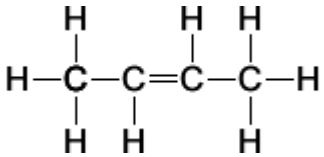
Q18.

Compound **X** is shown below. It is a member of a homologous series of hydrocarbons.



(a) (i) Deduce the general formula of the homologous series that contains **X**.

_____

(1)

(ii) Name a process used to obtain a sample of **X** from a mixture containing other members of the same homologous series.

_____

(1)

(b) There are several isomers of **X**.

(i) Give the IUPAC name of the position isomer of **X**.

_____

(1)

(ii) Draw the structure of a functional group isomer of **X**.

(1)

(c) At high temperatures, one molecule of $C_{15}H_{32}$ can be converted into two molecules of **X** and one molecule of another compound.

(i) Write an equation for this reaction.

_____

(1)

(ii) State the name of the process used to obtain a high yield of **X** from $C_{15}H_{32}$
Give **one** reason why this process is used in industry.

Name _____

Reason _____

_____

(2)

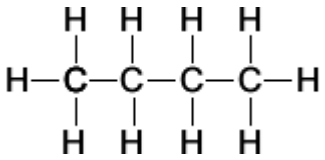
(iii) State why high temperatures are needed for this process.

_____

_____

(1)

(d) Compound **X** can be converted into compound **Y**.
Compound **Y** is shown below.



(i) Suggest the formula of a reagent that could be added to **X** in order to convert it into **Y**.

_____

(1)

(ii) Give **one** use of **Y**.

_____

(1)

(iii) Write an equation to show the reaction of **Y** in a limited supply of air to produce a solid and water only.

_____

(1)

(iv) When a sample of **Y**, contaminated with CH_3SH, is burned completely in air, a toxic gas is formed.
Identify this toxic gas and suggest a compound that could be used to remove the toxic gas from the products of combustion.

Toxic gas _____

Compound used to remove toxic gas _____

_____

(2)

(v) Suggest the name of the process that occurs when the toxic gas in part (d)(iv) is removed.

_____

(1)

(e) Explain why the boiling points of **X** and **Y** are similar.

(2)

(Total 16 marks)

Q19.

Methanol (CH_3OH) is an important fuel that can be synthesised from carbon dioxide.

(a) The table shows some standard enthalpies of formation.

	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
$\Delta H_f^{\ominus}$/kJ mol^{-1}	– 394	0	– 201	– 242

(i) Use these standard enthalpies of formation to calculate a value for the standard enthalpy change of this synthesis.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

(3)

(ii) State why the standard enthalpy of formation for hydrogen gas is zero.

(1)

(b) State and explain what happens to the yield of methanol when the total pressure is increased in this synthesis.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Effect on yield _____

Explanation _____

_____

_____

_____

_____

_____

(3)

(c) The hydrogen required for this synthesis is formed from methane and steam in a reversible reaction. The equation for this reaction is shown below.

$$CH_4(g) + H_2O(g) \rightleftharpoons C0(g) + 3H_2(g) \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

State and explain what happens to the yield of hydrogen in this reaction when the temperature is increased.

Effect on yield _____

Explanation _____

_____

_____

_____

_____

(3)

(d) The methanol produced by this synthesis has been described as a carbon-neutral fuel.

(i) State the meaning of the term *carbon-neutral*.

_____

_____

_____

_____

(1)

(ii) Write an equation for the complete combustion of methanol.

_____

(1)

(iii) The equation for the synthesis of methanol is shown below.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Use this equation and your answer to part (d)(ii) to deduce an equation to represent the overall chemical change that occurs when methanol behaves as a carbon-neutral fuel.

Equation _____

(1)

(e) A student carried out an experiment to determine the enthalpy change when a sample of methanol was burned.

The student found that the temperature of 140 g of water increased by 7.5 °C when 0.011 mol of methanol was burned in air and the heat produced was used to warm the water.

Use the student's results to calculate a value, in kJ mol^{-1}, for the enthalpy change when one mole of methanol was burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1}).

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 16 marks)

Q20.

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)

Q21.

