


Q8.

The following table shows the boiling points of some straight-chain alkanes.

	CH ₄	C ₂ H ₆	C ₃ H ₈	C ₄ H ₁₀	C ₅ H ₁₂
Boiling point / °C	-162	-88	-42	-1	36

- (a) State a process used to separate an alkane from a mixture of these alkanes.

(1)

- (b) Both C₃H₈ and C₄H₁₀ can be liquefied and used as fuels for camping stoves.

Suggest, with a reason, which of these two fuels is liquefied more easily.

(1)

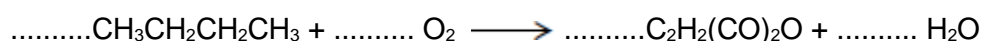
- (c) Write an equation for the complete combustion of C₄H₁₀

(1)

- (d) Explain why the complete combustion of C₄H₁₀ may contribute to environmental problems.

(1)

- (e) Balance the following equation that shows how butane is used to make the compound called maleic anhydride.



(1)

- (f) Ethanethiol (C₂H₅SH), a compound with an unpleasant smell, is added to gas to enable leaks from gas pipes to be more easily detected.

- (i) Write an equation for the combustion of ethanethiol to form carbon dioxide, water and sulfur dioxide.

(1)



- (ii) Identify a compound that is used to react with the sulfur dioxide in the products of combustion before they enter the atmosphere.

Give **one** reason why this compound reacts with sulfur dioxide.

Substance _____

Reason _____

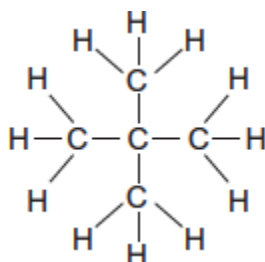
(2)

- (iii) Ethanethiol and ethanol molecules have similar shapes.

Explain why ethanol has the higher boiling point.

(2)

- (g) The following compound **X** is an isomer of one of the alkanes in the table on above.



- (i) Give the IUPAC name of **X**.

(1)

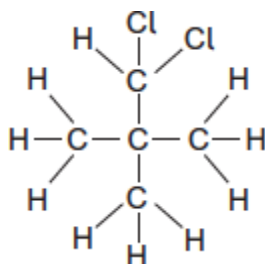
- (ii) **X** has a boiling point of 9.5 °C.

Explain why the boiling point of **X** is lower than that of its straight-chain isomer.

(2)



- (iii) The following compound **Y** is produced when **X** reacts with chlorine.



Deduce how many **other** position isomers of **Y** can be formed.
Write the number of **other** position isomers in this box.

(1)

- (h) Cracking of one molecule of an alkane **Z** produces one molecule of ethane, one molecule of propene and two molecules of ethene.

- (i) Deduce the molecular formula of **Z**.

(1)

- (ii) State the type of cracking that produces a high proportion of ethene and propene. Give the **two** conditions for this cracking process.

Type of cracking _____

Conditions _____

(2)

(Total 17 marks)

Q9.

Pent-1-ene is a member of the alkene homologous series.

- (a) Pent-1-ene can be separated from other alkenes.

State the physical property of alkenes that allows them to be separated from a mixture by fractional distillation.

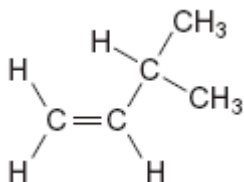
(1)



- (b) (i) State the meaning of the term *structural isomerism*.

(2)

- (ii) Name the branched chain isomer of pent-1-ene shown below.



(1)

- (iii) Draw the structure of a functional group isomer of pent-1-ene.

(1)

- (c) The cracking of one molecule of compound **X** produces pent-1-ene, ethene and butane in a 1:2:1 mol ratio.
Deduce the molecular formula of **X** and state a use for the ethene formed.

Molecular formula of **X** _____

Use of ethene _____

(2)

(Total 7 marks)



Q10.

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.

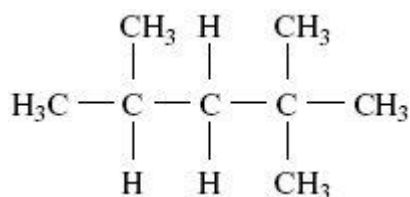
State how the oil company might have recognised the problem before the petrol was sold.

(2)

- (f) 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)



Q11.

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

(a) Any homologous series can be represented by a general formula.

(i) State **two** other characteristics of homologous series.

Characteristic 1 _____

Characteristic 2 _____

(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)

Q12.

(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)

Q13.

- (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)



Q14.

