1. (a) (i) OH/hydroxy/hydroxyl/ROH ✓

(ii) $C_nH_{2n+1}OH$ ✓

(iii) $C_7H_{15}OH$ / $C_7H_{16}O$ ✓

(b) 88. ✓

(c)(i) 1 mark for plotting the points ✓

1 mark for the line extended to enable b.pt of $C_8H_{17}OH$ to be estimated. ✓

(ii) I butan-1-ol 115 -125 °C ✓

II $C_8H_{17}OH$ 190 -205 °C ✓

(ii) Boiling point increases as the M_r increases/ proportional to M_r . ✓

[Total : 9]

2 (a) contains carbon and hydrogen **only** ✓

separates due to differences in boiling point ✓

(b) works out/uses $M_r = 156$ ✓

(ii) 132/156 method mark ✓

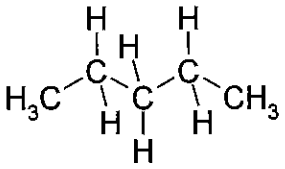
84.6% C ✓

(c) $C_{11}H_{24} \rightarrow C_9H_{20}$ ✓ + C_2H_4 ✓

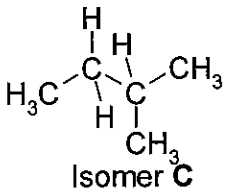
Ethene ✓

(d) (i) Draw the isomers of pentane.

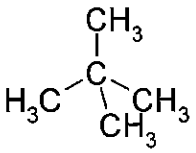
✓ ✓ ✓



Isomer **B**



Isomer **C**



Isomer **D**

(ii) **D**, **C**, **B** to match as drawn in (d)(i) ✓

(iii) less van der Waals' forces in **D**/ as chain length increases so does b pt./greater the branching~lower the boiling point ✓

(iv) $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$ ✓✓

($CO_2 + H_2O$ gets ✓)

(v) branched chains burn more efficiently/ add it to petrol ✓

[Total : 16]

3 (a) Initiation $Cl_2 \rightarrow 2Cl\bullet$ ✓

Propation 1 $C_3H_8 + Cl\bullet \rightarrow HCl + C_3H_7\bullet$ ✓

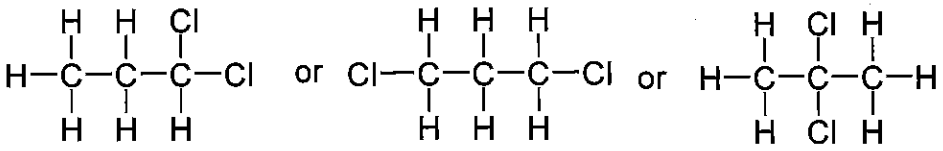
Propagation 2 $C_3H_7\bullet + Cl_2 \rightarrow C_3H_7Cl + Cl\bullet$ ✓

Termination Any two free radicals ✓

[4]

(b) (i) Compound **H** = 1,2-dichloropropane ✓

(ii) 1 mark for each correct structure ✓✓



(c) (i) water ✓

(ii) OH^- behaves as a nucleophile ✓

OH^- has a lone pair of electrons/ seeks out electron deficient areas/attracted to $C^{\delta+}$ ✓

(d) (i) reflux is the **continuous** process of **evaporation** followed by **condensation**/ description of what would be seen to indicate that the process is continuous ✓

(ii) orange ✓

to green ✓

(iii) $C_3H_7OH/C_3H_8O + 2[O] \rightarrow C_2H_5COOH/C_3H_6O_2 + H_2O$ ✓✓

(All three formulae correct gets one mark)

(e) wavenumber $1680 - 1750\ cm^{-1}$ ✓

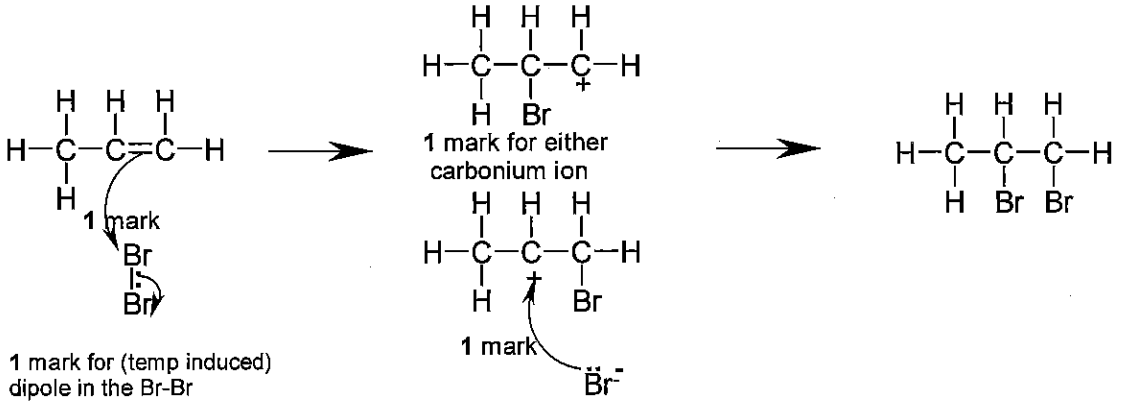
bond C=O ✓

wavenumber $2500 - 3300\ cm^{-1}$ ✓

bond O-H ✓

[Total : 19]

4 (a)



✓ ✓ ✓ ✓

[4]

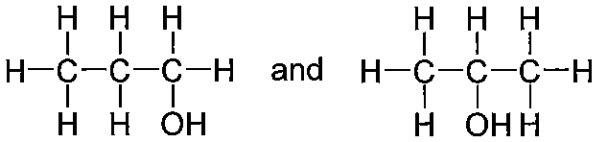
5 marking points for **max** of **4** marks

(b) (i)

(ii) reagent = H_2 ✓

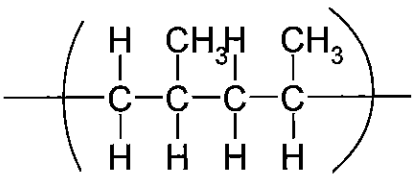
conditions = Ni/Pt as catalyst ✓

(iii) ✓✓



(c) (i) Addition polymer ✓

(ii)



✓

(iii) non-biodegradeable or words to that effect ✓

when burnt they release toxic fumes ✓

[Total : 13]

5 (a) (i) $C_4H_9OH/C_4H_{10}O$ ✓

(ii) $C_4H_9OH/C_4H_{10}O$ + HCl → C_4H_9Cl + H_2O ✓

(b) The upper layer because the organic compounds have a **lower density** than water. ✓

(c) (i) CO_2 ✓

(ii) HCl ✓

(d) (i) 51 °C ✓

(ii) 4/74 = 0.05(4) ✓

(iii) 3.75/92.5 = 0.04(1) ✓

(iv) 75% (allow 80% if (d) (ii) given as 0.05 / mark ecf for (d)(ii)/(d)(i) *100) ✓

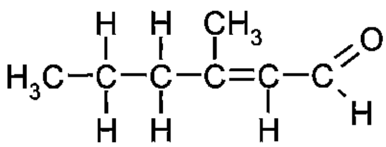
[Total : 9]

6 (a)

functional group 1	alkene			✓
test	add bromine			✓
observation	decolourised			✓
~~functional group 2~~	~~alcohol~~			~~✓~~
~~test~~	~~Na/~~	~~PCl_5/~~	~~RCO_2H~~	~~✓~~
~~observation~~	~~bubbles/H_2~~	~~white fumes/HCl~~	~~smell~~	~~✓~~

[6]

(b)



Compound **F**

✓

[1]

[Total : 7]

7 Fermentation ✓

Yeast/enzyme ✓

Temperature about 30 °C ✓

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

Batch process ✓

Hydration of ethene. ✓

Reagent steam/water at > 100 °C ✓

Temp/press 300 °C & 70 –100 atm ✓

Catalyst phosphoric acid ✓

$C_2H_4 + H_2O \rightarrow C_2H_5OH$ ✓

Continuous process ✓

1 mark available for *Quality of written communication*..... base the award of the mark on the ability to communicate the essential chemistry ✓

[Total : 12 max = 9]

8 Ethane saturated/single bonds only/ σ-bond ✓

tetrahedron ✓

109^o 28' ✓

Ethene unsaturated/double bonds/contains a π-bond ✓

draws or explains overlap of adjacent p-orbitals at right angle to the plane of the molecule ✓*

trigonal planar ✓

approx 120^o ✓

1 mark available for *Quality of written communication* ..... base the award of the mark on the ability to use essential technical language such as *saturated/unstaurated/tetrahedron, trigonal planar/ overlap of adjacent p-orbitals* ✓

[Total : 8]

1 (a)(i) **F** ✓

(ii) C_6H_{14} ✓

(iii) CH_2 ✓

(b) (i) **C**, **D** and **E** ✓

same (molecular) formula/number of atoms of each element,
different structure/arrangement of atoms/displayed formula/carbon backbone
not "spatial" arrangement ✓

(c) (i) **C** ✓

(ii) **C** ✓

(iii) van der Waals ✓

Any mention of van der Waal's /dispersion/London forces gets one mark

C> A &B due to the longer chain /number of electrons **hence** the greater the number of vdW's/ surface interaction/ intermolecular forces or converse ✓

C>D & E the more branched/compact/cannot pack together as close **hence** the fewer vdW's/surface interaction/ or converse ✓

Penalise only once

[Total :10]

2. (a) (i) Method mark if each element is divided by its own A_r

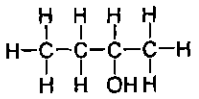
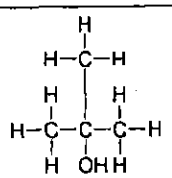
	C	.	H	:	O	
÷ by A_r	5 41	.	13.5	:	1.35	✓
÷ by 1.35	4	:	10	:	1	✓

Alternative approach is acceptable and would score both marks.

	C	:	H	:	O	
	$\frac{64.9 \times 74}{100}$	:	$\frac{13.5 \times 74}{100}$	:	$\frac{21.6 \times 74}{100}$	
	48	:	10(9.99)	:	16(15.9)	✓
Divide each by its own A_r						
	4	:	10	:	1	✓

(ii) $C_4H_{10}O = 48 + 10 + 16 = 74$ ∴ molecular formula = $C_4H_{10}O$ ✓
Must be some working as evidence as they are given M_r = 74 in the stem

(b)

structural isomer	displayed formula	name	classification	
1			primary	✓
2		butan-2-ol		✓✓
3		2-methylpropan-1-ol	primary	✓✓
4			tertiary	✓✓

Any unambiguous structure gets the marks
$CH_3CH_2CHOHCH_3$ is OK
and the minimum allowed for the second is $(CH_3)_3COH$

[7]

3 (a) *If correct formulae are given instead of name do **not** penalise.*

If both formula and name are given and they are conflicting the mark will not be awarded

reaction 1

sodium or potassium hydroxide/ OH^-/hydroxide/NaOH/KOH ✓
water/(aq)/ H_2O ✓

reaction 2

ammonia/NH_3 ✓
ethanol/ethanol+water/alc/C_2H_5OH ✓

reaction 3

sodium or potassium hydroxide/ OH^-/hydroxide/NaOH/KOH ✓

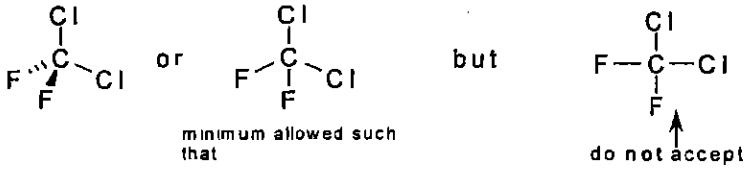
ethanol/ alc/ C_2H_5OH ✓

(b) Slower: ✓

C-Cl bond > C-Br bond/ C-Cl bond is shorter/stronger than C-Br bond/ Higher activation energy with C-Cl ✓

If faster is given .... this is incorrect and gets no mark
but if they give the reason for it being faster as

Cl is more electronegative/C-Cl is more polar this gets 1 mark ✓*ecf*

(c)(i) 

✓

(ii) $109^o\ 28'$ (range 108 – 110°) ✓

(iii) Volatile/low boiling point/ unreactive/ inert/non-flammable/non-toxic ✓

(iv) each takes one (covalent)electron/ $Cl_2 \rightarrow 2Cl\bullet$ ✓

(v) Bond : C-Cl ✓

Reason. C-Cl bond weaker/longer/ C-F bond stronger/ C-F>C-Cl ✓

(vi) Cl(•) ✓

(•) $CClF_2$ ✓

If (c) (v) incorrectly identified as C-F you (vi) can be marked consequentially

[Total : 16]

4. (a) Water/ H_2O/cyclohexanol/$C_6H_{11}OH$/$C_6H_{12}O$ ✓
(not H_3PO_4 as it boils/dehydrates @ 213 °C)

(b) (i) 100 ✓

(ii) 0 1 mark ecf to (i) ✓

(iii) 82 *(used for M_r of cyclohexene)* ✓

0.045 (*gets both marks)* ✓

(iv) $\frac{\text{moles of cyclohexene}}{\text{moles of cyclohexanol}} \times 100$ ✓

45% ✓

Part (iv) can be marked consequentially from parts (ii) and (iii) such that

(iii)/(ii) x 100 *gets 1 mark*

and would get both marks if the mathematics are carried out correctly

[Total : 7]

5. (a)(i) An Electrophile is an electron/lone pair acceptor ✓

(ii) Example anything with a + charge (except a metal ion) e.g Cl^+, NO_2^+, H^+ alsoaccept Br_2, Cl_2, H_2SO_4,HBr,H_2 ✓

(iii) Balanced equation for electrophilic addition,

$C_2H_4 + XY \rightarrow C_2H_4XY$/ $C_2H_4 + X_2 \rightarrow C_2H_4X_2$ ✓

(b)(i) Nucleophile is a electron/lone pair donor ✓

(ii) Example Cl^-, OH^-, CN^-, NH_3, H_2O, ROH ✓

(iii) Balanced equation for nucleophilic substitution,

$RX + Y^- \rightarrow RY + X^-$ / $RX + HY \rightarrow RY + HX$ ✓

typically Y^- could be anyone of Cl^-, OH^-, CN^-
whilst HY could be anyone of NH_3, H_2O, ROH

(c)(i) Free radical has a single/unpaired electron (**not** a free electron) ✓

(ii) Example any suitable radical e.g. •Cl , $•CH_3$, Br• ✓

(iii) Balanced equation for a free radical substitution.

$CH_4 + •Cl \rightarrow •CH_3 + HCl$ / $•CH_3 + Cl_2 \rightarrow CH_3Cl + •Cl$ /
$CH_4 + Cl_2$ or $2Cl• \rightarrow CH_3Cl + HCl$ ✓

[Total : 9]

6. (a)(i) (will be marked as a single sub-unit worth 4 marks) There are 5 marking points with a maximum of 4. If MnO_4^- used max = 3 marks

5 marking points for	**4** marks
4 marking points for	**3** marks
3 marking points for	**2** marks
2 marking points for	**1** mark

$Cr_2O_7^{2-}$ / dichromate/ sodium or potassium dichromate/ $Na_2Cr_2O_7$/ $K_2Cr_2O_7$ ✓

Acidified/ H^+/ sulphuric acid / H_2SO_4 ✓

reflux/heat/warm ✓

Orange ✓ to Green ✓

Record marks in the margin as 5 → 4 or 3 → 2

(ii) Reflux: ✓

to ensure complete oxidation/ avoid partial oxidation/to form the acid/to avoid distillation of aldehyde ✓

(iii) $C_7H_{16}O$ /$C_7H_{15}OH$ ✓

(iv) $C_7H_{16}O + 2[O] \rightarrow C_7H_{14}O_2 + H_2O$ (1mark for both products) ✓✓

Correctly balanced equation gets both marks

(v) aldehyde/$C_7H_{14}O$/ 2-ethyl-3-methylbutanal ✓

(b) (2-ethyl-3-methylbutan-2-ol is a) tertiary alcohol ✓

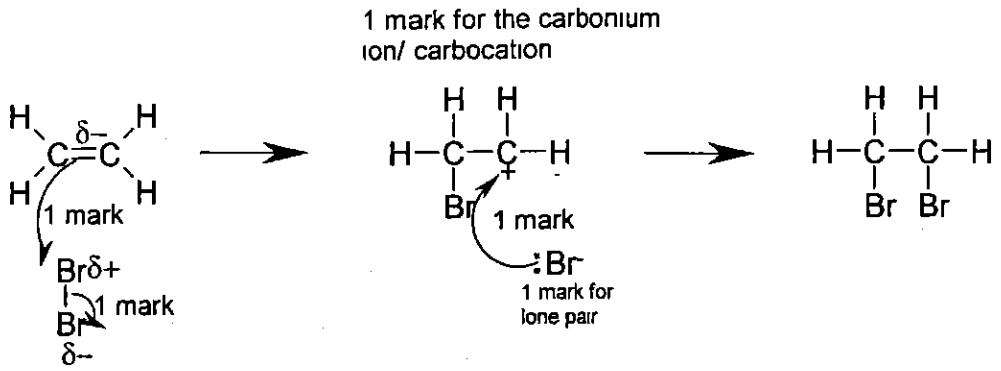
tertiary alcohols are **not** (readily) oxidised/does not react with (H^+)/$Cr_2O_7^{2-}$ ✓

[Total . 12]

7. (bromine is) decolourised (do not accept clear) ✓

Product: 1,2-dibromoethane ✓

Maximum of 4 marks for the mechanism



Electrophilic addition ✓

Induced dipole in the Br_2/ dipoles shown correctly on the Br-Br bond ✓

curly arrow on Br-Br bond as shown/hetrolytic fission ✓

Curly arrow from the π- bond to the bromine or words to that effect ✓

Intermediate carbonium ion/ carbocation ✓

Curly arrow from Br^- back to the carbonium ion/ carbocation/nucleophilic attack/Br^- forms a covalent bond with the carbocation ✓

Lone pair of electrons shown on the Br^- (and curly arrow from lone pair to the carbonium ion/ carbocation)/ Br^- acys as a lone pair donor ✓

[9marks; max = 6]

1 mark for quality of written expression awarded for the description / layout of the mechanism making use of appropriate chemical terms/symbols The mark should be awarded if two or more of the following are used correctly:

- lone pair
- polarised
- hetrolytic fission/hetrolysis
- induced dipole
- curly arrows
- carbonium ion/ carbocation
- electrophilic addition ✓

If two or more chemistry marks are awarded for the mechanism I would also expect the QWC to be awarded.