(a) There is a risk of gas explosions in coal mines. This risk is mainly due to the presence of methane. If the percentage of coal-mine methane (CMM) in the air in the mine is greater than 15%, the explosion risk is much lower. CMM slowly escapes from the mine into the atmosphere.

Write an equation to show the complete combustion of methane.

Suggest **one** reason why there is a much lower risk of an explosion if the percentage of CMM is greater than 15%.

State why it is beneficial to the environment to collect the CMM rather than allowing it to escape into the atmosphere.

_____

_____

_____

_____

_____

_____

(3)

(b) Methane can be obtained from crude oil. Some of this crude oil contains an impurity called methanethiol (CH_3SH). This impurity causes environmental problems when burned.

Write an equation to show the complete combustion of methanethiol.

State why calcium oxide can be used to remove the sulfur-containing product of this combustion reaction.

State **one** pollution problem that is caused by the release of this sulfur-containing product into the atmosphere.

_____

_____

_____

_____

_____

_____

(3)

(Total 6 marks)

Q22.

Pentane is a member of the alkane homologous series.

(a) Give the general formula for the homologous series of alkanes.

_____

(1)

(b) One of the structural isomers of pentane is 2,2-dimethylpropane.

Draw the displayed formula of 2,2-dimethylpropane.

State the type of structural isomerism shown.

_____

(2)

(c) A molecule of hydrocarbon **Y** can be thermally cracked to form one molecule of pentane and two molecules of ethene only.

Deduce the molecular formula of **Y**.

State why high temperatures are necessary for cracking reactions to occur.

Give **one** reason why thermal cracking reactions are carried out in industry.

(3)

(d) Write an equation for the incomplete combustion of pentane to form a solid pollutant.

Suggest why this solid pollutant is an environmental problem.

(2)

(e) Pentane can react with chlorine as shown in the following equation.

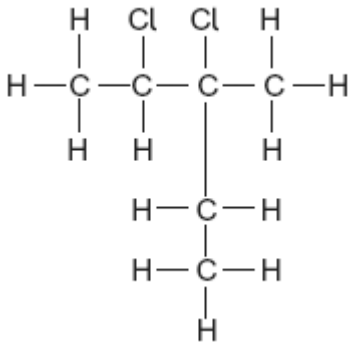
$$C_5H_{12} + Cl_2 \rightarrow C_5H_{11}Cl + HCl$$

Calculate the percentage atom economy for the formation of $C_5H_{11}Cl$

Deduce how many straight-chain isomers of $C_5H_{11}Cl$ could be formed.

(3)

(f) Consider the following compound.



Name this compound.

Deduce the empirical formula of this compound.

_____

_____

_____

_____

(2)

(Total 13 marks)

Q23.

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)

Mark Scheme

Q18.

(a) (i) C_nH_{2n} / C_xH_{2x}

1

(ii) Fractional distillation / GLC / gas liquid chromatography / fractionation

*Do **not** allow cracking / distillation*

1

(b) (i) But-1-ene / but1ene

Ignore hyphens and commas

*Do **not** allow butene-1 / but-2-ene / butane / butane /alkene / C_4H_8 / propene / straight-chain alkene*

1

(ii) A structure of cyclobutane or methyl-cyclopropane

Allow skeletal formula.

1

(c) (i) $C_{15}H_{32} \rightarrow 2C_4H_8 + C_7H_{16}$

Do not accept multiples.

1

(ii) Thermal cracking

Not catalytic cracking or cracking.

1

To produce products that are in greater demand / more valuable / more expensive / more profitable

The (unsaturated) alkene or the (unsaturated) molecule or X produced can be polymerised or can be made into plastics.

Ignore more useful products.

1

(iii) Break (C–C or C–H) bonds

Allow to overcome the activation energy.

Allow to break the carbon chain.

Penalise breaking wrong bonds.

1

(d) (i) H_2

Only.

1

(ii) Fuel / LPG

Allow camping gas, lighter fuel, propellant, refrigerant, cordless appliances.

Do not allow petrol or motor fuel.

Ignore natural gas.

