CH_3CH_2CHClCH_3 + Cl\bullet$

Allow equations in either order

Allow dot anywhere on the second carbon

Ignore extra initiation and termination steps

M2

(d) $Cl\bullet$

*Allow Cl or Chlorine in **M1** and **M4***

M1

$Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$

Penalise absence of dot once in the equations

M2

$ClO\bullet + O_3 \rightarrow Cl\bullet + 2O_2$

Allow dot anywhere on the radical

Apply the list principle in the equations and penalise

M3

$Cl\bullet$ is regenerated (and causes a chain reaction in the decomposition of ozone)

initiation from Cl_2

Allow equations in either order.

Ignore $Cl\bullet$ acts as a catalyst

M4

[10]

Q7.

C

[1]

Q8.

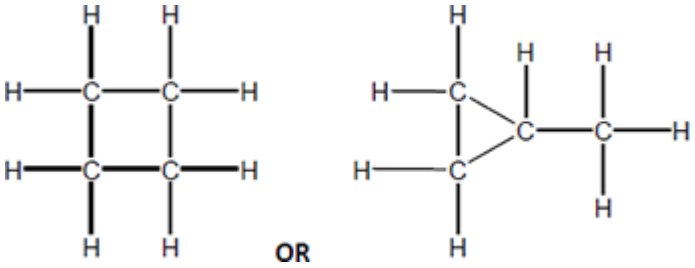
D

[1]

Q9.

(a) Alkenes

1



Correctly drawn molecule of cyclobutane or methyl cyclopropane, need not be displayed formula

1

(b) C_6H_{14} (or correct alkane structure with 6 carbons)

Allow hexane or any other correctly named alkane with 6 carbons

1

(c) Poly(but-2-ene)

1

(d) High pressure

Allow pressure □ MPa

Mention of catalyst loses the mark

1

(e) This question is marked using levels of response. Refer to the Mark Scheme

Instructions for Examiners for guidance on how to mark this question.

Level 3

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer communicates the whole process coherently and shows a logical progression from stage 1 and stage 2 (in either order) to stage 3.

5–6 marks

Level 2

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows progression. Some steps in each stage may be out of order and incomplete.

3–4 marks

Level 1

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

1–2 marks

Level 0

Insufficient correct chemistry to gain a mark.

0 marks

Indicative chemistry content

Stage 1*: consider effect of higher temperature on yield*

(Or vice versa for lower temperature)

- *Le Chatelier's principle predicts that equilibrium shifts to oppose any increase in temperature*
- *Exothermic reaction, so equilibrium shifts in endothermic direction / to the left*
- *So a Higher T will reduce yield*

Stage 2*: consider effect of higher temperature on rate*

(Or vice versa for lower temperature)

- *At higher temperature, more high energy molecules*
- *more collisions have E>Ea*
- *So rate of reaction increases / time to reach equilibrium decreases*

Stage 3*: conclusion*

Industrial conditions chosen to achieve (cost-effective) balance of suitable yield at reasonable rate

[11]