Record marks for the question by counting ✓given for the chemistry as a total (max =6) followed by either ✓QWC or xQWC and the total for the question {chemistry + QWC} circled at the end of the question. It should look something like·

5
✓QWC

6

8. (a) **Cracking:**

The lighter/smaller/shorter fractions are the more useful/ in demand ✓

Heavier/longer chains cracked into shorter chains + alkene ✓

Suitable balanced equation ✓

Using heat/catalyst/ both ✓

Point of fission is variable therefore get a great variety of products ✓

Alkenes have great importance as a starting point for other products/suitable example/equation e.g. ethanol/polymers etc ✓

Reforming:

(Reforming converts straight chains into) ring compounds/cycloalkanes/arenes ✓

Suitable balanced equation for cycloalkane ✓
$C_6H_{14} \rightarrow C_6H_{12} + H_2$
Suitable balanced equation for arene ✓
$C_6H_{14} \rightarrow C_6H_6 + 4H_2$ / $C_6H_{12} \rightarrow C_6H_6 + 3H_2$

Isomerisation:

Isomerisation converts straight chains into branched chains. ✓

Suitable example. ✓

Ring compounds and/or branched chain compounds are better fuels than straight chain compounds (***not** just good fuels, there must be a comparison*)/ added to petrol to promote smoother combustion/ avoid knocking/ increase octane number or rating. ✓

12 max = 9

(1 mark is available for the quality of written communication.)
This mark should be awarded for spelling, punctuation and grammar. It will be unusual **not** to give the mark. ✓

Record marks for the question by counting ✓given for the chemistry as a total (max =9) followed by either ✓QWC or xQWC and the total for the question {chemistry + QWC} circled at the end of the question It should look something like:

7
✓QWC

1(a)(i) propan-1-ol ✓

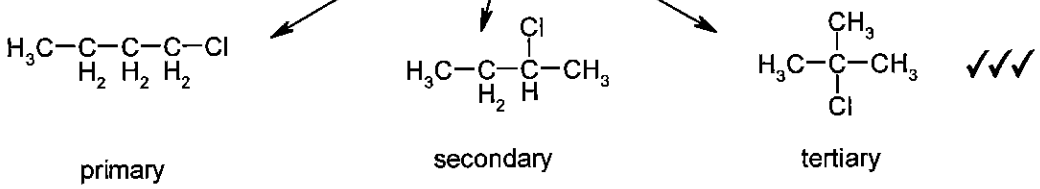
(ii) butan-2-ol ✓

(b) C_6H_{14} ✓

(c) C_3H_7 *(ecf to (b))* ✓

(d) alkane /C_nH_{2n+2} ✓

(e) any unambiguous structure



primary secondary tertiary ✓✓✓

[Total : 8]

2 (a) (i) Fission = bond breaking ✓

(ii) Cl_2 with methane is <u>homolytic</u> fission ✓

Cl_2 with ethene is <u>heterolytic</u> fission ✓

(iii) Homolytic fission $Cl_2 \rightarrow Cl\bullet + Cl\bullet$ / 2 Cl•/ 2Cl ✓

Heterolytic fission $Cl_2 \rightarrow Cl^+ + Cl^-$ ✓

(b) nucleophile = Cl^- ✓

electrophile = Cl^+ ✓

free radical = $Cl^\bullet$/Cl ✓

3 (a) (i) C_nH_{2n+2} ✓

(ii) CH_2 ✓

(iii) $C_{16}H_{34}$ ✓

(b) (i) shorter chain alkane & alkene ✓

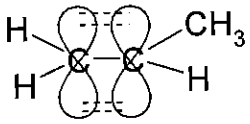
clearly stated use: used in fuel/additive to petrol/polymers/ethanol etc not simply "more useful". ✓

(ii) $C_{12}H_{24}$ ✓

(c) (i) bond angle **a** $109^o\ 28^/$ (allow range $109 - 110^o$) ✓

bond angle **b** (allow range $118 - 122^o$) ✓

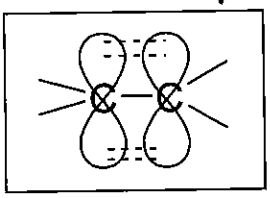
(ii)



The overlap of adjacent p orbitals ✓

Suitable diagram ✓

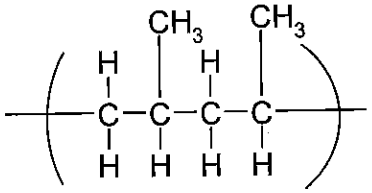
Minimum allowed



(iii) (Addition of) bromine ✓

which is decolourised by propene/ or converse ✓

(d) (i)



✓✓

1mark for the backbone of 4C's + the two end bonds
not just the end-bonds

(ii) addition polymerisation ✓

(e) (i) non-biodegradeable or words to that effect/ eye-sore or wtte ✓

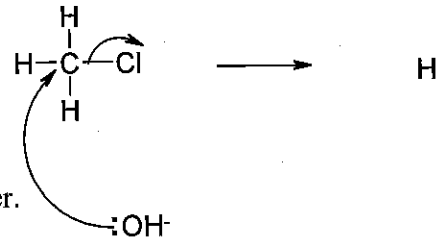
(ii) Advantage: combustion for energy production ✓
Disadvantage: produce toxic/harmful/dangerous fumes ✓

[Total : 18]

4

(a) $^{\delta+}C—Cl^{\delta-}$ ✓

(b) (i) lone pair donor ✓

(ii) 

✓✓

marking points

curly arrow showing bonded pair in C-Cl bond move to the Cl ✓

curly arrow from OH^- to C

(c) (i) Faster.

lone pair not essential

The C-I bond is

weaker/longer. ✓

(ii) Reagent: $AgNO_3(aq)/Ag^+(aq)$ or some reference to a solution/aq or ethanolic ✓✓
$AgNO_3/Ag^+$ gets 1 mark

(AgCl is) white/milky solid/ppt ✓

(AgI is} yellow solid/ppt ✓

Final mark requires a comparison of either the rate or the extent of the precipitation:
AgI(s) ppt first/fastest/heaviest/denser (or vice versa for AgCl) ✓

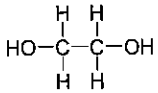
(d) (i)

C	H	Br	
12.76/12	2.13/1	85.11/79.9	
1.06	2.13	1.06(5)	✓
1	2	1	✓

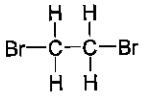
(ii) empirical unit (CH_2Br) has a mass = 93.9 or equivalent working ✓

Molecular formula is ∴ $C_2H_4Br_2$ = 187.8 ✓

(iii) 1,1-dibromoethane ✓ and 1,2-dibromethane ✓

(e)(i) 

✓

(ii)  ✓

(iii) $C_2H_4Br_2 + 2OH^- \rightarrow C_2H_4(OH)_2 + 2Br^-$/
$C_2H_4Br_2 + 2H_2O \rightarrow C_2H_4(OH)_2 + 2HBr$ ✓✓

$C_2H_4Br_2$, OH^- / H_2O & $C_2H_4(OH)_2$/ $C_2H_6O_2$ scores1 mark

(iv) Lowers freezing point of water/ non-corrosive/ has H-bonds/ miscible with water/ high boiling point ✓

[Total : 22]

5 (a) (i) catalyst/ speeds up ✓

(ii) *refluxed* =continuous evaporation & condensation or wtte ✓

(iii) CO_2 ✓

(b) (i) $CH_3CO_2H = 60$ ✓

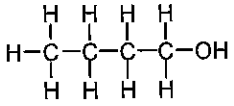
(ii) 0.1 (mol) *(6/(i) for ecf)* ✓

(iii) 0.1 (mol) ✓

(iv) 7.8/130 = 0.06 {(iv)/(ii) x 100} ✓

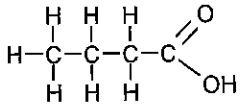
(v) 60% ✓

(c)(i)



✓

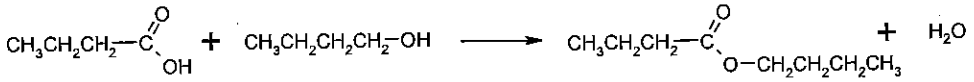
(ii)



✓

or $CH_3CH_2CH_2CO_2H$ /$CH_3(CH_2)_2CO_2H$

(iii)



$C_4H_8O_2$/ C_3H_7COOH $C_4H_{10}O$ / C_4H_9OH $C_8H_{16}O_2$

✓

or the equivalent

[Total : 11]

6 (a) alcohol/ROH/ OH/hydroxy(l) *not COH/OH* ✓

alkene/C=C ✓

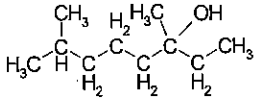
(b) (i) contains **no** double/multiple bonds/single bonds **only** ✓

(ii) Ni/Pt/Pd/Rh ✓

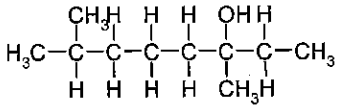
(iii) 1 mark if 1C=C correctly hydrogenated

2 marks if both C=C correctly hydrogenated

$C_{10}H_{22}O$ gets both marks

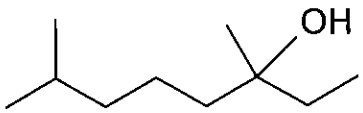


gets both marks



✓✓

(iv)



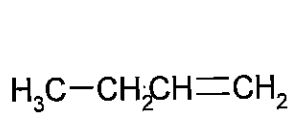
✓

[Total : 7]

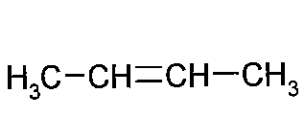
7

(a) Structural isomerism: same **molecular** formula, different structure /displayed formula ✓

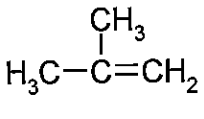
1 mark for each structure and name (must have both) ✓✓✓



but-1-ene



but-2-ene



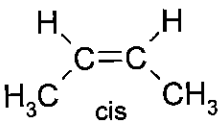
(2-)methylpropene

cyclobutane and methylcyclopropane are valid alternatives.

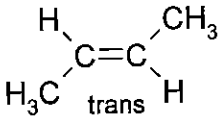
If correct structure given but names not included, penalise once only, hence maximum of 2

Max of 4 marks for structural isomerism

Cis-trans isomerism: correctly draws and identifies cis/trans isomers of but-2-ene ✓✓



cis



trans

If but-1-ene shown as part of cis-trans deduce 1 mark

key features: C=C double bond ✓

which results in restricted rotation ✓

but each C in the C=C bond must be bonded to two different atoms/groups ✓

Max of 5 marks for *cis-trans* isomerism

Two marks available for QWC.

1 mark for structured logical response to the question. ✓

1 mark for correct use of words/terms such as:
restricted rotation
each C in the C=C bond must be bonded to two different atoms/groups
molecular formula
arrangement in space
geometric

Any two gets the QWC ✓

(b) Reagents/conditions: water + temperature > 100 °C /steam/$H_2O(g)$ ✓
phosphoric acid ✓

equation: $CH_3CH{=}CH_2 + H_2O \rightarrow C_3H_7OH$ ✓

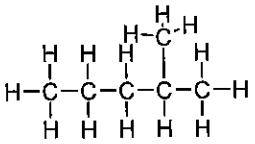
possible alcohols: propan-1-ol and propan-2-ol ✓✓

1. (a) (i) $C_6H_{14} \rightarrow C_3H_6 + C_3H_8$ ✓

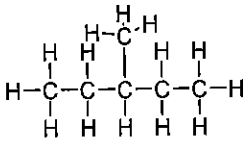
(ii) propane ✓

(b) $C_6H_{14} \longrightarrow C_6H_{12}$ or  $+ H_2$ ✓

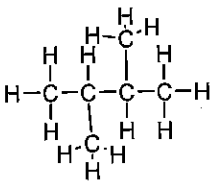
(c)



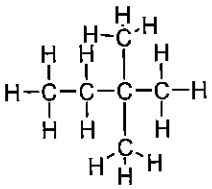
2-methyl pentane



3-methylpentane



2,3-dimethylbutane



2,2-dimethylbutane

Any two correct formulae and names ✓✓✓✓

(d) More efficient/useful or better fuels/burn smoother/added to petrol/ increase octane rating or number ✓

(e) (i) biofuels are fuels produced from plant/animal waste ✓

(ii) Fossil fuels are non-renewable because they take millions of years to form
Must specify time $>10^6$ years ✓

Ethanol is renewable because its feedstock (e.g.sugar, glucose, fruit, carbohydrate) can be continuously re-grown/replaced ✓

[Total : 11]

2 (a)(i) reaction I CH_3CH_2OH/C_2H_5OH – not C_2H_6O ✓

re[redacted] ✓

(ii) reaction I nucleophilic ✓ substitution ✓

re[redacted] ✓

(b) [redacted] ✓

[redacted] ✓

(c) (i)

Alkene	$CH_3CH_2CH=CH_2$ ✓	$CH_3CH=CHCH_3$ ✓
Name	But-1-ene ✓	But-2-ene ✓

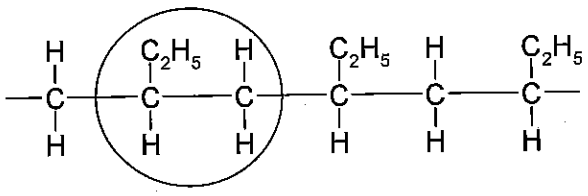
(ii) 1 mark for identifying but-2-ene as having *cis-trans* isomers ✓

1 mark for labelling **both** correctly ✓

(iii) (C=C) double bond ✓

each C in the C=C must be bonded to two different atoms/groups ✓

(d) (i)



✓

(ii) addition ✓

(iii) $C_2H_5CH=CH_2$ / but-1-ene – not butene, by relating back to their answer for (c) (i) ✓

[Total : 18]

3

(a) name/formula of propan –1-ol ✓ name/formula of propan-2-ol ✓
also accept the ether, $C_2H_5OCH_3$

(b) (i) 0.15 ✓

(ii) 0.3 mol of the alcohol, C_3H_8O, reacts with 0.1 mol $Na_2Cr_2O_7$
hence $Na_2Cr_2O_7$ is in excess (this mark is only available if first point is made) ✓

(iii) orange ✓ to green/blue-green/ dark green ✓

(c) (i) 5.22/58 (mark is for $M_r = 58$) ✓

0.09 ✓

(ii) 30% e.c.f. c(i) /0.3 * 100 ✓

(d) (i) carbonyl/C=O/a list that includes at least **two** of aldehyde, ketone, carboxylic acid and/or ester ✓

(ii) OH hydrogen bonded in a <u>carboxylic acid</u> ✓

(iv) propan-1-ol/$CH_3CH_2CH_2OH$ (no marks)
because there is evidence of oxidation to a carboxylic acid ✓

[Total : 12]

4.

(a)(i) Empirical formula: 3.2(25) : 9.7 : 3.2(25) ✓

CH_3O ✓

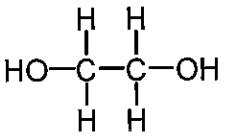
(ii) Molecular formula $C_2H_6O_2$ ✓

Alternative method:			
%	C	H	O
	38.7 x62/100	9.7x62/100	51.6x62/100
	24	6	32
÷Ar	2	6	2

∴ (molecular) formula = $C_2H_6O_2$ gets all two marks, but must also state that the empirical formula is CH_3O to get the third mark.

(b) Shows hydrogen bonds in alcohol ✓

(c) ethane-1,2-diol



✓

(d) hydrogen bonds ✓

[6]

5. **chlorine and methane** *6 available marks*

free radical substitution ✓

Initiation $Cl_2 \rightarrow 2Cl\bullet$ ✓

Propagation 1 $CH_4 + Cl\bullet \rightarrow HCl + CH_3\bullet$ ✓

Propagation 2 $CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$ ✓

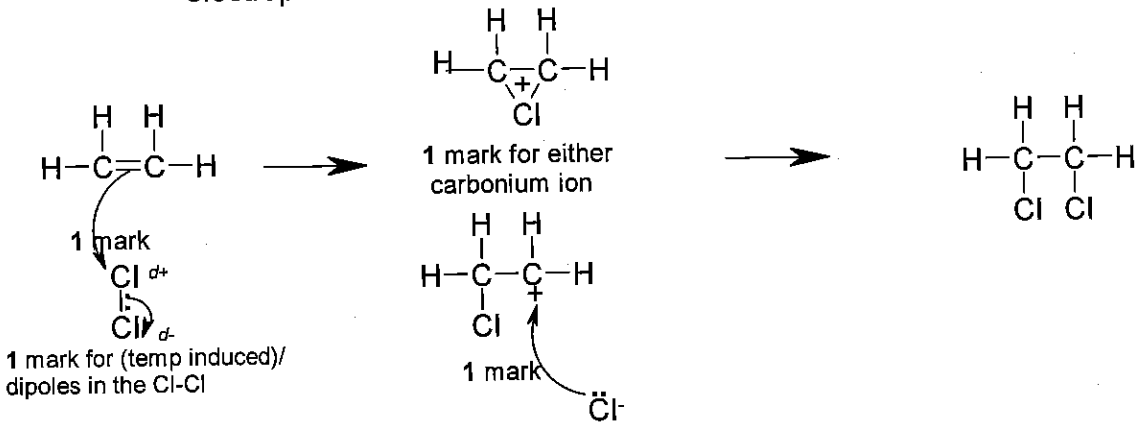
Termination Any two free radicals ✓

Homolytic fission ✓

---

chlorine and ethene *6 available marks*

electrophilic addition ✓



marking points for the mechanism:

- curly arrow from the C=C bond to the Cl_2
- correct dipoles on the Cl-Cl bond or curly arrow showing movement of bonded pair of electrons
- intermediate carbonium ion/carbocation
- curly arrow from Cl^- to the intermediate

✓✓✓✓

Heterolytic Fission ✓

---

1 mark is available in this question for the quality of the written communication. SPAG plus correct use o at least four of the following terms:*free radical, substitution, initiation, propagation, termination, homolytic fission or equivalent term, electrophilic, addition, heterolytic fission or equivalent term, carbonium ion, carbocation, photochemical, photodissociation.*

Show the QWC mark at the end by either ✓QWC or ×QWC [13]

1.

(a)(i) B ✔ [1]

(ii) C ✔ [1]

(iii) B ✔ [1]

(iv) [redacted] [1]

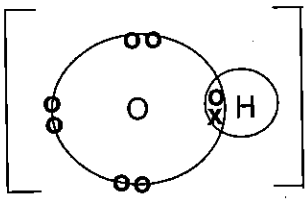
(b) equation $C_4H_9Br + NH_3 \rightarrow C_4H_9NH_2 + HBr$ (or $C_4H_9NH_3^+Br^-$) ✔ [1]

name: [redacted] ✔ [1]

solvent ethanol/alcohol ✔ [1]

(c) (i) lone pair (of electrons) donor ✔ [1]

(ii)



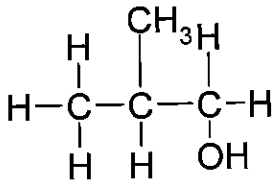
If diagram shows a total of 8 electrons ✔[1]

and has a negative charge. ✔[1]
only award if the diagram shows 8 electrons

(iii) unambiguous identification of organic product:

2-methylpropan-1-ol,

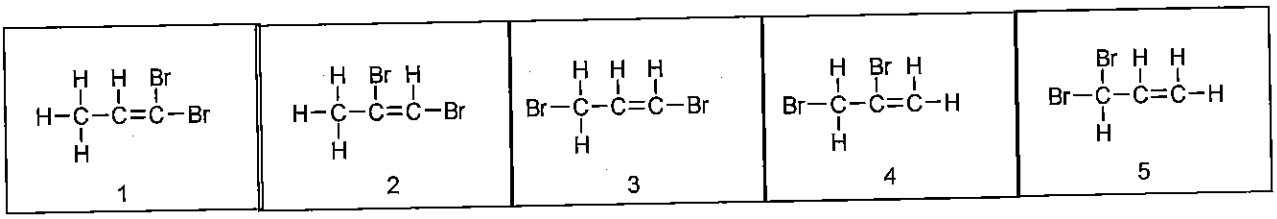
$(CH_3)_2CHCH_2OH$ ✔ [1]



[Total : 12]

2. (a)(i) same molecular formula -different structure ✔✔ [2]
same formula -different structure only scores 1 mark

(ii)

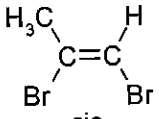


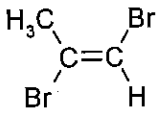
✔[1] ✔[1] ✔[1]

(iii) 1,1-dibromopropene ✔ [1]

(b)

(i) ✔[1]


cis


trans

✔[1]

(ii) bond angle = $120^{o} \pm 4^{o}$ ✔ [1]

(iii) Each C in the C=C is **not** bonded to two different atoms/groups/ or equivalent. ✔ [1]

(iv) Must be 1,3-dibromopropene. ✔ [1]

[Total : 11]

3.