1

(iii) $C_4H_{10} + 2.5O_2 \rightarrow 4C + 5H_2O$

Accept multiples.

1

(iv) SO^2 / sulfur dioxide

If other sulfur oxides, mark on.

1

Calcium oxide / CaO / lime / quicklime

Allow $CaCO_3$ / allow $Ca(OH)_2$ or names.

Allow any solid base.

M2 dependent on M1.

Do not allow limewater.

1

(v) Neutralisation

Allow acid-base reaction.

Allow flue gas desulfurisation / FGD

1

(e) (Molecules) are similar sizes / have similar M_r / have similar number of electrons

Chemical error CE = 0/2 if breaking bonds.

Allow similar number of carbon and hydrogen atoms / similar surface area / similar chain length.

Can accept same number of carbon atoms.

Do not accept same number of H atoms / same number of bonds.

Ignore similar amount of bonds.

1

Similar van der Waals forces <u>between molecules</u> / similar <u>intermolecular</u> forces (IMF)

Not similar incorrect IMF eg dipole-dipole

1

[16]

Q19.

(a) (i) **M1** **(could be scored by a correct mathematical expression which <u>must</u> have <u>all</u> ΔH symbols and the $\sum$ or SUM)**

M1 $\underline{\Delta H_r} = \Sigma\Delta H_f$ **(products)** - $\Sigma\Delta H_f$ **(reactants)**

OR a <u>correct cycle of balanced equations with 1C, $3H_2$ and $1O_2$</u>

M2 $\underline{\Delta H_r} = -201 + (-242) - (-394)$
$\underline{\Delta H_r} = -201 - 242 + 394$
$\underline{\Delta H_r} = -443 + 394$
(This also scores M1)

M3 = – **49** (kJ mol^{-1})
(Award 1 mark ONLY for + 49)

Correct answer gains full marks

Credit 1 mark ONLY for + 49 (kJ mol^{-1})

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either correct cycle of balanced equations with 1C, $3H_2$ and $1O_2$*

  *OR a clear statement of **M1** which could be in words and scores only **M1***

3

(ii) It is an element / elemental

Ignore reference to "standard state"

OR

By definition

1

(b) **M1** (The yield) increases / goes up / gets more

*If M1 is given as "decreases" / "no effect" / "no change" then CE= 0 for clip, but mark on only **M2** and **M3** from a blank M1*

M2 There are more moles / molecules (of gas) on the left / of reactants
OR fewer moles / molecules (of gas) on the right
/ products
OR there are 4 moles /molecules (of gas) on the left and 2 moles / molecules on the right.
OR (equilibrium) shifts / moves to the side with less moles / molecules

*Ignore "volumes", "particles" "atoms" and "species" for **M2***

M3: Can only score M3 if M2 is correct

The (position of) equilibrium shifts / moves (from left to right) to oppose the increase in pressure

*For **M3**, not simply "to oppose the change"*

*For **M3** credit the equilibrium shifts / moves (to right) to lower / decrease the pressure*

(There must be a specific reference to the change that is opposed)

3

(c) **M1** Yield increases goes up

M2 The (forward) reaction / to the right is endothermic OR takes in/ absorbs heat

OR

The reverse reaction / to the left is exothermic OR gives out / releases heat

*If M1 is given as "decrease" / "no effect" / "no change" then CE= 0 for clip, but mark on only **M2** and **M3** from a blank **M1***

Can only score M3 if M2 is correct

M3 The (position of) equilibrium shifts / moves (from left to right) to oppose the increase

in temperature **(QoL)**

*For **M3**, not simply "to oppose the change"*

*For **M3**, credit the (position of) equilibrium shifts / moves **(QoL)***

*to absorb the heat **OR***

*to cool the reaction **OR***

to lower the temperature

(There must be a specific reference to the change that is opposed)

3

(d) (i) An activity which has no net / overall (annual) carbon emissions to the atmosphere

OR

An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere.

OR

There is no change in the total amount / level of carbon dioxide /CO_2 carbon /greenhouse gas present in the atmosphere.