- (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)


Q8.

- (a) Fractional distillation / fractionation / GLC / gas liquid chromatography 1
- (b) C_4H_{10}
Need C_4H_{10} and the reason for the mark
 Because it has a higher bp / has stronger IMF / larger molecule / longer chain / larger surface (area) 1
- (c) $C_4H_{10} + 6\frac{1}{2} O_2 \longrightarrow 4CO_2 + 5H_2O$
Accept multiples
Ignore state symbols 1
- (d) CO_2 or H_2O evolved is a greenhouse gas / CO_2 or H_2O evolved contribute to global warming / the products are greenhouse gases
Ignore climate change 1
- (e) $CH_3CH_2CH_2CH_3 + 3.5O_2 \longrightarrow C_2H_2(CO)_2O + 4H_2O$
Accept multiples
Allow with or without a number 1 before the organic molecules 1
- (f) (i) $C_2H_5SH + 4.5O_2 \longrightarrow 2CO_2 + 3H_2O + SO_2$
Accept multiples 1
- (ii) Calcium oxide / calcium carbonate
Allow any base or alkali
Allow correct formulae 1
- Neutralises the SO_2 / acid base reaction / it is a base
Can only score M2 if base or alkali used in M1
Allow M2 if blank in M1 1
- (iii) Ethanol contains hydrogen bonding
Breaking covalent bonds CE = 0 / 2
 Which is stronger than IMF (VDW / dipole-dipole forces) in ethanethiol / (H bonding) is the strongest IMF
Only award M2 if M1 given, but allow IMF in ethanol are stronger than in ethanethiol for maximum 1 mark 1
- (g) (i) (2,2-)dimethylpropane
Ignore punctuation 1
- (ii) Because molecule is smaller / less polarisable / has less surface (area) / is more spherical / molecules can't get as close to one another (to feel the vdW)



forces)

Allow converse answers referring to straight chain isomers CE = 0 / 2 if breaking bonds

1

vdW intermolecular forces or vdW force between molecules are weaker or fewer

Need vdW rather than just IMF

1

(iii) 1 or one

1

(h) (i) C_9H_{20}

$H_{20}C_9$

1

(ii) Thermal (cracking)

If not thermal cracking CE = 0 / 2

1

High pressure AND high temperature

If blank mark on

Allow high P and T

1

OR

Pressure of ≥ 10 atm, ≥ 1 MPa ≥ 1000 kPa

AND temp of $400\text{ }^\circ\text{C} \leq T \leq 1000\text{ }^\circ\text{C}$ or $650\text{ K} \leq T \leq 1300\text{ K}$

Do not allow high heat

If no units for T, then range must be 650 – 1000

1

[17]

Q9.

(a) (Different) boiling points

Ignore mp's, references to imf, different volatilities

1

(b) (i) Compound which have the same molecular formula

Accept same no and type of atom for M1

But If same (chemical) formula M1 = 0 but allow M2

If empirical formula CE = 0/2

1

but different structures/different structural formulae/different displayed formulae

M2 dependent on M1

1

(ii) 3-methylbut-1-ene

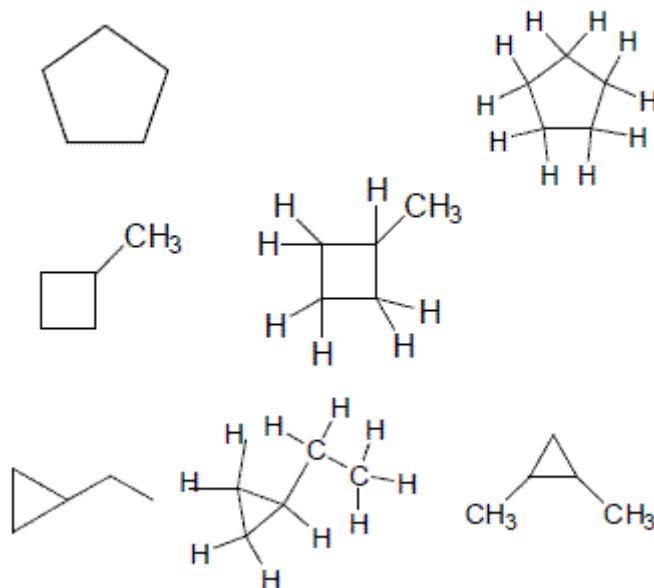
only



ignore commas and hyphens

1

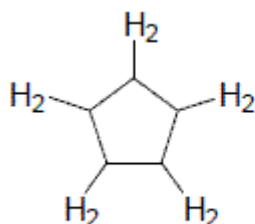
(iii)