(a)

(i) H ✔ [1]

(ii) G ✔ [1]

(iii) van der Waals/ instantaneous or temporary induced dipoles ✔ [1]

(b)

(i) contains a single/unpaired/lone electron/ **not** free electron ✔ [1]

(ii) $Br_2 \rightarrow 2\ Br\bullet$ ✔ [1]

(iii) Homolysis/ homolytic fission/homolytic cleavage ✔ [1]

(iv) $Br\bullet + C_5H_{12} \rightarrow \bullet C_5H_{11} + HBr$ ✔ [1]

$\bullet C_5H_{11} + Br_2 \rightarrow C_5H_{11}Br + Br\bullet$ ✔ [1]

(c)

I	isomer **G**,	1	✔	[1]
II	isomer **H**,	3	✔	[1]
III	isomer **I**,	4	✔	[1]

[Total : 11]

4. (a)

(i) $C_{10}H_{20}O$ ✔ [1]

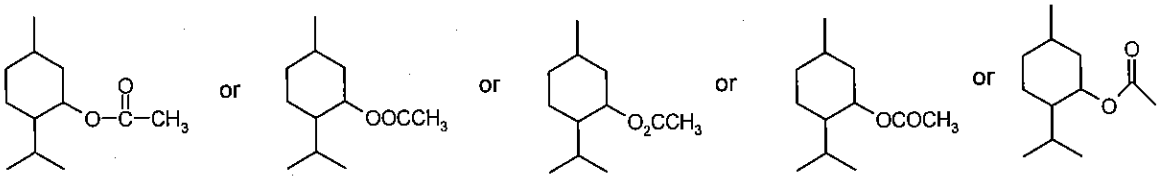
(ii) alcohol/ OH/ hydroxy(*l*) ✔ [1]

secondary ✔ [1]

(b)

1 mark for each alkene ✔✔ [2]

(c)



or full structural formula showing all the atoms

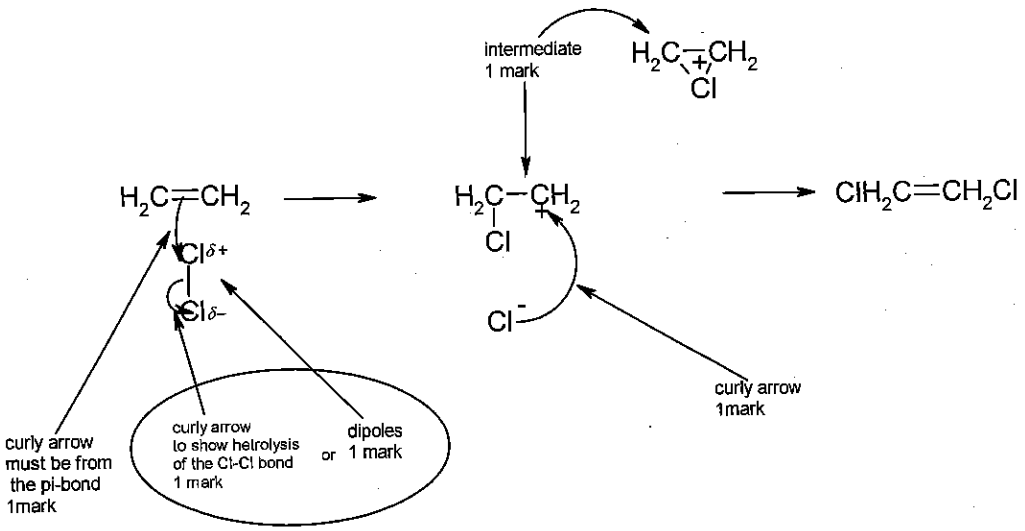
1 mark is available for the ester group showing CH_3 bonded via COO to a ring

2 marks for structure as shown ✔✔ [2]

[Total : 7]

5. (a) (i) electrophilic ✔ [1] addition ✔ [1]

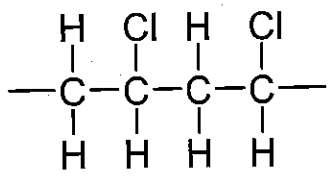
(ii)



4 marking points: curly arrow from double bond to Cl_2,
curly arrow showing movement of electrons in the Cl-Cl bond **or** the dipole in the Cl-Cl,
Intermediate carbocation/carbonium ion,
Curly arrow from Cl^- to intermediate. ✔✔✔✔ [4]

(c) (i)

look for 2 Cl + backbone of 4 C's



✔ [1]

"must show end-bonds"

(ii) *general problems:*

non-biodegradable/ not broken down by bacteria/ do not decompose ✔ [1]

when burnt toxic fumes are produced ✔ [1]

specific problem of PVC:

also produce HCl/ Cl free radicals when burnt ✔ [1]

(ii) removal of toxic products or HCl formed during combustion <u>by gas scrubbers</u>/ by dissolving in a spray of alkali/ recycling/feedstock recycling/use energy from combustion for domestic heating/ manufacture biodegradable polymers . ✔ [1]

[Total : 10]

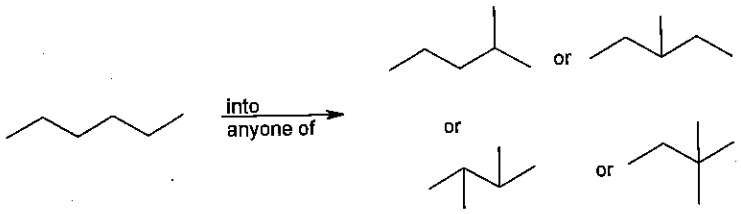
6. 3 marks for equations,
2 marks for correctly explaining (in words) each of the 3 processes.
1 mark for correctly explaining (in words) 2 of the processes.

Cracking. equation for long chain alkane into shorter chain alkane + alkene. ✔ [1]

Isomerisation

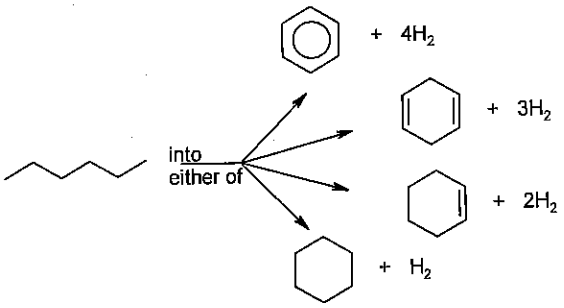
equation for straight chain alkane converted into a branched chain alkane ✔ [1]

equation could be in the form of:



Reforming

to show straight chain into ring (& must be balanced with appropriate number of H_2.) ✔[1]



(All three processes require) the use of heat and/or a catalyst (Allow once) ✔ [1]

Importance of the products: max of 3 marks. ✔✔✔ [3]

- more volatile/lower boiling points
- used in fuels because they burn better/smoother/more efficiently/more efficient fuel
- additive to petrol
- reduce knocking/pinking/increase octane number or rating
- alkenes can form polymers/PVC (see Q5)/alcohols etc

1 mark for quality of written communication to be awarded for clear presentation and SPAG. ✔ [1]

[Total :8]

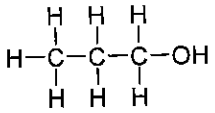
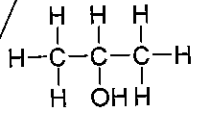
1.

(a)(i) ÷ each by its own A_r to give 5 : 13.3 : 1.67 ✓ [1]

÷ each by 1.67 to give 3 : 8 : 1 ✓ [1]

(ii) Evidence of working e.g. 36 + 8 + 16 = 60 / that C_3H_8O adds up to 60 ✓ [1]

(b) unambiguous structure/formula of propan-1-ol & propan-2-ol to include:

 or $CH_3CH_2CH_2OH$ /  or $CH_3CH(OH)CH_3$ or $(CH_3)_2CHOH$

✓✓ [2]

(c)(i) dichromate/ $Cr_2O_7^{2-}$ /MnO_4^- ✓ [1]

(ii) orange to green
purple to green/brown/black/pink/colourless ✓✓ [2]

(iii) <u>continuous</u> boiling/evaporation **and** condensation /
<u>heating &</u> return of liquid to reaction flask/
simple sketch showing vertical condenser & heat
(any reference to a closed system negates the mark) ✓ [1]

(d)(i) OH/alcohol/hydroxy/hydroxyl – not hydroxide ✓ [1]

(ii) C=O/carbonyl – not CO ✓ [1]

(iii) carboxylic acid/-CO_2H/-COOH ✓ [1]

(e) propan-1-ol (no marks)
propan-1-ol oxidised to a carboxylic acid/ ✓ [1]

(f) C_3H_8O + 2[O] → CH_3CH_2COOH / $C_3H_6O_2$ + H_2O ✓✓ [2]
1 mark available if, CH_3CH_2COOH & H_2O *present in the equation*

[Total : 15]

2.

(a)(i) 1,1-dibromoethene ✓ [1]

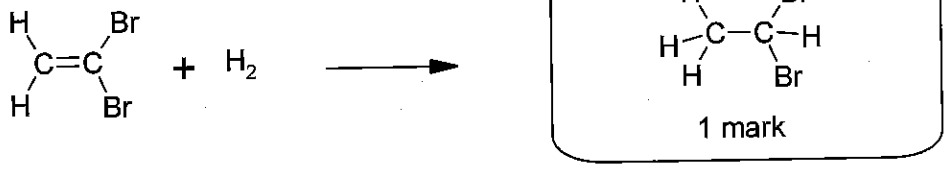
(ii) CHBr ✓ [1]

(b)(i) (Br_2 is) decolourised ✓ [1]

(ii) electrophilic ✓ [1]
addition ✓ [1]

(c) allow names & unambiguous formulae throughout part (c)

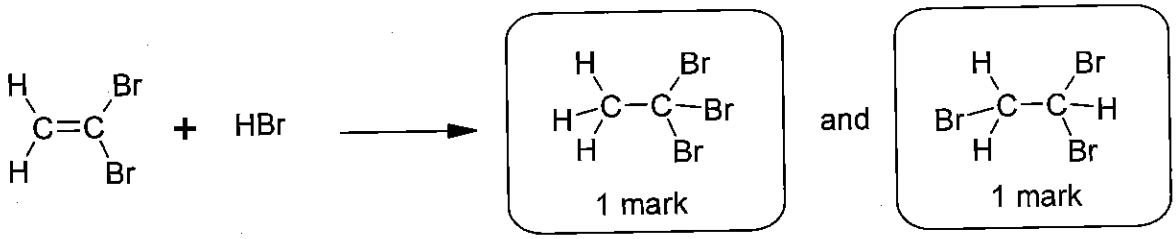
(i) Isomer **C** reacts with H_2.



✓ [1]

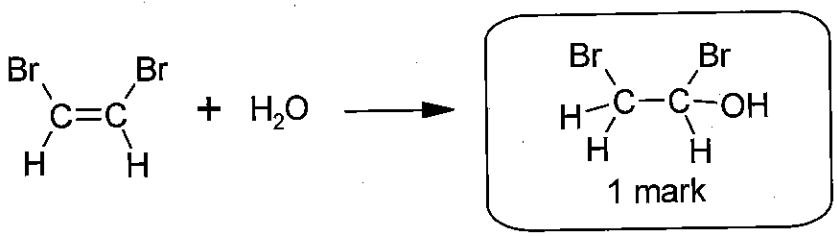
conditions suitable catalyst such as Ni/Pt/Pd ✓ [1]

(ii)



✓✓ [2]

(iii)



✓ [1]

conditions phosphoric acid (catalyst) ✓ [1]
temp ≥ 100 °C/ steam ✓ [1]

[Total : 12]

3.

(a) non-polar ✓ [1]

hence particles not attracted to methane ✓ [1]

(b)

- (free radical) substitution ✓ [1]
- $CH_4 + Br_2 \rightarrow CH_3Br + HBr$ ✓ [1]
- ultra violet/UV light ✓ [1]
- $Br_2 \rightarrow 2\ Br\bullet$ ✓ [1]
- homolysis/ homolytic fission ✓ [1]
- $Br\bullet + CH_4 \rightarrow \bullet CH_3 + HBr$ ✓ [1]
- $\bullet CH_3 + Br_2 \rightarrow CH_3Br + Br\bullet$ ✓ [1]
- any two free radicals $2\ Br\bullet \rightarrow Br_2$ ✓ [1]

free rads are difficult to control/react with anything/very reactive ✓ [1]

identifies one of CH_2Br_2/ $CHBr_3$/ CBr_4 or can be polysubstituted ✓ [1]

[10 max = 9]

1 QWC mark is available for using specific chemical terms.

chemical terms: initiation, propagation, termination, free radical substitution, homolysis/ homolytic fission, photochemical

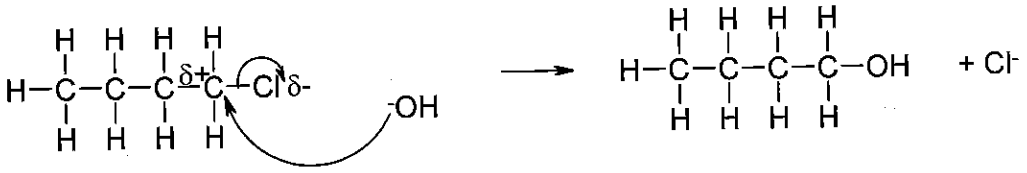
*any **two** terms used correctly* ✓ [1]

[Total : 11]

4.

(a) (i) $C_4H_9Br + OH^-/NaOH/H_2O \rightarrow C_4H_9OH/\ C_4H_{10}O + Br^-/NaBr/HBr$ ✓ [1]

(ii)



marking points:

dipoles

curly arrow from OH^- to $C^{\delta+}$

curly arrow from C-Cl bond to Cl

✓✓✓ [3]

(b)(i) Fastest – 1-iodobutane & slowest 1-chlorobutane ✓ [1]

(ii) C-I has the weakest bond/ C-Cl has the strongest bond ✓ [1]

[Total : 6]

5.

(a) $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓ [1]

(b) (i) M_r of $C_6H_{12}O_6$ = 180 ✓ [1]

200 moles (0.2 will be a common error) ✓ [1]

(ii) 400 moles/ ecf to (a)(ii) *2 ✓ [1]

(iii) 50 moles ✓ [1]

(iv) (iii)/(ii) x 100 = 12.5% ✓ [1]

(c) (i) (must **name**) aldehyde/carbonyl ✓ [1]

(i) CH_3CO_2H/ CO_2 ✓ [1]

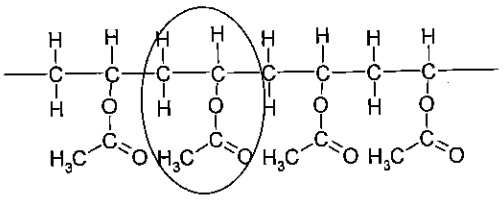
(d) $CH_3OH + [O] \rightarrow HCHO/CH_2O + H_2O$ ✓✓ [2]

(e)(i) $CH_3OH + 1^1/_2 O_2 \rightarrow CO_2 + 2H_2O$ /$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$ ✓ [1]

(ii) burns more cleanly/ reduces CO(g) emissions / reduces benzene emissions/ less pollutants/ higher octane rating(number)/less knocking/ / improves combustion/ better fuel/ burns more cleanly/ absorbs free radicals/ oxygenates ✓ [1]

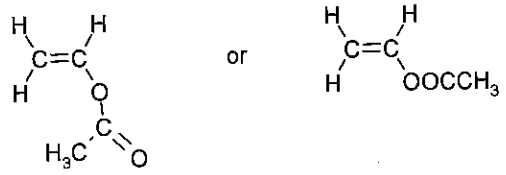
(f)(i) $CH_3OH + CO \rightarrow CH_3CO_2H$ ✓ [1]

(ii)



✓ [1]

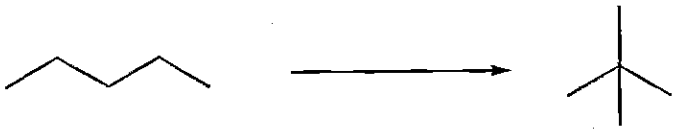
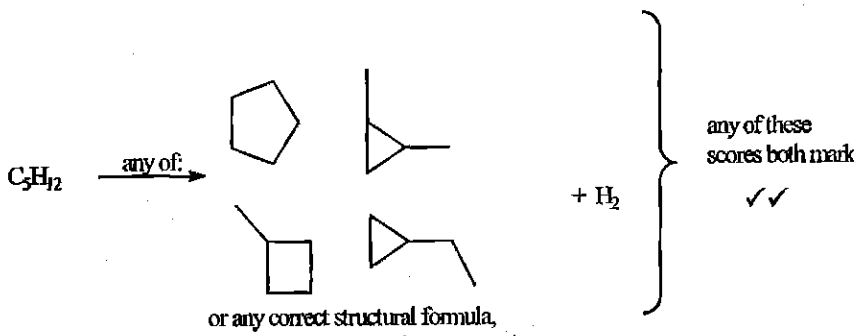
(iii)



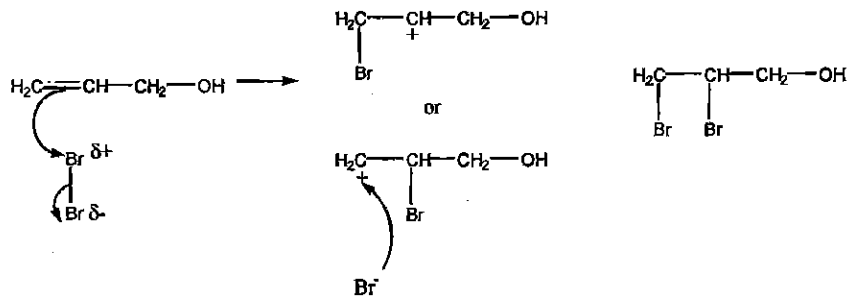
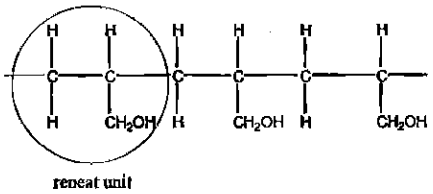
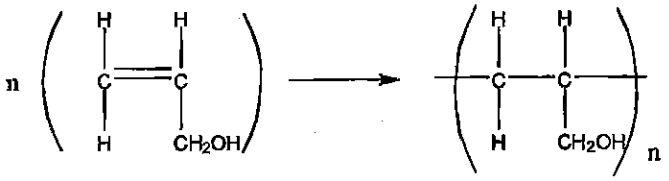
✓ [1]