The idea that the carbon /CO_2 given out equals the carbon /CO_2 that was taken in from the atmosphere

1

(ii) $CH_3OH + \mathbf{1}½\ O_2 \rightarrow CO_2 + \mathbf{2}H_2O$

Ignore state symbols

Accept multiples

1

(iii) $\mathbf{3}H_2 + \mathbf{1}½\ O_2 \rightarrow \mathbf{3}H_2O$

Ignore state symbols

OR

Accept multiples

$\mathbf{2}H_2 + O_2 \rightarrow \mathbf{2}H_2O$

Extra species must be crossed through

1

(e) **M1** $q = m\ c\ \Delta T$

Award full marks for correct answer

Ignore the case for each letter

OR $q = 140 \times 4.18 \times 7.5$

M2 = 4389 (J) OR 4.389 (kJ) OR 4.39 (kJ) OR 4.4 (kJ)(also scores M1)

M3 Using 0.0110 mol

therefore $\Delta H =$ **– 399** ($kJmol^{-1}$)

OR **– 400**

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect; +399 **gains 2 marks***

*Penalise **M2** for arithmetic error and mark on*

*In **M1**, do not penalise incorrect cases in the formula*

If $\Delta T = 280.5$; score $q = m\ c\ \Delta T$ only

*If c = 4.81 (leads to 5050.5) penalise **M2** ONLY and mark on for **M3** = – 459*

+399 or +400 gains 2 marks

Ignore incorrect units

3

[16]

Q20.

(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]

Q21.

(a) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Accept multiples

Ignore state symbols even if incorrect

1

Not enough oxygen / air

1

CMM / methane is a greenhouse gas / contributes to global warming

Do not allow formation of CO_2 / CO_2 is a greenhouse gas

Apply list principle, eg

CH_4 is a greenhouse gas and toxic = 0

CH_4 is a greenhouse gas and damages ozone = 0

Allow CH_4 and CO_2 are greenhouses gases

Allow collect to use as a fuel so fossil fuels do not run out (as quickly)

1

(b) $CH_3SH + 3O_2 \rightarrow CO_2 + 2H_2O + SO_2$

Accept multiples

Ignore state symbols even if incorrect

1

Calcium oxide is basic (and SO_2 is acidic) /

CaO neutralises SO_2 /

CaO reacts with SO_2 to form gypsum / salt / solid / $CaSO_4$ / $CaSO_3$

Allow $CaO + SO_2 \rightarrow CaSO_3$

M2 and M3 can only be scored if SO_2 seen somewhere in the answer

1

Acid rain

Allow consequence of acid rain eg increased rusting of iron / fish in lakes die / problems for asthmatics

Apply list principle

Ignore air pollution

1

[6]

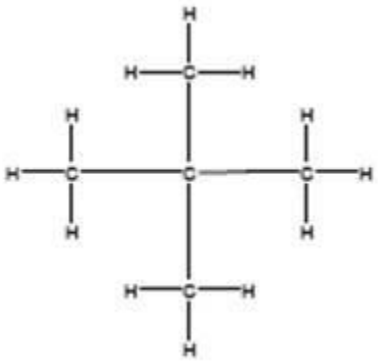
Q22.

(a) $C_n H_{2n+2}$

Allow x in place of n

1

(b)



Chain

Must show every bond

Allow branched chain

2

(c) C_9H_{20}

Only

1

To break the (C-C and/or C-H) bonds

M2=0 if break C=C

1

To make products which are in greater demand / higher value / make alkenes

Not more useful products

Allow specific answers relating to question

1

(d) $C_5H_{12} + 3O_2 \rightarrow 5C + 6H_2O$

Allow other balanced equations which give C and CO/CO_2

1

Causes global dimming / exacerbates asthma / causes breathing problems / makes visibility poor / smog

Apply list principle

Ignore causes cancer / toxic

1

(e) $\frac{106.5}{143}$ (x 100)

1

74.48%

Allow 74.5%

1

3

Only

1

(f) 2,3-dichloro-3-methylpentane

Ignore punctuation

1

$\underline{C_3H_6Cl}$

Only

1

[13]

Q23.

(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]