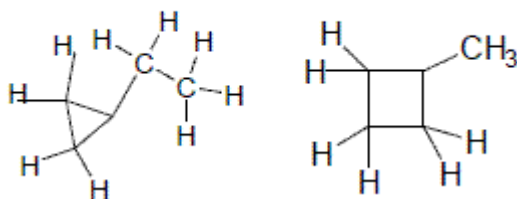
Allow any correct structure with a cyclic alkane

1

Do not allow



or



i.e with an H missing on one C

(c) $C_{13}H_{28}$

only

1

Making plastics/used to make polymers or polythene/used to make antifreeze/make ethanol/ripening fruit/any named additional polymer

not used as a plastic/polymer/antifreeze

not just 'polymers' – we need to see that they are being made

1

[6]


Q10.

- (a) Single bonds only /no double or multiple bonds; 1
- Contains carbon and hydrogen only;
C and H only
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 tower or column / cooler at top of column 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) $C_8H_{18} + 8\frac{1}{2} O_2 \rightarrow 8CO + 9H_2O$;
Allow multiples 1
- Rh/ Pd/Pt/Ir or in words;



- Penalise contradiction of name and symbol* 1
- $2\text{CO} + 2\text{NO} \rightarrow 2\text{CO}_2 + \text{N}_2$ / $2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2$;
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]

Q11.

- (a) (i) any two from:
 show a gradation/trend/gradual change in physical properties/
 a specified property
 differ by CH_2
 chemically similar or react in the same way
 have the same functional group
(penalise 'same molecular formula')
(penalise 'same empirical formula') 2
- (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) C₁₄H₃₀ only
(penalise as a contradiction if correct answer is accompanied by other structural formulae)
- 1
- (iii) C₁₀H₂₂ + 5½O₂ → 10C + 11H₂O
(or double this equation)
- 1
- (c) (i) ½N₂ + ½O₂ → NO
(or double this equation)
- 1
- (ii) Platinum or palladium or rhodium
- 1
- (iii) 2CO + 2NO → 2CO₂ + N₂ or
2NO → N₂ + O₂ or
(ignore extra O₂ molecules provided the equation balances)
- C + 2NO → CO₂ + N₂
(or half of each of these equations)
- C₈H₁₈ + 25NO → 8CO₂ + 12½N₂ + 9H₂O
(or double this equation)
- 1

[10]

Q12.

- (a) (i) fractional distillation or fractionation
- 1
- (ii) C₉H₂₀ only
- 1
- (iii) C₁₁H₂₄ + 17O₂ → 11CO₂ + 12H₂O
- 1
- (iv) C₁₁H₂₄ + 6O₂ → 11C + 12H₂O
- 1
- (b) (i) C₁₀H₂₂ → C₃H₆ + C₇H₁₆
- 1
- (ii) correctly drawn structure of methylpropene
(insist on clearly drawn C-C and C=C bonds)
- 1
- (c) Any two from



- o chemically similar or chemically the same or react in the same way
- o same functional group
- o same general formula
- o differ by CH₂
(penalise same molecular formula or same empirical formula)

2

[8]

Q13.

- (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 [$> 1 \text{ atm} \leq 10 \text{ atm}$ **OR 1 megaPa, 1000 kPa] (1)**
NOT high pressure

4

[11]

Q14.

- (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



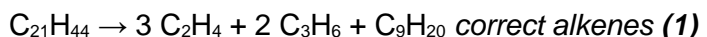
Negative temperature gradient on the column
or temperature of column decreases upwards **(1)**

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)**



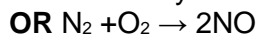
Accept CH₂CH₂ & CH₂CHCH₃ all correct (1)

3

- (c) (i) Sulphur (containing impurities) burn to form **or forms** SO₂ **or** oxides of sulphur *(if oxide identified, must be correct)* **(1)**
OR equation: e.g. S + O₂ → SO₂ **or** H₂S + 1½O₂ → SO₂ + H₂O

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

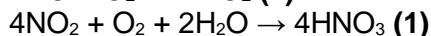
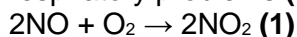
- (ii) NO formed by reaction between N₂ and O₂ from the air **(1)**



High combustion temperature **or** spark in engine **(1)**

provides E_A **or** sufficient heat / energy to break N≡N **(1)**

- (iii) Need to remove NO as forms acid rain **or** toxic product **or** causes respiratory problems **(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 N₂ + CO₂ **(1)**



Max 10

[17]