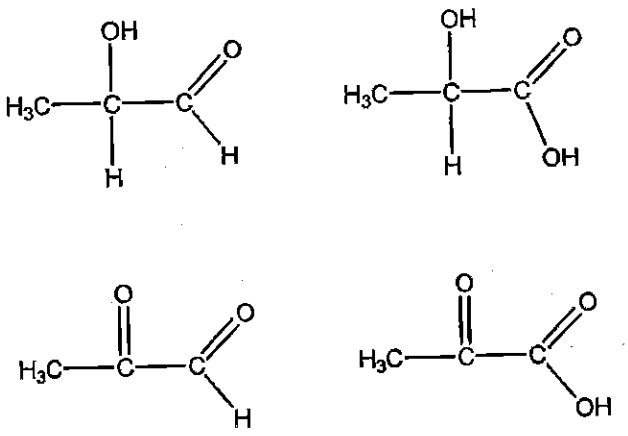
[Total : 15]

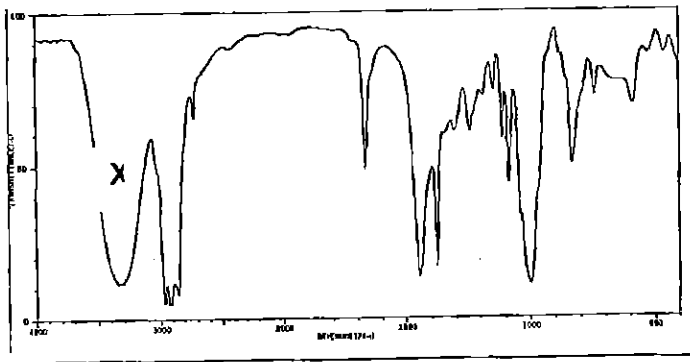
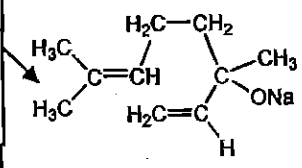
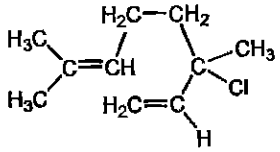
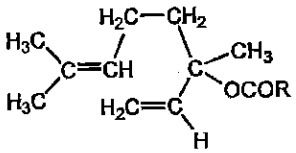
2812 Chains and Rings

Question No.			Max Mark
1a	i	boiling point increases with increased chain length/M_r ✓ more surface interaction/electrons/van der Waals/intermolecular forces ✓	2
	ii	boiling point decreases with increased branching ✓ less surface contact/cannot pack as close/fewer van der Waals/fewer intermolecular forces ✓	2
	iii	59 – 68 °C ✓	1
b	i	1 mark for pentane ✓and one for 2,2-dimethylpropane✓  allow 1 mark if not skeletal but both correct.	2
	ii	 ✓ $C_5H_{12} \longrightarrow C_5H_{10} + H_2$ scores 1 mark only pentane ⟶ cyclopentane or less without the H_2 – scores 1 mark	2
	iii	better fuels/burn more efficiently/increases octane rating/used as a fuel additives/reduces knocking(ignite less easily) ✓ do not allow "*easier to burn*" as this is the same as pre-ignition	1

Question No.			Max Mark
2a		C-H bond energy is large ✓ alkanes/C-H bonds are non-polar ✓ hence alkanes are not attracted / not attacked by nucleophiles or electrophiles ✓ 2 from 3 allow 1 mark for *"no double bond therefore will not react with electrophiles"*	2
b	i	(molecule/atom/particle *(not ion)* that) contains an unpaired/single/lone electron ✓ (not free electron)	1
	ii	homolytic/homolysis	1
	iii	uv/sunlight/high temperature/ >200°C✓ (**not** just heat or hot or high temp + high pressure)	1
	iv	$CH_3CH_2CH_3 + Cl\bullet \longrightarrow CH_3CH_2CH_2\bullet + HCl$ ✓ $CH_3CH_2CH_2\bullet + Cl_2 \longrightarrow CH_3CH_2CH_2Cl + Cl\bullet$ ✓	2
	v	$CH_3CH_2CH_2\bullet + CH_3CH_2CH_2\bullet$ ($\longrightarrow C_6H_{14}$)/explained in words but must refer to propyl (not propane) free radicals ✓ *if correct equation ignore "propane free rads"*	1
c	i	$CH_3CH_2CH_3$ /$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$ ✓	1
	ii	Possibility of forming CO/ incomplete combustion/good ventilation allows complete combustion ✓	1

Question No.			Max Mark
3a	i	hydrogen ✓ Ni/Pt/Rh/Pd ✓	2
	ii	H_2O/steam ✓ H_3PO_4 / H_2SO_4 ✓	2
	iii	HBr/ NaBr + H_2SO_4 / NaBr + H^+ ✓	1
b		 curly arrow from π-bond to $Br^{\delta+}$ ✓ correct dipoles on Br-Br + curly arrow from Br-Br bond to $Br^{\delta-}$ ✓ correct intermediate(allow primary/secondary carbonium ion or bromonium ion) ✓ curly arrow from Br^- to C^+/ carbonium ion ✓	4
c	i	 backbone of 6 carbon atoms as shown ✓ repeat unit identified ✓ *do not penalize linkage to $-CH_2OH$ side chain*	2
	ii	 monomer and repeat unit correctly shown ✓ correct position on the n_s ✓ n $CH_2CHCH_2OH \longrightarrow (CH_2CHCH_2OH)_n$ gets both marks n $C_3H_6O \longrightarrow (C_3H_6O)_n$ gets both marks *do not penalize linkage to $-CH_2OH$ side chain*	2
	iii	poly(prop-2-en-1-ol)/polyprop-2-en-1-ol ✓	1

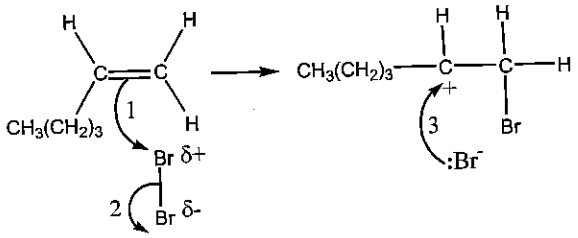
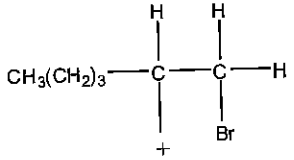
3d	i	$CH_3CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2COOH + H_2O$ ✓✓ $C_3H_7OH + 2[O] \longrightarrow C_2H_5COOH + H_2O$ ✓✓ $C_3H_8O + 2[O] \longrightarrow C_3H_6O_2 + H_2O$ ✓✓ correct product CH_3CH_2COOH scores 1 ✓ if aldehyde is made but the equation is correctly balanced $CH_3CH_2CH_2OH + [O] \longrightarrow CH_3CH_2CHO + H_2O$ scores 1 ✓ do not allow C_3H_6O or CH_3CH_2COH	2
	iii	 ✓✓ Any two of the above. The first two have a chiral centre and if they draw two correct optical isomers with 'wedge-shaped' bonds award both marks.	2

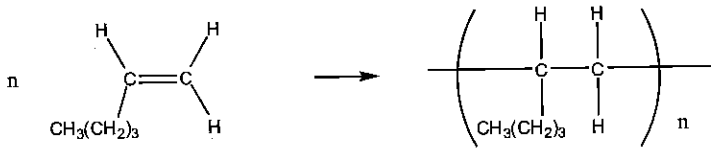
Question No.			Max Mark
4a	C : H : O 6.5 : 11.7 : 0.65 ✓ 10 : 18 : 1 hence = $C_{10}H_{18}O$ ✓ M_R /120 + 18 +16 = 154 ✓	154 x 77.9/100 = 120 = 10 Cs 154 x 11.7/100 = 18 = 18 Hs 154 x 10.4/100 = 16 = 1 O hence = $C_{10}H_{18}O$ gets all 3 marks✓✓✓	3
b i	contains a (C=C) double bond/ an alkene/ C≡C/ alkyne/ unsaturated ✓		1
ii	uses correctly 159.8/ 160 as M_r of Br_2 ✓ 3.196 ÷ 159.8 = 0.02 mole of Br_2 ✓ 0.04 ✓ecf (used 80 instead of 160)		2
iii	compound must have two C=C double bonds/ one C≡C triple bond ✓		1
c			1
d i	linalool ✓		1
ii	It's the only tertiary alcohol/ the others would be oxidized/are primary alcohols ✓		1
iii	reacts with Na/ PCl_5/$SOCl_2$ /RCOCl ✓ H_2 or HCl or SO_2 ✓		3
Na compound H_2 Na alkoxide worth 1 mark	correct organic product  or  or 		
	mark ecf to d (i)		

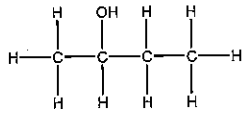
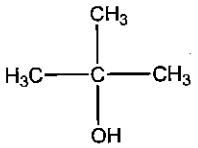
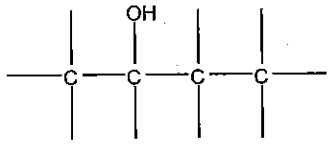
Question No.				Max Mark
5	a	There are two possible methods but marks common to both are add Ag^+/ $AgNO_3$ ✓ warm/heat in (water bath)/ warm to a specified temp between 30 – 70 °C ✓ equi-molar quantities of RX/ same number of drops of RX/ same amount of RX✓ precipitate formed/goes cloudy ✓		4
		if $AgNO_3$ dissolved in ethanol ✓ must monitor **rate** ✓of ppt	if using NaOH must be followed by HNO_3 before adding the $AgNO_3$ ✓ must monitor **amount** ✓of ppt	2
		C-I is fastest and C-Cl is slowest /correct order ✓ because C-Cl bond strongest/shortest & C-I weakest/longest/ refers to the strength of the bonding in named halogens ✓ $Ag^+ + X^- \longrightarrow AgX$ ✓ $R\text{-}X + OH^-/ H_2O \longrightarrow R\text{-}OH + X^-/ HX$ ✓		4 ***max = 8***
		SPAG – two correct sentences in which the meaning is clear.		1
				9

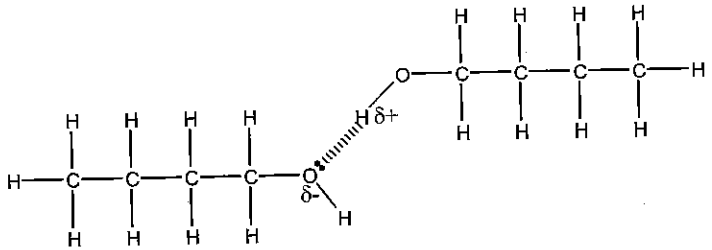
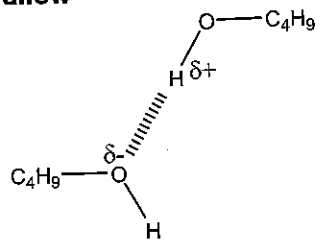
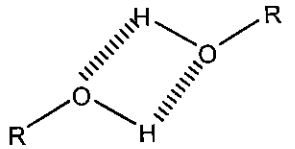
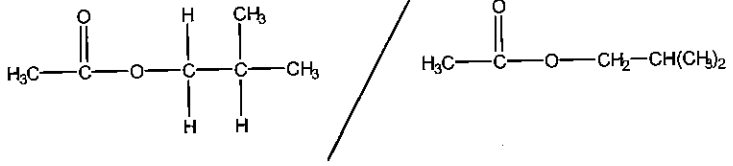
2812 Chains and Rings

Question	Expected Answers	Marks	Additional Guidance
1 a i	C_6H_{14} ✓	1	there is no other acceptable response
ii	C_3H_6Br ✓	1	there is no other acceptable response
iii	hexan-2-ol ✓	1	Allow hexanol-2 do **not allow** e.g. 2-hexanol, hex-2-ol, hexa-2-ol
iv	HBr ✓	1	Allow NaBr + H_2SO_4/ HBr + H_2SO_4 Do **not allow** dil. H_2SO_4/ H_2SO_4(aq)

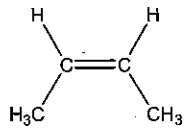
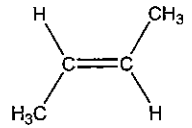
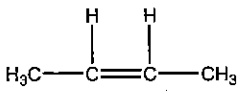
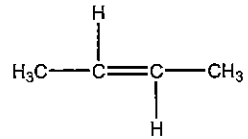
b	i	 1. curly arrow from π- bond to $Br^{(\delta+)}$✓ 2. correct dipoles **&** curly arrow from bond to $Br^{\delta-}$✓ 3. intermediate (either primary/secondary carbonium/bromonium ion) ✓ 4. Br must have charge **and** lone pair. Curly arrow from anywhere on Br to C+✓	**4**	curly arrow must have full arrow head if half-arrow heads used, penalize once **only**. **ignore** δ– on C=C double bond **ignore** ·· on Br—Br bond curly arrows must be precise – curly arrow **1** must start at the C=C double bond (not the C) and must go to the $Br^{\delta+}$ or just above the $Br^{\delta+}$ curly arrow **2** must start from the Br–Br bond and go to the $Br^{\delta-}$ or just past the $Br^{\delta-}$ curly arrow **3** must go from Br^- to the C+ **allow** primary carbonium ion or bromonium ion as an alternative to the carbonium ion If HBr is used instead of Br_2 candidate loses marking point 1. If ethene (or other alkene) appears as the intermediate, candidate loses marking point 3. If intermediate has $C^{\delta+}$, candidate loses marking point 3. If intermediate drawn as  candidate loses marking point 3.

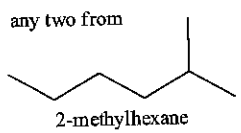
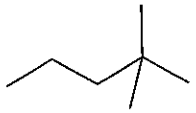
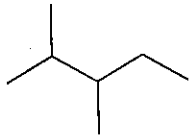
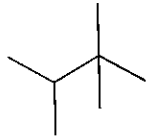
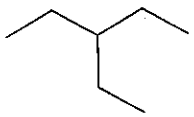
Question	Expected Answers	Marks	Additional Guidance
ii	(electrophilic) addition ✓	1	nucleophilic addition loses the mark **ignore** bromination.
iii	decolourises/(red/orange/brown/yellow) to colourless ✓	1	**not** goes clear **not** discolours
c i	 1. 1 mark if monomer and repeat unit are correct ✓ 2. 1 mark if the n_s are shown in correct position and bracket around repeat unit✓	2	**Ignore** bond linkage to $(CH_2)_3CH_3$ **unless** the bond clearly goes to the CH_3. *n* $C_6H_{12} \longrightarrow (C_6H_{12})_n$ also gets both marks **Allow** if end bonds are within brackets. If end bonds are not shown, candidate loses marking point 1. If equation is not balanced, candidate loses marking point 2. If they draw 2(monomers) ⟶ 2 repeat units candidate loses marking point 2.
ii	poly(hex-1-ene)/polyhex-1-ene ✓	1	**Allow** poly(hexene-1) / polyhexene-1
	Total	13	

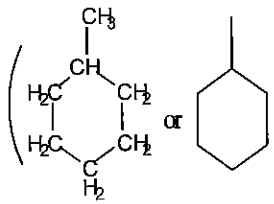
Question No.	Expected Answers			Marks	Additional Guidance
2a	same molecular formula, different structure/arrangement of atoms ✓			1	**not** same formula **Allow** different displayed/skeletal formulae
b	 ✓		secondary ✓	6	**Penalise** bond linkage to OH **once** in this question. Do **not** penalise bond linkage to CH_3. If names written as methylprop-1-ol and methylprop-2-ol, penalise once in this question. **allow** $CH_3CH(OH)CH_2CH_3$ / $CH_3CH(OH)C_2H_5$
		methylpropan-1-ol ✓	primary ✓		**allow** 2-methylpropan-1-ol
	✓ 	methylpropan-2-ol ✓			**allow** 2-methylpropan-2-ol **allow** $(CH_3)_3COH$ **penalise** "sticks" once **only** in this question. e.g  **DO NOT** penalise "sticks" elsewhere on the paper.

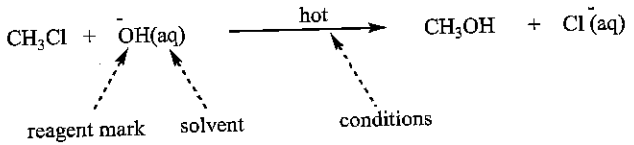
c	 1. H-bond shown in correct position ✓ 2. dipoles shown as $O^{\delta-}$ and as $-O-H^{\delta+}$ ✓ 3. lone pair shown on O as part of a dotted …. hydrogen bond ✓	**3**	**allow**   if two H-bonds are shown between the two O–H, candidate loses marking point 1. If hydrogen bond drawn between butan-1-ol and water candidate loses marking point 1.
d		**1**	ester group **must** be displayed **Allow** C_4H_9 etc.
e i	1. butanoic acid ✓ 2. ir spectrum shows OH at about 3000 cm^{-1} ✓ 3. C=O at about 1700 cm^{-1} ✓ OR 1. butanoic acid ✓ 2. ir spectrum shows peaks at about 1700 cm^{-1} and 3000 cm^{-1} ✓ 3. peaks correctly identified as C=O and O–H respectively. ✓	**3**	**Check spectrum for labels.** **Allow** correctly labelled peaks on spectrum. **allow** ranges in data book: 2500 – 3300 cm^{-1} for O–H 1680 – 1750 cm^{-1} for C=O **not** 3230 – 3550 cm^{-1} for O–H

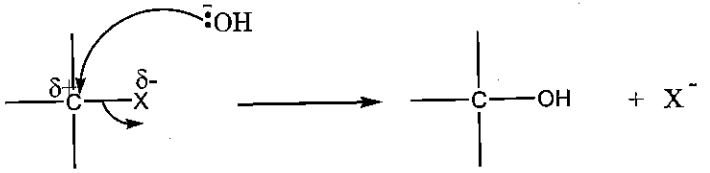
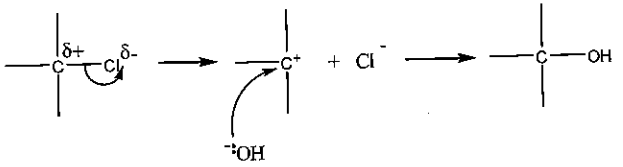
ii	$C_4H_9OH + 2[O] \longrightarrow C_3H_7COOH + H_2O$ ✓✓ Allow ecf to e(i) as aldehyde/butanal. $C_4H_9OH + [O] \rightarrow CH_3\,CH_2CH_2CHO + H_2O$ ✓✓	2	If candidate identifies e(i) as carboxylic acid but writes equation for aldehyde. No marks. **allow** $C_4H_{10}O + 2[O] \longrightarrow C_4H_8O_2 + H_2O$ ✓✓ correct product C_3H_7COOH / $C_3H_7CO_2H$ scores 1 ✓ **Allow** as ecf $C_4H_{10}O + [O] \rightarrow C_4H_8O + H_2O$ ✓✓ but as ecf $C_4H_{10}O + [O] \rightarrow CH_3\,CH_2CH_2COH + H_2O$ / scores 1 mark. If the equation is not balanced, 1 mark available for unambiguous formula of the correct / ecf organic product. e.g $C_4H_8O_2$ or C_4H_8O would **not** score the mark
	Total	16	

Question No.	Expected Answers	Marks	Additional Guidance
3a i	working to show C : H ratio 1 : 2 ✓ CH_2 ✓	2	**must** see working as C_4H_8 is given as the molecular formula in part (ii) If calculation of C : H ratio is incorrect allow ecf for empirical formula.
ii	working (56/14 = 4) to show molecular formula is C_4H_8 / 4 x 12 + 8 =56 ✓	1	**Allow** 85.7% of 56 = 48 therefore 4 C
b	 cis trans 1. skeletal formulae ✓ 2. correct structure in correct box✓	2	**allow** 1 mark if *cis-trans* correctly drawn as structural/displayed formulae and correctly labeled.  cis  trans or  cis  trans scores 1 mark if both skeletal formulae drawn correctly but in the wrong boxes – 1 mark can be awarded
	Total	5	

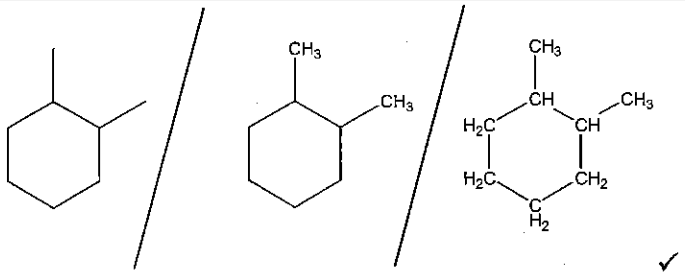
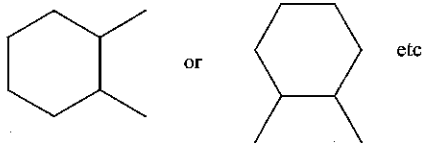
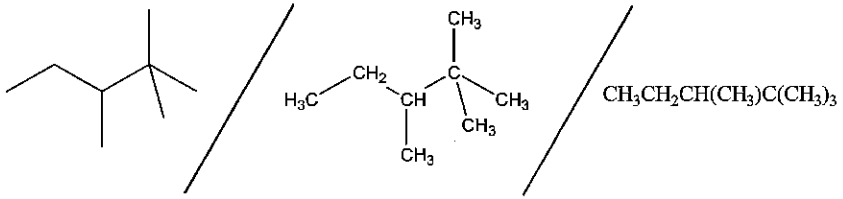
Question	Expected Answers	Marks	Additional Guidance
4a i	any two from  2-methylhexane  2,2-dimethylpentane  2,3-dimethylpentane  2,2,3-trimethylbutane  3-ethylpentane ✓✓	2	**allow** 1 mark if **two** correct isomers are drawn using either displayed or structural formula e.g. any two from: $(CH_3)_2CH(CH_2)_3CH_3$, $(CH_3)_3C(CH_2)_2CH_3$, $(CH_3)_2CHCH(CH_3)CH_2CH_3$, $(CH_3)_2CHC(CH_3)_3$, $(C_2H_5)_3CH$ award 1 mark for correct isomers but deduct one mark for not drawing skeletal formulae.
ii	3,3-dimethylpentane ✓	1	**Ignore** comma and hyphen Not bimethyl/bismethyl
iii	F ✓	1	**Allow** 3-methylhexane.

b		heptane correct formula or structure →  or or $C_6H_{11}CH_3$ + H_2 1. Unambiguous organic product ✓ 2. Balanced equation ✓	**2**	heptane correct formula or structure → C_7H_{14} + H_2 scores only 1 ✓ Do not allow 2H / 2[H].
c	**i**	M_r = 88 ✓ % O = $^{16}/_{88}$ * 100 = 18.2 (%) ✓	**2**	18.2(%) with no working scores 2 marks 18.18 (%) with no working scores 1 mark **Allow** ecf on incorrect M_r
	ii	$C_5H_{12}O$ + 7½ O_2 ⟶ 5 CO_2 + 6 H_2O ✓✓	**2**	correct formula for MTBE – **allow** $C_5H_{12}O$/ $C_4H_9OCH_3$/ displayed formula as shown in question **allow** 1 mark if formula for MTBE and mole ratio are correct such that **1**MTBE :**5**CO_2 + **6**H_2O gets 1 mark✓ If formula of MTBE is incorrect **allow** ecf for balanced equation. Max 1 mark.
d	**i**	low boiling point/easily vapourised/evaporates quickly/turns to a gas easily ✓	**1**	**Ignore** reference to flammability.
	ii	loss of petrol by evaporation/fuel-air mixture might be incorrect/not enough liquid petrol getting to the engine/carburettor/causes knocking/ causes pre-ignition/ causes auto-ignition/more difficult to store or transport/more difficult to fill-up ✓	**1**	**Ignore** vague answers such as more chance of catching fire/explosion/dangerous

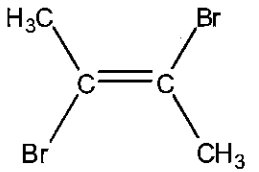
Question	Expected Answers	Marks	Additional Guidance
	Ticks ✓must be used for this question. Use ✓or × for QWC		
5a	1. reagent – OH^-/NaOH/KOH 2. solvent – water/aqueous (ignore reference to ethanol) 3. conditions- hot/warm/reflux/heat ✓✓ $RX + OH^-/H_2O \longrightarrow ROH + X^-/HX$ ✓	3	**need** all three for 2 marks, any 2 scores 1 mark **allow** general equation using **R** or any correct equation **allow** reagent, conditions & solvent mark from the equation such that  scores all 3 marks if acid catalyst used ….it **cancels** the OH^- reagent

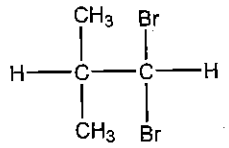
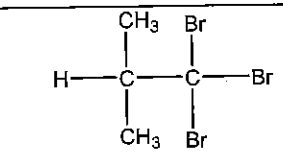
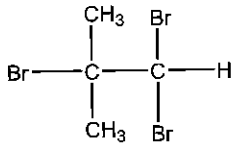
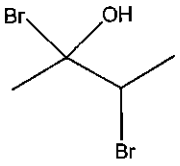
b	 1. correct dipole ✓ 2. The OH must have lone pair on O **and** charge e.g. :OH^-. Curly arrow from anywhere on the OH^- to $C^{\delta+}$ ✓ 3. curly arrow from C—X bond to $X^{\delta-}$ ✓ 4. states that the mechanism is nucleophilic substitution/draws correct products ✓	4	"nucleophilic substitution" **cannot** be credited from part a. **Penalise** bond linkage to OH **once** in this question. **credit** S_N1 mechanism: can score all 4 marks. 
	Total	**14**	

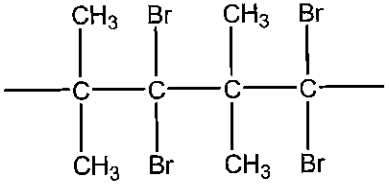
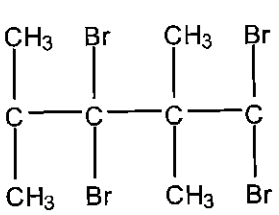
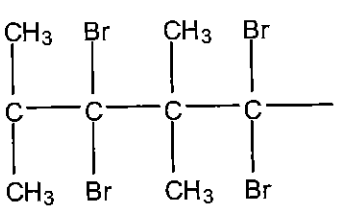
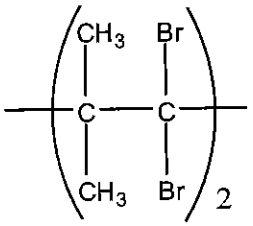
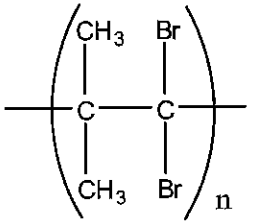
2812 Chains and Rings

Question			Expected Answers	Marks	Additional Guidance
1	(a)		compound/molecule that contains carbon & hydrogen **only** ✓	1	**allow** hydrocarbons contain carbon & hydrogen **only** **allow** molecules that contain carbon & hydrogen **only**
	(b)		$C_{14}H_{30} \longrightarrow C_8H_{18} + C_6H_{12}$ ✓	1	**allow** $CH_3(CH_2)_{12}CH_3 \longrightarrow CH_3(CH_2)_6CH_3 + C_6H_{12}$ **allow** any isomer of C_6H_{12} or any combination of alkenes that add up to C_6H_{12}.
	(c)	(i)	 ✓	1	**allow** different orientations as long as the two methyl groups are on adjacent Cs 
		(ii)	hydrogen/H_2 ✓	1	no other correct response
	(d)	(i)	 ✓	1	**allow** any unambiguous form of 2,2,3-trimethylpentane

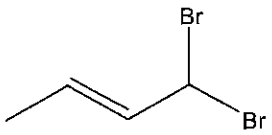
Question			Expected Answers	Marks	Additional Guidance
		(ii)	$C_8H_{18} + 12½O_2 \longrightarrow 8CO_2 + 9H_2O$ ✓✓ 1 mark if all formulae are correct both marks if correctly balanced	2	**allow** $2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$ **allow** structural, displayed or skeletal formula of C_8H_{18}.
	(e)	(i)	(feedstock is obtained) from plants ✓ which can be re-grown ✓	2	**allow** made from sugar cane/beet/biomass *for 1 mark* **not allow** just sugar **allow** made from sugar because it can be re-grown *for 2 marks* **not allow** just fermentation **allow** fermentation from/of plants *for first marking point*
		(ii)	CO_2 used in photosynthesis is balanced by CO_2 released in combustion/ it is carbon neutral ✓	1	**not allow** does not produce greenhouse gases **allow** doesn't emit any oxides of nitrogen/sulphur **not allow** doesn't produce toxic gases/acid rain If two statements are made and one is incorrect the mark is lost e.g. is carbon neutral and does not produce greenhouse gases *this gets ✗ con*
			Total	**10**	

Question			Expected Answers	Marks	Additional Guidance
2	(a)	i	1,1-dibromomethylpropene✓	1	**allow** 1,1-dibromo-2-methylpropene **allow** 2-methyl-1,1-dibromopropene **allow** methyl-1,1-dibromopropene **also allow** any of the above with prop-1-ene
		ii	M_r = 213.8 ✓ % = (159.8/213.8) x 100 = 74.7 ✓	2	**not allow** M_r = 214 for first mark **allow** any of: % = 75/74.74 or any correct rounding up to and including the calculator value of 74.74275023 **allow** **ecf** for correct rounding of 74.76635514 if used M_r 214 **ecf** for correctly calculating percentage from incorrect M_r 37.4% scores 1 mark
		(iii)	any dibromobut-1-ene any dibromobut-2-ene (except 2,3-dibromobut-2-ene) any dibromomethylpropene (except 1,1-dibromomethylpropene) any dibromocyclobutane any dibromomethylcyclopropane ✓	1	see page 10 at end of question for skeletal formulae of acceptable isomers Most common **incorrect** response is *trans*-2,3-dibromobut-2-ene 
	(b)	i	decolourised ✓	1	**not allow** goes clear / discoloured **allow** turns colourless/orange colour disappears **ignore** "clear" if "decolourises and goes clear" i.e. not 'CON'
		ii	electrophilic addition ✓	1	
		iii	molecular formula = $C_4H_6Br_4$ ✓ empirical formula = $C_2H_3Br_2$ ✓	2	 **allow** ecf from molecular formula $C_xH_yBr_z$

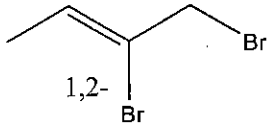
Question	Expected Answers	Marks	Additional Guidance
(c)	 ✓ Ni/Pt ✓	2	Ignore bond linkage
(d) i	**B** is symmetrical ✓	1	**allow** **A** isn't symmetrical **ignore** A is asymmetric
ii	 ✓  ✓	2	Ignore bond linkage
e) i	 ✓	1	**Do not allow** bond linkage to H in the OH, bond must **clearly** go to the O
ii	reagent: steam/$H_2O_{(g)}$ ✓ conditions: phosphoric acid ✓	2	**allow** H_2O but only if temp is quoted above 100°C **allow** sulphuric acid **not allow** acid catalyst **allow** reagent: phosphoric acid ✓ **allow** conditions: steam ✓ mention of alkali ✗ *con* acid mark

Question	Expected Answers	Marks	Additional Guidance
(f)	 backbone of 4 carbon atoms with "two end bonds" ✓ 4 CH_3s and 4 Brs attached ✓	2	 or  or  or  score 1 mark **allow** more than two repeat units **ignore** CH_3 bond linkage
	Total	18	

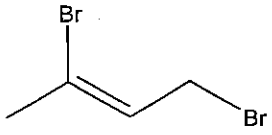
dibromobut-2-ene



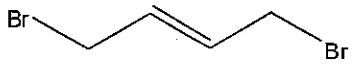
1,1-



1,2-

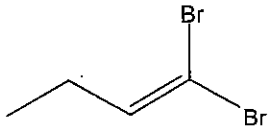


1,3-

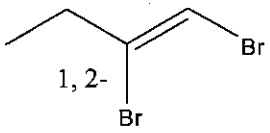


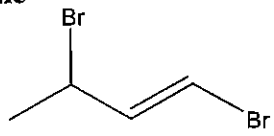
1,4-

dibromobut-1-ene

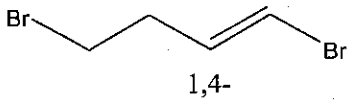


1,1-

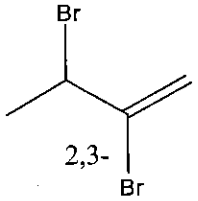


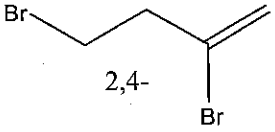


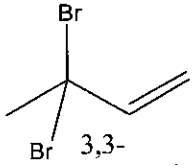
1,3-

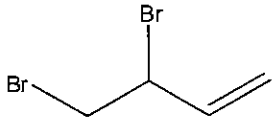


1,4-



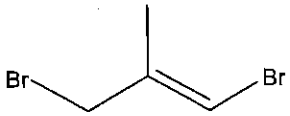




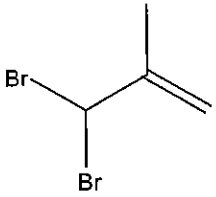


3,4-

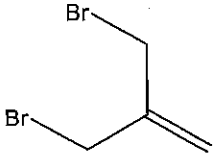
dibromomethylpropene



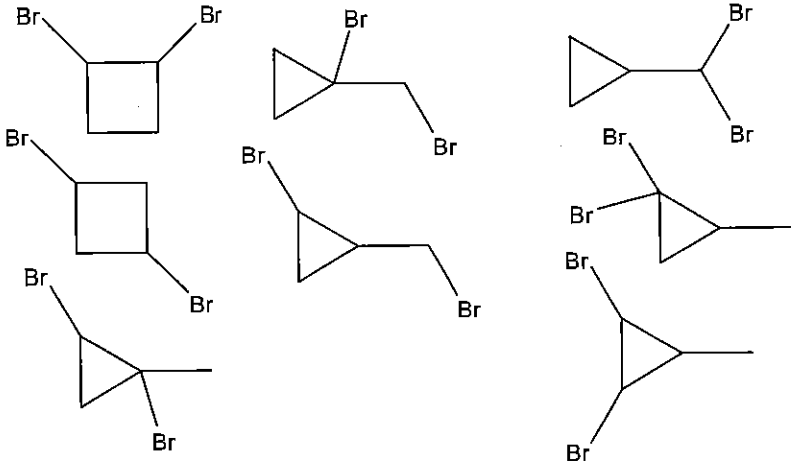
1,3-



3,3-

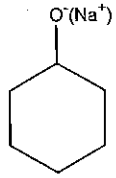
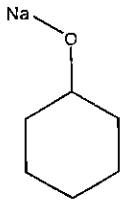
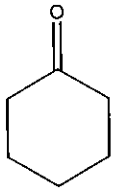
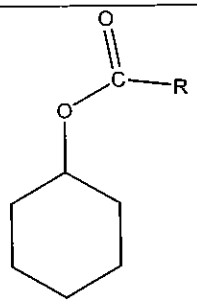
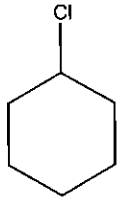
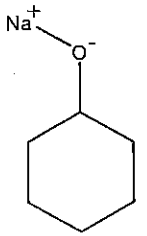


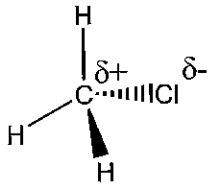
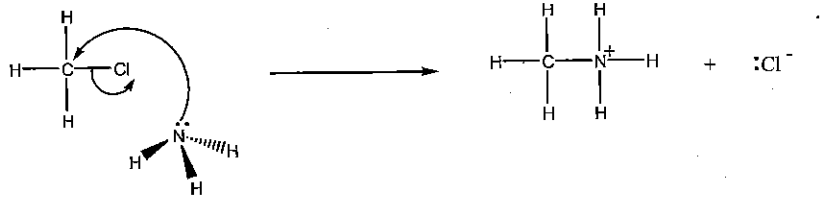
dibromocycloalkanes



Q3a should be marked as a complete question NOT by item response

Question			Expected Answers	Marks	Additional Guidance
3	(a)	i	100 ✓	1	If incorrect ecf can be awarded for 3a(ii)
		ii	0.05 ✓	1	Check for ecf from 3a(i) if incorrect check response to part (iii) which can score all 3 marks as **ecf** to incorrect answer in (ii)
		iii	moles of cyclohexene = 1.8/82 / 0.02195 / 0.022 ✓ % yield = (0.022/0.05) x 100 = 43.9% ✓ % yield to 2 sig figs = 44% ✓	3	44% scores all 3 marks **allow** alternative method theoretical mass of cyclohexene = 0.05 x 82 = 4.1(g)✓ % yield = (1.8/4.1) x 100 = 43.9%✓ % yield to 2 sig figs = 44% ✓ **ecf** if M_r of cyclohexene is incorrect, the remaining two marks can be awarded e.c.f **ecf** % yield = (0.022/incorrect answer to (a)(ii)) x 100 for *max 3 marks* **do not allow** moles of cyclohexene rounded to 0.02 which will then lead to 40% yield. **allow** 40% will score 2 out of the 3 available marks **allow** 36% for *max 1 mark*

Question			Expected Answers				Marks	Additional Guidance
(b)		i	(peak between) 3230–3550 (cm^{-1}) ✓ which shows presence of OH ✓				2	**do not allow** 2500–3500 (cm^{-1}) For OH **allow** peak within stated range Ignore any reference to C–O peak
		ii	Na	H^+ and $Cr_2O_7^{2-}$	RCOOH and conc H_2SO_4	PCl_5/ $SOCl_2$	1	**allow** RCOCl with observation of white fumes and product same as carboxylic acid
			bubbles/fizzes/effervesces **not allow** hydrogen gas/ gas evolved	orange to green	if RCOOH observation mark is not available	white fumes	1	If manganate(VII) used as oxidising agent then allow marks for observation (purple to colourless/green/brown) and product of cyclohexanone only
		iii	 charges not essential but **do not allow** 				1	**not allow** $C_6H_{11}ONa$ / $C_6H_{11}OOCR$/ $C_6H_{11}Cl$ product mark must be related to correct reagent. If no reagent then no product mark is possible **allow** one mark for bromocyclohexane as product if HBr used as reagent but no marks for reagent or observations **not allow** 
						Total:	10	

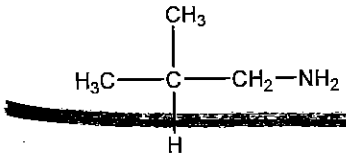
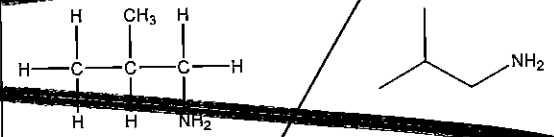
Question	Expected Answers	Marks	Additional Guidance
4 (a)	 ✓ bond angle 109° 28' ✓	2	**allow** 109·5/ 109–110
(b) i	electron pair donor ✓	1	**allow** lone pair (of electrons) donor
ii	 Step 1 curly arrow from lone pair on N to C ✓ curly arrow from C—Cl bond to Cl ✓	2	**not allow** any incorrect charges on reagents *✗con 1 mark*
iii	$CH_3Cl + 2NH_3 \longrightarrow CH_3NH_2 + NH_4Cl$ ✓	1	**allow** $CH_3Cl + 2NH_3 \longrightarrow CH_3NH_2 + NH_4^+ + Cl^-$ **not allow** $CH_3Cl + NH_3 \longrightarrow CH_3NH_2 + HCl$ **not allow** $CH_3Cl + 2NH_3 \longrightarrow CH_3NH_2 + HCl + NH_3$
iv	methylamine/aminomethane ✓	1	**allow** even if equation in (b)(iii) is incorrect.

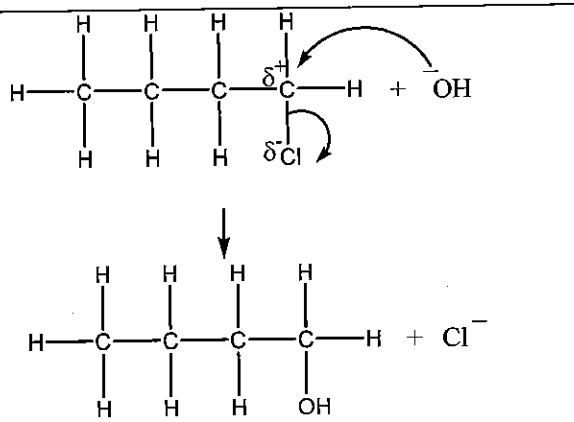
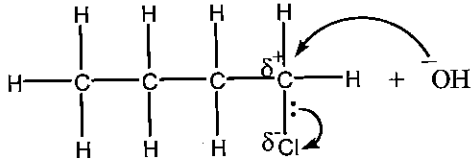
Question	Expected Answers	Marks	Additional Guidance
(c)	reaction would be faster ✓ C—I bond is weaker/has lower bond enthalpy (than C—Cl bond) ✓	2	second mark is dependent on first mark *e.g. reaction is slower because C—I bond is weaker* scores no marks. **not allow** iodomethane / CH_3I has lower/weaker bond energy/enthalpy **not allow** C—I bond is longer **allow** C—I bond is longer, therefore weaker **not allow** iodine bond is weaker
	Total	**9**	

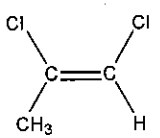
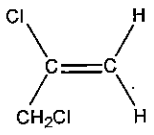
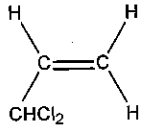
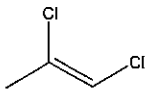
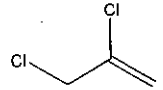
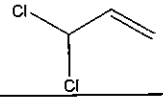
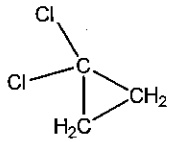
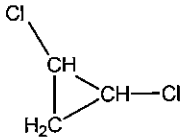
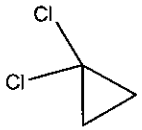
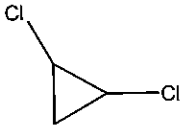
Question	Expected Answers	Marks	Additional Guidance
5 (a)	alkanes are non-polar ✓ nucleophiles/electrophiles are **attracted** to polar substances ✓ C–H bonds are strong ✓ allow max of 2 from 3	2	**allow** C–H bonds have little/no polarity/no dipoles **allow** no regions of high or low electron density **allow** nucleophiles/electrophiles/reagents are **not** attracted to non-polar substances **not allow** attacks/reacts as an alternative to attracts **allow** bonds in alkanes are strong
(b)	Free radical substitution ✓ balanced equation $C_5H_{12} + Br_2 \rightarrow C_5H_{11}Br + HBr$ ✓ mechanism $Br_2 \longrightarrow 2Br\bullet$ ✓ $Br\bullet + C_5H_{12} \longrightarrow HBr + \bullet C_5H_{11}$ ✓ $\bullet C_5H_{11} + Br_2 \longrightarrow C_5H_{11}Br + Br\bullet$ ✓ any two free radicals to show termination step ✓ conditions: uv ✓ bond fission: homolytic fission ✓ mixed products due to: • multiple substitution of H (in C_5H_{12}) • several isomers of $C_5H_{11}Br$ • different products could be formed in termination step* any two from three ✓✓	10	if a different alkane is used **do not allow** mark for either propagation step but the rest can be marked ecf If error in first propagation step ecf can be awarded for second propagation step **allow** any one of: $2Br\bullet \longrightarrow Br_2$ $Br\bullet + \bullet C_5H_{11} \longrightarrow C_5H_{11}Br$ $\bullet C_5H_{11} + \bullet C_5H_{11} \longrightarrow C_{10}H_{22}$ If H• formed in propagation allow ecf for a termination equation using the H• **allow** sunlight/high temperature **allow** homolysis/homolytic cleavage **do not allow** free radicals are very reactive/difficult to control * must be stated not just assumed if they write more than one termination step.

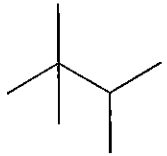
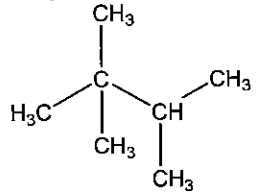
Question	Expected Answers	Marks	Additional Guidance
QWC	Well structured answer and uses all three of initiation, propagation and termination correctly✓	1	
	Total	13	

2812 Chains and Rings

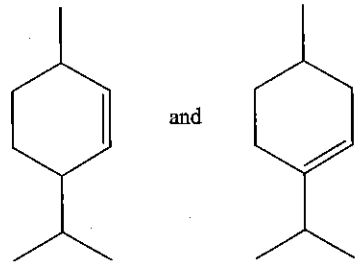
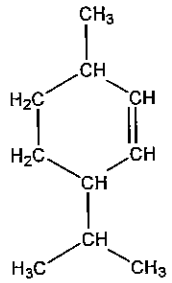
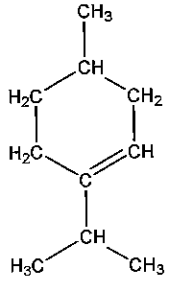
Question			Expected Answers	Marks	Additional Guidance
1	a	(i)	*D* ✓	1	no other acceptable response
		(ii)	*B* ✓	1	no other acceptable response
		(iii)	*D* ✓	1	no other acceptable response
		(iv)	*A and B* ✓	1	no other acceptable response
	b	(i)	 ✓	1	**allow** $(CH_3)_2CHCH_2NH_2$ **allow**  **ignore** bond linkage & lack of Hs
		(ii)	ethanol ✓	1	**allow** ethanolic/alcohol/alcoholic/C_2H_5OH **not allow** ethanoic
	c	(i)	electron pair donor/lone pair donor ✓	1	**allow** donator

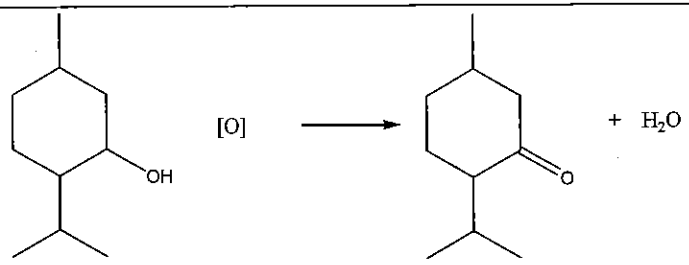
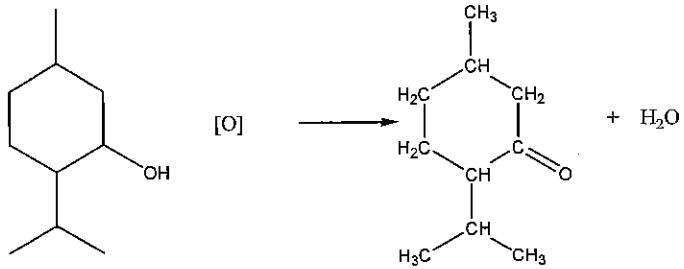
		(ii)	 curly arrow from O of the OH^- to the $C^{\delta+}$ ✓ correct dipole **and** curly arrow from C—Cl bond to $Cl^{\delta-}$ ✓ correct products ✓	3	**ignore** if 2 dots on the C—Cl bond  **allow** lone pairs shown on O and/or Cl **ignore** bond linkage & lack of Hs **allow** max of 2 out of 3 marks if single headed arrows used
				10	

Question			Expected Answers	Marks	Additional Guidance
2	a	(i)	same molecular formula ✓ different structure/structural formula/ displayed formula ✓	2	**allow** same molecular formula, different arrangement of atoms same molecular formula different arrangement in space – scores 1 mark same formula, different structure – scores 1 mark **not allow** same atoms different structure etc
		(ii)	 (1,2-dichloro-)  (2,3-dichloro-)  (3,3-dichloro-)	3	**allow** correct structural formulae such as $CH_3C(Cl)CHCl$, $CH_2ClC(Cl)CH_2$, $CHCl_2CHCH_2$ **allow** correct skeletal formulae   
		(iii)	1,1-dichloropropene ✓	1	**allow** 1,1-dichloroprop-1-ene **do not allow** 1,1-chloroprop(-1-)ene/1-dichloroprop(-1-)ene/dichloroprop(-1-)ene **ignore** commas/hypens **allow** 11dichloroprop1ene
		(iv)	 or  ✓	1	**allow**  or  **do not allow** names
	b		because they have (C=C) double bond which restricts rotation ✓ and each C in the C=C is bonded to (two) different groups or atoms ✓	2	
				9	

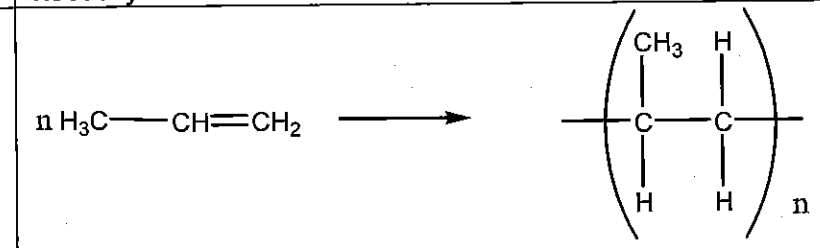
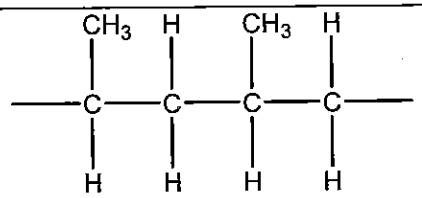
Question			Expected Answers	Marks	Additional Guidance
3	a	(i)	F ✓	1	no other acceptable answer
		(ii)	van der Waals ✓	1	**allow** vdW/vdw **ignore** spelling of van der Waals **not allow** intermolecular forces/ dipole-dipole/H-bonds
		(iii)	2,2,3-trimethylbutane/  ✓	1	**allow** either name or any unambiguous formula  $(CH_3)_3CCH(CH_3)_2$
	b	(i)	(particle/atom/molecule that) contains an unpaired/single electron ✓	1	**allow** .... contains an unpaired electron/has a single unpaired electron **do not allow** a *free* electron **do not allow** an ion with an unpaired/single electron
		(ii)	$Cl_2 \longrightarrow 2Cl^{\bullet}$ ✓	1	**allow** $Cl_2 \longrightarrow Cl^{\bullet} + Cl^{\bullet}$ / $\frac{1}{2}Cl_2 \longrightarrow Cl^{\bullet}$
		(iii)	homolytic (fission)/ ✓	1	**allow** homolysis/ homolytic cleavage
		(iv)	$C_7H_{16} + Cl^{\bullet} \longrightarrow {}^{\bullet}C_7H_{15} + HCl$ ✓ ${}^{\bullet}C_7H_{15} + Cl_2 \longrightarrow C_7H_{15}Cl + Cl^{\bullet}$ ✓	2	**allow** $C_7H_{15}^{\bullet}$ no other alternatives
		(v)	${}^{\bullet}C_7H_{15} + {}^{\bullet}C_7H_{15} \longrightarrow C_{14}H_{30}$ or $C_7H_{15}C_7H_{15}$ ✓	1	allow $2{}^{\bullet}C_7H_{15} \longrightarrow C_{14}H_{30}$ or $C_7H_{15}C_7H_{15}$ ✓

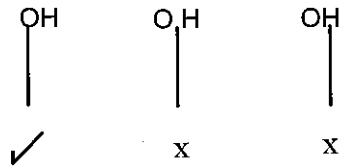
	c	(i)	compound **E** has **6** isomers ✓	1	no other acceptable answer
		(ii)	compound **G** has **3** isomers ✓	1	no other acceptable answer
				11	

Question			Expected Answers	Marks	Additional Guidance
4	a	(i)	$C_{10}H_{20}O$ ✓	1	no other acceptable answer
		(ii)	secondary ✓	1	**allow** 2nd ary/circle or underline "*secondary*" on the paper/2°
	b	(i)	 and ✓ ✓	2	**allow**  and 
		(ii)	ester✓	1	no other acceptable answer
	c	(i)	reagent $Cr_2O_7^{2-}$ ✓ conditions H^+ & heat ✓	2	**allow** dichromate/ sodium or potassium dichromate/ $K_2Cr_2O_7/Na_2Cr_2O_7$ **allow** $KMnO_4$ and then corresponding colour change in (ii) **conditions** mark dependent on a reasonable attempt at the reagent acidified/ sulfuric acid/sulfuric acid/ H_2SO_4 warm/ reflux/heat under reflux/distil
		(ii)	orange to green ✓	1	**allow** orange to black/dark green **do not allow** green **allow** purple to green/brown/pink/colourless if $KMnO_4$ used in (i) but do not allow orange to green. mark as "x con"

		(iii)	 ✓	1	**allow** 
		(iv)	lack of peak in range 3230–3550 (cm^{-1}) ✓	1	**allow** lack of broad peak at about 3000 (cm^{-1}) **do not allow** range quoted as 2500 – 3300 (cm^{-1})/approx 3000 (cm^{-1}) **ignore** any reference to C—O/1000 – 1300 (cm^{-1}) **ignore** any reference to discussion of C=O peak
				10	

Question			Expected Answers	Marks	Additional Guidance
5	a		Crude oil can be separated by fractional distillation because the compounds/fractions have different boiling points ✓ (AW) fractionation produces insufficient quantities of the 'petrol' fraction ✓ (AW) **balanced equation** to illustrate cracking ✓ alkenes which are used to produce alcohols or polymers✓ (AW) **balanced equation** to illustrate isomerisation ✓ **balanced equation** to illustrate reforming to obtain cycloalkanes (and arenes) ✓and H_2 ✓ which promote more efficient combustion/ better fuels/increases octane number/reduces knocking/ reduces pre-ignition ✓ * (AW) (*credited once)	8	**allow** different volatilities/ condenses at different temperatures **not allow** more demand **allow** alternate wording (AW) throughout 4 marks for equations – if equations not linked to process, **allow** max of 3 out of 4 **do not allow** just "*more useful*" can award two marks for balanced equation for reforming if both a cyclic compound and H_2 shown. 1 mark if H_2 absent but cyclic compound structure shown **not allow** word equations
			• ethanol is renewable ✓ • obtained from plants/ named plant ✓ • equation for fermentation $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓ • oil-based fuels are finite/take millions of years to form ✓	4	**not allow** obtained from sugar **not allow** oil is non-renewable **allow** an alternative argument based on carbon emission • ethanol is carbon neutral ✓ • obtained from plants which photosynthesise✓ • oil based fuels are **net** carbon emitters ✓
			$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$ ✓	1	**allow** CH_3CH_2OH **not allow** C_2H_6O

QWC			Correctly uses, and spells correctly, at least **three** of: boiling point efficient, renewable additive, finite octane number/rating, fermentation knocking, fossil pre-ignition, carbon neutral cycloalkanes, van der Waals, cyclic , intermolecular arene biofuel volatility, viscosity	1	
	b	**(i)**	 ✓	1	**allow** n $C_3H_6 \longrightarrow (C_3H_6)_n$
		(ii)		1	**allow** bracket around the two repeat units with or without the following "n"
	c	**(i)**	reagent: H_2O ✓ conditions: temperature > 100°C and a H^+ catalyst ✓	2	**allow** steam and H^+ for both marks **allow** hot aqueous acid for both marks conditions mark is dependent on correct reagent **allow** H_2SO_4/H_3PO_4 **ignore** any reference to pressure

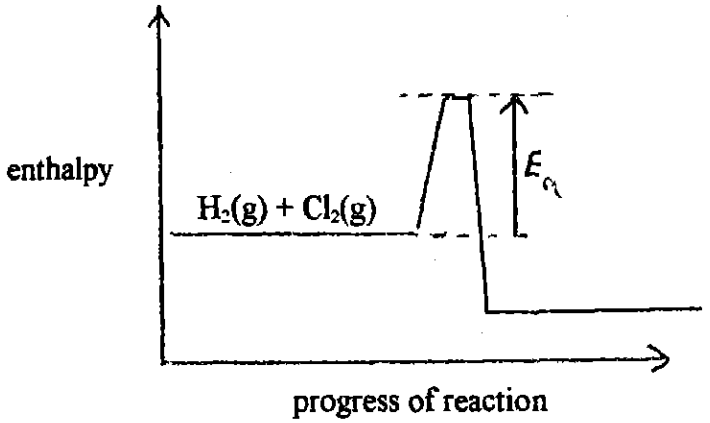
		(ii)	propan-1-ol ✓ and propan-2-ol ✓	2	**allow** any unambiguous formula **not allow** C_3H_7OH or propanol **do not allow** bond linkage must be correct. The bond must clearly go to the O  **do not allow** if Hs are not shown
				20	

Mark Scheme Page 1 of 4	Unit Code 2813/01	Session Jan	Year 2001	Version post-QPEC
Abbreviations, annotations and conventions used in the Mark Scheme	/ = alternative and acceptable answers for the same marking point ; = separates marking points NOT = answers which are not worthy of credit ( ) = words which are not essential to gain credit _____ = (underlining) key words which must be used to gain credit ecf = error carried forward AW = alternative wording ora = or reverse argument			

Question	Expected Answers		Marks
1 (a) (i)	the enthalpy change when 1 mole of compound	✓	
	is formed from its elements (under standard conditions)	✓	[2]
(ii)	$\frac{1}{2}N_2(g) + O_2(g) \longrightarrow NO_2(g)$ *(balancing ✓) (state symbols ✓)* *(N.B. NOT→ $2NO_2$)*		[2]
(iii)	$\Delta H_x + 2 \times 90 = 2 \times 33$	✓	
	$\Delta H_x = 66 - 180$	✓ ecf	
	$= -114$ (kJ mol-1)	✓ ecf	[3]
(b)	ΔH is positive (or reaction is endothermic) *or* high activation energy *or* strong N≡N bond	✓	[1]
(c) (i)	$4\,CO + 2\,NO_2 \longrightarrow 4\,CO_2 + N_2$	✓	[1]
(ii)	heterogeneous	✓	
	different phases (solid/gas)	✓	[2]
(iii)	adsorption (of gases) onto the surface brings molecules together active sites subsequent desorption *(any two)*	✓✓	[2]
(iv)	reactions only occur on its surface	✓	
	so larger surface area = faster rate of reaction	✓	[2]
			[Total: 15]

Question	Expected Answers		Mark
2. (a) (i)	sunlight / ultraviolet light	✓	[1
(ii)	$Cl + O_3 \longrightarrow ClO + O_2$ $ClO + O \longrightarrow Cl + O_2$	✓ ✓	[2
(iii)	$2O_3 \longrightarrow 3O_2$ *or* $O_3 + O \longrightarrow 2O_2$	✓	[1
(iv)	~~homogeneous~~ ~~(catalyst and reactants both in) gaseous phase~~	✓ ✓	[2
(b) (i)	118.5	✓	[1
(ii)	C_8H_{18}	✓ecf	[1
(iii)	to avoid destroying the ozone layer	✓	[1
(iv)	(hydrocarbons are more) flammable *or* explosive *or* are greenhouse gases	✓	[1 [Total: 10

Question	Expected Answers		Marks
3. (a)	the energy required to <u>break</u> <u>1 mole</u> of bonds	✓ ✓	[2]
(b) (i)	$x + 436 = 2(432) - 184$ $x = 244$ kJ mol^{-1}	✓ ✓ ecf	[2]
(ii)	$x + 568 = ½(436 + 158)$ $x = -271$ kJ mol^{-1}	✓ ✓ ecf	[2]
(c) (i)	a strong acid is completely ionised to $H^+(aq)$ a weak acid is incompletely ionised (NOT unionised)	✓ ✓	[2]
(ii)	H-F is a stronger bond than H-Cl so is less likely to break (to give $H^+ + F^-$)	✓ ✓	[2]
(iii)	$2HCl + MgO \longrightarrow MgCl_2 + H_2O$ $2H^+ + MgO \longrightarrow Mg^{2+} + H_2O$	✓	[1]
(d) (i)	the spark provides the <u>activation energy</u>	✓	[1]
(ii)	diagram should: include E_a labelled show an exothermic reaction	✓ ✓	[2]



[Total: 14]

Question	Expected Answers		Marks
4. (a) (i)	*pressure:*	between 80 atm and 1000 atm ✓	
	temperature:	between 400°C and 550°C ✓	
	catalyst:	iron ✓	[3]
(b)	(increased pressure) increases the rate ✓ because molecules are closer together (so collide more often) ✓ (NOT molecules go faster/have more energy)		[2]
(c) (i)	high T pushes equilibrium over to l.h.side ✓ because reaction is exothermic (from l. to r.) ✓		[2]
(ii)	high pressure pushes equilibrium over to r.h.side ✓ because 4 moles of gas are going to 2 moles of gas ✓		[2]
(d)	if the temperature is too high, ⇒ low yield at equilibrium ✓ if the temperature is too low, ⇒ slow rate of reaction ✓		[2]
(e) (i)	$\underline{2}\,NH_3 + CO_2 \longrightarrow NH_2CONH_2 + H_2O$ ✓		[1]
(ii)	$M_r(NH_3) = 17$ $M_r(NH_2CONH_2) = 60$ ✓ 34g gives 60g so 1 kg gives 60/34 = **1.76 kg**		✓ecf [2]
			[Total: 14]

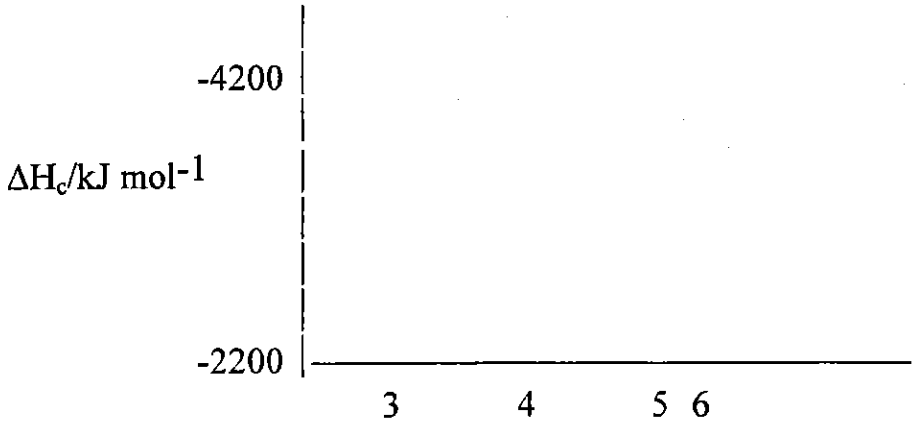
5.	*diagram:*	labelled axes correct shape of distribution curve higher temperature curve of correct shape/position E_a labelled	
	text or diagram:	(shaded areas ⇒) more molecules with $E > E_a$ at higher T E_a(catalysed) is lower than uncatalysed hence more molecules with $E > E_a$(cat)	
		any 6 points ✓✓✓✓✓✓	[6]
		Q of w C: ✓	[1]
			Total: [7]

Question	Expected Answers	Marks
1 (a)(i) *	the enthalpy change when 1 mole (in words) of compound/substance ✓ [N.B NOT element in its standard state, and NOT 1 mol of elements, if a compound is being made] (is formed from its) elements under standard conditions *or* at 100 kPa and a stated temperature *or* at room temperature and pressure ✓	[2]
(ii)	$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l)$ *balanced for 1 mole of water* ✓ *state symbols (u/c -anything on left, but has to be $H_2O(l)$ on RHS)* ✓	[2]
(b)	x - 75 - 2(286) = -394 [x = 75 + 572 - 394] *(x 2)* ✓ *(correct +/- signs)* ✓ x = (+)**253** (kJ mol^{-1}) ✓ecf *correct ans ⇒ [3] marks.* *Award [2] for any of the following: -33, +103, -253, -891, +1041* *Award [1] for any of the following: +33, -183, -605, +755, -1041*	[3]
(c) (i)	enthalpy $N_2(g) + 3H_2(g)$ progress of reaction *look for.* *ΔH shown as exothermic o r- 92 kJ mol^{-1}* ✓ *E_{act} or 68 kJ mol^{-1} from reactants to trans. state* ✓ *product labelled correctly **after** transition state* ✓	[3]
(ii)	92 + 68 =**160** (kJ mol^{-1}) ✓ (no ecf)	[1] total 11

Question	Expected Answers	Marks
2 (a)	$C_6H_6(l) + 7½O_2(g) \rightarrow 6CO_2(g) + 3H_2O(l)$ (*or 15/2*) *Correct formulae and state symbols* ✓ *balanced for 1 mole of C_6H_6* ✓	[2]
(b)	x - 3267 = 3(-1301) *(x 3)* ✓ *(correct +/- signs)* ✓	
	x = **-636** (kJ mol^{-1}) ✓ecf *correct ans ⇒ [3] marks.*	[3]
*	*Award [2] for any of the following: +636, +1966, ±7170, +665* *Award [1] for any of the following: -1966, ±4568, -665* ***If no other mark has been awarded**, you could award [1] for 3 x (-)1301*	
(c) (i)	(rate) increases ✓ more molecules have $E > E_a$ *or* enough energy to react (at higher T) ✓ collision rate increases (with T) *or* there are more (effective) collisions ✓ *N B. there is no mark for "molecules go faster/have more energy"*	[3]
(ii)	(rate) increases ✓ (because they are closer together) molecules collide more often *or* more collisions *or* more molecules in contact with the catalyst ✓ *N.B. no mark for molecules go faster/have more energy*	[2]
(d) *	it's a catalyst *or* it speeds up the reaction ✓ by lowering E_{act} *or* providing alternative route with lower energy *or* adsorbs/forms (temporary) bonds with the reagents ✓ *N.B. no mark for "provides surface" or "extra surface area"*	[2]
		total 12

Question	Expected Answers	Marks
3 (a)	• forward rate = reverse rate (***not*** *concentration of reactants and products are equal)* • can be approached from either direction *or* reversible reaction *or* (constant) change from reactants to products and vice versa • no change in overall macroscopic properties (*or* one specified property, e.g. colour/concentration) *or* <u>appears</u> to have stopped • takes place in a closed system *(any two bullet points)* ✓✓	[2]
(b)	a change in conditions *or* a disturbance will cause a shift in the (position of) <u>equilibrium</u> ✓	
*	in the direction that minimises/opposes/reduces/attempts to balance out/ the effect of the change ✓ *N.B. do not accept "cancels" or "equals" or "balances" or "restores" without the "attempt"*	[2]
(c)	solution would turn <u>yellow</u> (allow yellow-green) ✓ *(do not allow this mark if candidate says it goes yellow and then back to green again!)*	
	(increasing/added $[H^+]$ pushes) the <u>equilibrium</u> to left hand side *or* <u>equilibrium</u> shifts to form more HIn ecf ✓ *ecf: if candidate states that the colour goes blue, then the first mark is lost, but the second can be awarded for stating that the eqm. goes to the* ***right***	[2]
(d)	(colour goes from yellow to) <u>green</u> u/c ✓	
*	then to <u>blue</u> (allow blue-green) ✓ *(do not allow this mark if candidate says it goes blue and then back to green again!)*	
*	*N B. allow e.c.f for* ***both*** *these marks as follows:* *if candidate has said in (c) that colour goes blue, then these two marks are for (blue to) gree n[1], and yellow(-green) [1] (don't allow "blue" in both!)*	
	OH^- reacts with/removes H^+ (*or* equation) *or* is a proton acceptor *or* neutralises the acid ✓ *N.B. not just "OH- is a base"*	[4] total 10
	shifting the <u>equilibrium</u> to the right hand side *or* <u>equilibrium</u> shifts to form more In^- ecf✓	
	(the word "equilibrium" need only appear once in parts (c) and (d) If it is omitted from ***both*** *(c) and (d), deduct [1] only. If it is omitted from only* ***one*** *part, allow full marks (as long as the chemistry is correct!))*	

Question	Expected Answers	Marks
4 (a)	a strong acid is completely ionised/dissociated (to $H^+(aq)$) *or* gives 1 mol of $H^+(aq)$ for each 1 mol of HA ✓ a weak acid is incompletely ionised/dissociated (NOT unionised) *or* gives less than 1 mol of $H^+(aq)$ for each 1 mol of HA ✓	[2]
	N B. if neither of the above two marks can be awarded, you can award [1] for the statement that "strong acids donate protons/H+ more readily than weak acids	[1]
(b) (i)	$CaCO_3 + 2HA \longrightarrow CaA_2 + H_2O + CO_2$ ✓ *or* $CaCO_3 + 2H^+ \longrightarrow Ca^{2+} + H_2O + CO_2$ *or* $CO_3^{2-} + 2H^+ \longrightarrow H_2O + CO_2$	
(ii)	• (average) energy/speed/movement <u>of molecules/particles</u> increases with temperature • more (molecules) have $E > E_a$ (at higher T) *or* have enough energy to react *N.B. do not allow this point if candidate has stated that the E_a decreases with temperature* • activation energy is the minimum energy molecules need in order to react • collision rate *or* number of collisions increases (with T) *(any three bullet points)* ✓✓✓ *N.B. the first two bullet points could be read into two labelled Boltzmann distribution curves, showing E_a*	[3] total 6

Question	Expected Answers	Marks
5 (a) (i)	the energy/enthalpy/heat required to break ✓ 1 mole of bonds *or* a bond per molecule in 1 mole ✓ *N.B. do not allow "(energy needed to break the bonds in) 1 mole of compound"*	[2]
(ii)	¼CH_4(g) ⟶ ¼C + H *(i.e balanced for 1 mol of H)* ✓✓✓ *If the above three marks cannot be awarded (this is more than likely!), allow the following:* Any equation with CH_4(g) on the left hand side ✓ Any equation showing the breaking of a CH bond, e.g. C + 4H *or* CH_3 + H on the right hand side ✓	[3]
(b)	total BE on left = 2(C-C) + 8(C-H) + 5(O=O) = +6488 kJ ✓ total BE on right = 6(C=O) + 8(O-H) = +8542 kJ ✓ *N.B. if neither of these two marks can be awarded, you could award [1] if* ***all*** *of the correct multipliers (2, 8, 5, 6, 8) have been used.* ΔH = 6488-8542 = **-2054** (kJ mol^{-1}) ✓ecf *([3] for correct ans)* *(ecf: award the mark for correctly taking* ***their*** *total BE on right from* ***their*** *total BE on left.* ***Not*** *vice versa. If you cannot clearly see which is BE on right and which is BE on left, don't award this mark)*	[3]
(c) (i)	*either:* average bond energies are not applicable to particular bonds *or.* ΔH_c is for H_2O**(l)**, whereas bond energies are for gases ✓ *N.B. ingore any ref. to changes in conditions/temperature etc.*	[1]
(ii) *		[1]
(iii)	*plotting of points* ***and*** *a straight line* ✓	[1]
(iv)	-3450 to -3550 (kJ mol^{-1}) (ignore absence of sign, but do not allow +)✓ (allow e.c.f. - correct interpretation of incorrect graph)	[1]
	Successive members/molecules/compounds/formulae increase by a regular/fixed/the same amount (of C and/or H) *or* by a CH_2 group ✓	12 max 11

Question	Expected Answers	Marks
6 (a)	• mention of **two** of the following *as pollutants*, or *as products of combustion* or *as being present in exhaust gases*: carbon monoxide, nitrogen monoxide, nitrogen dioxide, unburned hydrocarbons (ignore any ref to sulphur compounds) • heterogeneous (catalysis) (not homogeneous/catalytic) • needs a high temperature • (reactants) adsorbed onto the catalyst's surface • weakly/temporarily bonded to the catalyst • bonds in reactants are weakened • (products easily) desorbed after reaction *or* lost/released from surface • description of how one of the pollutants undergoes transformation into harmless products, e.g. $CO + NO \longrightarrow CO_2 + \frac{1}{2}N_2$ (*or* $2CO + O_2 \longrightarrow 2CO_2$ *or* $2NO \longrightarrow N_2 + O_2$ *or* h/c + $O_2 \longrightarrow CO_2 + H_2O$) (*or* in words - equation does not need to be balanced) *any five bullet points* ✓✓✓✓✓ *Q of WC:* Look for two things here; the overall account must read clearly, and make sense grammatically (ignore spellings), and in addition at least **one** of the following words should be used correctly in a suitable context: heterogeneous, catalyst, adsorption, desorption., oxidation, reduction *Indicate this mark as* Q✓	[6]
(b)	• Haber process converts nitrogen/N_2 (from the air hence cheap and plentiful) into ammonia/NH_3 *or* in an (unbalance) equation *ammonia is used* • as a refrigerant *and to make* • fertilizers • such as ammonia itself, ammonium sulphate *or* other ammonium salt *or* urea etc. • which are needed for more crops/food),. *and nitric acid, which is used to make* • explosives *or* a named N-containing explosive, • polyamides/nylon, • dyes etc. *any 4 bullet points* ✓✓✓✓	[4] total 10

Abbreviations, annotations and conventions used in the Mark Scheme	/ = alternative and acceptable answers for the same marking point , = separates marking points NOT = answers which are not worthy of credit ( ) = words which are not essential to gain credit _____ = (underlining) key words which must be used to gain credit ecf = error carried forward AW = alternative wording ora = or reverse argument

1 (a) (i) the enthalpy change when **1 mole** of compound/substance is formed ✓
from its **elements** under **standard conditions** (of temperature and pressure) ✓

[2]

(ii) temperature of 298K (or 25 °C) ✓

pressure of 1 atmos (or 100 kPa or 101 kPa) ✓

[2]

(b) (i) a reaction that gives out heat/energy to its surrounds or in which the reactants react with a decrease in internal enthalpy/energy. [NOT temperature rise] ✓

[1]

(ii) e.g. combustion/burning of fuels (*or* stated fuel, e.g. alkanes) *or* respiration *or* metabolism *or* (unbalanced) equation representing this. [NOT just 'burning' on its own] ✓

[1]

(c) (i) $\Delta H = 4(-242) - 2(+51) - 9$ (✓ for x2 and x4)
$= -968 - 102 - 9$ (✓ for the correct signs)
$= -1079$ kJ mol^{-1} (✓ for the answer) *ecf*
(see separate list of alternatives)

[3]

(ii) Because the products are **gases** (if products are identified, both must be correct) [NOT low activation energy] ✓

[1]
Total: [10]

2 (a) at a high temperature (accept any stated temperature above 0°C) ✓

[1]

(b) photosynthesis requires (only) **light.** *or* 'energy from the sun'
[NOT heat, or heat from the sun] ✓

[1]

(c) (i) 6(O-H) + 6(C=O) ✓

= 6 x 464 + 6 x 750
= 7284 (kJ mol^{-1}) ✓

ecf

[2]

(ii) 3(O=O) + 4(C-H) + 2(C-C) + 2(C-O) + 2(O-H) + C=O ✓

= 3 x 498 + 4 x 413 + 2 x 347 + 2 x 358 + 2 x 464 + 750
= 6234 (kJ mol^{-1}) ✓

ecf

(see separate list of alternatives allow [1] if only C-C is omitted)

[2]

(iii) ΔH = 7284 - 6234
= + 1050 kJ mol^{-1} *ecf* (i.e. (i)-(ii)) ✓

[1] ecf

(d) diagram ✓

[to include: $C_3H_6O_3 + 3O_2$ as product
and ΔH *or* '+1050', drawn to be consistent with answer to part (iii) above]

[1]
Total: [8]

3 (a) (i) distribution curve (T_1):

starts at(0,0) and goes to a maximum ✓

right hand side tails off to x-axis exponentially ✓

[it can *reach* the axis, but not cross it]

[2]

(ii) second curve (T_2):

starts at (0,0) and has its maximum at a lower ordinate value ✓

and to the right of the T_1 maximum ✓

[2]

(b) the (minimum) energy that molecules/particles need to have in order to react
or energy required for effective collisions
or minimum energy needed for a reaction to occur
or energy needed to break bonds [NOT the energy needed to start a reaction] ✓

[1]

(c) *at higher temperature*
more molecules have $E > E_a$ [NOT just 'more molecules have higher energy'] ✓

∴ greater chance of reacting on collision (*or* more **successful** collisions) ✓

[NOT just 'more collisions']
∴ faster reaction *or* increased rate ✓u/c
(*or* accept the converse arguments at a lower temperature)

[3]

(d) (i)

B < **C** < **D** < **A**

smallest E_{act} largest E_{act}

✓✓ (all correct: [2]

(*either* C<D<B<A *or* C<D<A<B, i.e.one in wrong place: [1])

[2]

(ii) no bonds broken in B ⇒ low E_{act} ✓

the others go in order of bond energies ✓ [2]
(*or* wtte – e.g. A has the greatest bond energy)

Total: [12]

4 (a) a catalyst speeds up a reaction (without being used up). ✓
it offers a different route ✓
of lower activation energy ✓

[3]

(b) heterogeneous ✓

[1]

(c) needs to happen in a closed system
no change in macroscopic properties
forward and backward reactions continue to proceed
but at the same **rate** as each other [NOT same *extent*]

any two✓✓

[2]

(d) (i) *(When a system in dynamic equilibrium is subjected to a change in conditions...)*
the (position of) **equilibrium** [NOT reaction] will shift (*or* be restored) ✓
in the direction that minimises the effect of the change
or opposes the change [NOT negates or cancels the change] ✓

[2]

(ii) pressure
equilibrium shifts to the left ✓
because 9 moles of gas on LHS and 10 moles of gas on RHS
or less particles on left hand side of equation ✓u/c

temperature
equilibrium shifts to the left hand side ✓
because reaction is exothermic *or* ΔH is negative ✓u/c

[4]

(e) To speed up reaction. ✓
or To obtain a reasonable yield at reasonable rate.

[1]

Total: [13]

5 (a) (i) ammonia is acting as a base/alkali/proton acceptor
[NOT ammonia reacts with/absorbs protons] ✓

[1]

(ii) M_r for $(NH_4)_2SO_4$ = 132.1 ✓
2 x 17 ⟶ 132.1 *(mark for 2 x 17)* ✓
∴ 100 ⟶ 132.1 x 100/34
= **388-390 g** ✓ecf

[3]

(iii) fertiliser ✓

[1]

(b) **Gas**/CO_2 is **evolved/given off** *or* reaction **fizzes**. ✓
[this mark is NEGATED if a change of colour is mentioned]

$$MgCO_3 + 2HNO_3 \longrightarrow Mg(NO_3)_2 + H_2O + CO_2$$

correct formulae of reagents ✓
equation balanced ✓

[3]
Total: [8]

6 CFCs affect the **ozone** layer ✓
C-Cl bond breaks with UV *or* energy from sunlight ✓
giving Cl **radicals** *or* Cl• *or* Cl **atoms** (the Cl can be read into an equation, but 'radical'/'atom' has to be in words) ✓
homogeneous ✓
catalysis ✓

word explanation of how Cl acts as a homogeneous catalysis (e.g. it is regenerated) ✓

mention of chain reaction ✓
hence one Cl breaks down many O_3 ✓
$Cl + O_3 \longrightarrow ClO + O_2$ ✓
$ClO + O \longrightarrow Cl + O_2$ *or* $ClO + O_3 \longrightarrow Cl + 2\,O_2$ ✓
[ignore $O_3 \longrightarrow O_2 + O$]

10 points: any 8 score
Q of w C (at least one sensible sentence): ✓

[9]
Total: [9]

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	_____	= (underlining) key words which must be used to gain credit
	ecf	= error carried forward
	AW	= alternative wording
	ora	= or reverse argument

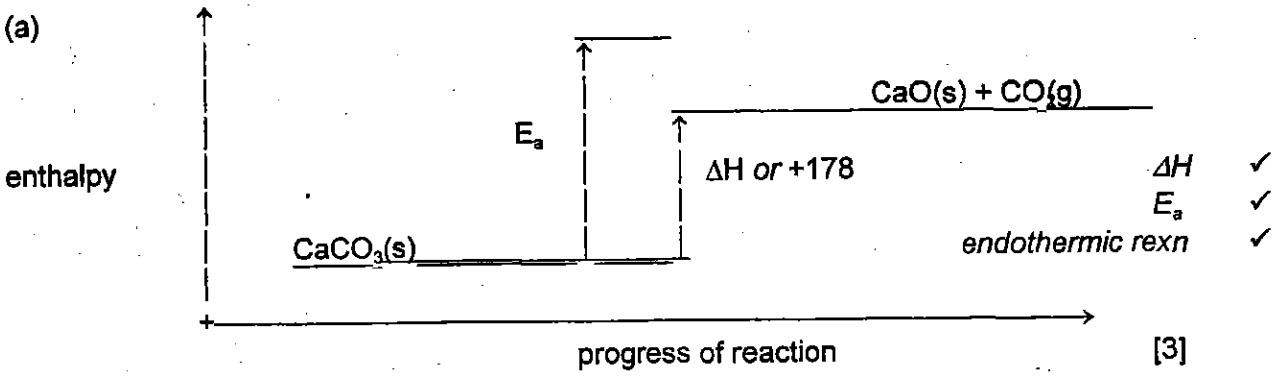
1 (a) E = -(31.9-18.0) x 4.18 x 100 ✓
E = (-)5810 J ✓ ~~[3]~~ [2]
(allow 2905 for **[1]** mark, also allow 5.81 **J** for [1])

(b) 2.0 x 50/1000 = **0.1 moles** ✓ [1]

(c) -5810/(0.1 x 1000) = **-58.1 kJ mol^{-1}** ✓(sign, u/c) ✓ecf ~~[1]~~ [2]
(allow ecf for (ans to (a))/(ans to (b) x 1000), allow sign mark even if value is wrong)

Total: **5**

2 (a)



[3]

(marks for E_a and ΔH are for label + arrow. Allow double-headed arrows *or* lines. Last mark is for products being higher than reactants. If arrow is single-headed its direction must be consistent with height of products (i.e .in the exo or endothermic direction))

(b) (high T) speeds up reaction *or* (gives energy to) overcome activation energy ✓
or provides energy to **break** bonds *or* reaction has a big E_a.
and (gives the energy needed to carry out the) **endothermic** reaction ✓
or reaction takes in heat

[2]

(c) ΔH = 82 - 178 = -96 kJ mol^{-1} ✓(sign) ✓ [2]
(allow [1] only for +96 *or* 96 *or* ±260, sign mark is conditional on 96 being correct)

Total: **7**

3 (a) (i) reaction 3.1: 413 - 432 = **-19** (kJ mol^{-1}) ✓
reaction 3.2: 243 - 327 = **-84** (kJ mol^{-1}) ✓ [2]
(if both signs are wrong, i.e. +19 and +84, penalise once only, and award [1])

(ii) reaction 3.2 is faster, because weaker bonds are being broken
or lower likely E_{act} *or* less energy needed ✓ [1]

(b) for reaction 3.3: a comparison of E(C-Cl) with *either* E(C-H) *or* E(H-Cl)
or a calculation, e.g. ΔH = 413 - 327 = +86 ✓ [1]
(the reaction is) is too endothermic (to take place) *or* it has a highly positive ΔH ✓ [1]
or too high an E_a *or* too much energy is needed Total: **5**

4 (a) C_8H_{18} + **12.5** O_2 ⟶ **8** CO_2 + **9** H_2O (*or* doubled) ✓ [1]

(b) (i) + (ii) ✓✓✓✓[4]

fuel	ΔH_c per mole of alkane burned (kJ mol^{-1})	ΔH_c per mole of CO_2 produced (kJ)	moles of CO_2 produced per kJ of heat given out
methane	-890	***-890***	***1.1 – 1.15 x 10^{-3}*** **(a)** ecf
octane	-5479	***-684 to –685*** ecf from incorrectly balanced equation	***1.4 – 1.5 x 10^{-3}*** **(b)** ecf (needs a calc. - not just a ratio)

(iii) ratio (= 1.124/1.462) = 0.7 – 0.8 ✓ecf, i.e. any **(a)/(b)** [1]
(allow a whole number fraction)

(c) (i) unburned h/c low-level ozone *or* smog *or* greenhouse gas *or* carcinogenic
NOT ozone depletion, smoke, pollution, sootiness etc
CO poisonous/toxic (to animals - ignore refs to trees etc) *or* reacts with haemoglobin
(mention of greenhouse gas *or* acid rain *or* ozone depletion **negates** any valid CO effect mentioned)
NO smog *or* acid rain *or* bad for lungs *or* causes respiratory problems *or* irritant NOT poisonous. (Ignore ozone depletion) ✓✓✓ [3]

(ii) from the combination of N_2 and O_2 (from the air) (or equation) ✓ [1]

(iii) NO + CO ⟶ ½N_2 + CO_2 (*or* double) ✓ [1]

(iv) Pt *or* Pd *or* Rh *or* all (any other metal negates the mark) ✓ [1]

(v) in a different phase/state (to the reactants) *or* a solid reacting with gases ✓ [1]

(vi) rate of reaction is increased the hotter it is *or* more molecules with E > E_a *or* more energy available to break bonds *or* more energy available to overcome activation (barrier) *or* increased collision rate ✓ [1]
Total: **14**

5 (a) pressure increases the rate of reaction ✓
because the molecules are pushed closer together *or* become more concentrated *or* collide more often *or* more collisions
(NOT because they are travelling faster *or* have more energy – mention of either of these **negates** any correct comment) ✓ [2]

(b) (i) (increasing T will) increase yield *or* drive equilibrium over to right ✓
or favour the forward reaction
because it's an endothermic reaction *or* ΔH is positive ✓ [2]

(ii) (increasing P will) decrease yield *or* drive equilibrium over to left ✓
or favour the backward reaction
because there are more (gas) moles on the right than the left. ✓ [2]

(c) *either* each reaction requires different conditions of temperature *or* pressure
or the reaction use different catalysts (N.B. not just unspecified "different conditions") ✓ [1]

Total: **7**

6 acid = contains H^+ *or* proton donor *or* $\rightarrow H^+$ in an equation *or* an electron **pair** acceptor ✓

4 main reactions: HCl(aq) + metal (from Ca to Fe in reactivity)
HCl(aq) + (insoluble) metal oxide
HCl(aq) + soluble metal hydroxide *or* ammonia
HCl(aq) + carbonate (any one - allow hydrogencarbonate too)
also allow: HCl(aq) + an alcohol + $ZnCl_2$, giving a chloroalkane

an example of each to include the name or correct formula of reactant (can be read into an equation) ***and*** a description of the observation ✓✓✓
[if none of these 3 marks has been awarded there are 2 ways in which a **salvage mark** may be given for stating 3 correct reagents but no observations ***or*** for stating the 3 general (word) equations for acid reactions]

observations: ***metal*** dissolves *or* H_2 evolved *or* gas evolved/produced/formed *or* fizzes
(in words, not to be read from $H_2(g)$ in the equation)
carbonate dissolves *or* CO_2 evolved *or* gas evolved *or* fizzes
(in words, not to be read from $CO_2(g)$ in the equation)
metal oxide dissolves
soluble hydroxide heats up *or* changes the colour of an indicator
(for any metal that gives coloured salts, allow the correct colour of the solution as an observation)
also allow: solution (of alcohol) turns cloudy

balanced chemical equations (any two from the five reaction types above) ✓✓
[for reactive metals, e.g. Na, allow [1] for balanced equation, but not the observation mark]

ionic equations (any two) [these must not include any spectator ions] ✓✓
[8] max [6]

QWC (two informative sentences) ✓ [1]

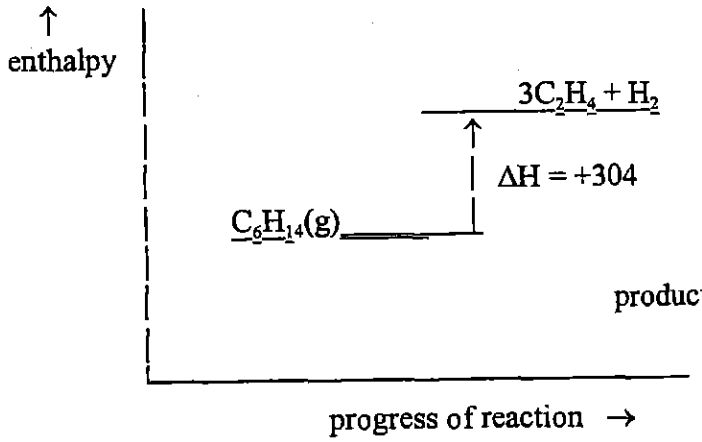
Total: **7**

1 (a) (i) the energy required to <u>break</u> ✓
<u>1 mole</u> of bonds ✓ [2]

(ii) bonds broken: 5x (C-C) + 14 x (C-H) = 1750 + 5740 = 7490 ✓
bonds formed: 3 x (C=C) + 12 x (C-H) + (H-H) = 1830 + 4920 + 436 = 7186 ✓

ΔH = (+)304 kJ mol^{-1} ✓ [3]

(b)



labels ✓
products higher than reactant (ecf from a(ii)) ✓
ΔH shown (or value) (ecf) ✓
[3]

8

2 (a) ΔH°_{r} = 4 x 90 + 6 x (-242) - 4 x (-)46
= -908 kJ mol^{-1}

✓✓✓ [3]

(b) (i) a change in conditions *or* a disturbance will cause a shift in the (position of) equilibrium ✓
in the direction that minimises/opposes/reduces/attempts to balance out/compensates for [NOT cancels out] the effect of the change ✓ [2]

(ii) the equilibrium will move to the left hand side ✓
because there are fewer moles (of gas on that side) ✓ [2]

(c) (i) (heterogeneous) catalyst *or* to speed up the reaction *or* to increase surface area ✓ [1]

(ii) to allow time for the (slow) reaction to take place (on the surface)
or to allow adsorption to take place ✓ [1]

(d) $4NO + 2H_2O + 3O_2 \longrightarrow 4HNO_3$ balancing of oxygen ✓
balancing of C and H ✓ [2]

11

3 (a) *any 2 of:*

- forward rate = reverse rate (***not** concentration of reactants and products are equal)*
- can be approached from either direction *or* reversible reaction *or* (constant) change from reactants to products and vice versa
- no change in overall macroscopic properties (*or* one specified property, e.g. colour/concentration) *or* appears to have stopped
- takes place in a closed system

✓✓ [2]

(b) (i) (orange means that the solution has become weakly) **acidic** ✓

adding $CO_2(g)$ pushes each of the above equilibria to the right hand side *or* forms more products ✓ [2]

(ii) (conc sulphuric acid provides) $H^+(aq)$ ions ✓

(adding $H^+(aq)$ pushes the) equilibria/reactions over to the left hand side *or* favours the reverse reaction ✓ [2]

6

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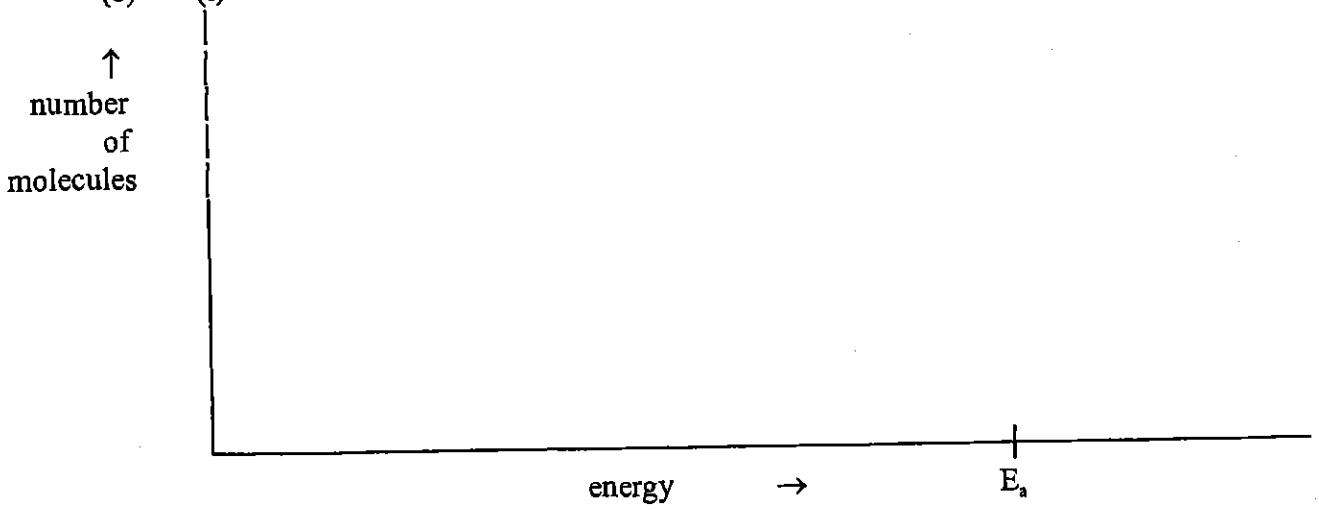
4 (a) more molecules of the reagent in the same space *or* molecules closer together ✓

leading to more chance of *or* greater frequency/rate of collisions ✓ [2]

(b) (i)



maximum at higher E ✓

at lower peak height ✓ [2]

(check that the line is NOT steeper at the start, or turned up at the end, and that it crosses the original line to the right of the maximum)

(ii) higher proportion of/more molecules have $E > E_a$ at T_2 ✓

therefore more collisions are effective/successful OWTTE ✓ [2]

6

5 (a) (i) effervescence/fizzing/gas evolved ✓ [1]

(ii) $H_2SO_4 + Na_2CO_3 \longrightarrow Na_2SO_4 + H_2O + CO_2$

Na_2SO_4 ✓

$H_2O + CO_2$ ✓ [2]

(b) (i) ammonia is a base/alkali/proton acceptor/electron pair donor ✓ [1]

(ii) $(NH_4)_2SO_4 = 2 \times (14 + 4) + 32 + 4 \times 16 = 132$ ✓

$\%N = 100 \times 28/132$

$= 21.2\%$ ✓ [2]

(iii) as a fertiliser ✓ [1]

7

6

- process **A** is photosynthesis. [1]
- process **B** is respiration *or* the burning/combustion of food [1]
- process **C** is combustion *or* the/burning of fuels [1]

- process **A** occurs in plants [1]
- process **B** occurs in animals [1]
- process **C** occurs in cars etc [1]

- process **A** is endothermic; process **B** and process **C** are exothermic ([2]for all three correct, [1] for two correct, [0] for only one correct) [2]

- the energy of sunlight is 'captured' in photosynthesis/process **A** (OWTTE) [1]

9 max 7

1(a) 400 - 550 °C *or* 670 – 825 K (assume Celsius if no units specified) ✓ [1]

(b) (i) rate/reaction is (too) slow *or* "time consuming" (ignore ref. to "yield", but don't award mark if candidate states that "**equilibrium** yield is low") ✓ [1]

(ii) equilibrium/reaction is pushed over to left hand side *or* yield is decreased ✓ [1]

or less ammonia is formed (NOT "is expensive")

(c) (i) *either* the rate *or* the (equilibrium) yield will increase (*or* more NH_3 formed) ✓ [1]

(ii) costs will be high *or* safety will be compromised *or* is dangerous ✓ [1]
(NOT environmental problems)

(d) they are recycled/re-used/put back in/re-reacted ✓ [1]

(e) *any 2 of:* as, or to make, fertilisers *or* refrigerants;
to make nitric acid, polyamides, explosives, dyes ✓✓ [2]
(NOT "in agriculture", "as a feedstock", "in gunpowder". If "making" is not mentioned in the appropriate context, deduct [1] max)

8

2(a) *any 2 of:*

- forward rate/reaction = reverse rate/reaction
  (*a statement that the concentration of reactants and products are equal* ***negates)***
- can be approached from either direction *or* reversible reaction *or* (constant) change
  from reactants to products and vice versa
- no change in overall macroscopic properties (*or* one specified property, e.g. colour/concentration) *or* <u>appears</u> to have stopped
- takes place in a closed system ✓✓ [2]

(b) bonds broken: 4 x (S-Cl) = 4 x 255 = **1020** ✓
(*or* *2 x (S-Cl)* = *2 x 255* = ***510***)

bonds formed: 2 x (S-Cl) + 1 x (S-S) +1 x (Cl-Cl) = 2 x 255 + 266 + 242 =**1018**✓
(*or 1 x (S-S) + 1 x (Cl-Cl)* = *266 + 242* =***508***)

ΔH = (+)2 kJ mol^{-1} ans.(i.e. broken – formed) ✓(e.c.f.) [3]

(possible e.c.f values:: - 2 *or* +268 *or* ± 2038 *or* ±1018 as a result of 510 + 518 [2])
(there may be others!) -268 [1]

allow "working" marks for: sum of bonds on l.h.s. ✓
sum of bonds on r.h.s. ✓

(c) because is positive *or* reaction is endothermic ✓(consistent with ans. in b)
equilibrium/reaction will move to right hand side ✓(consistent with ans. in b)
but not by very much because ΔH is so small ✓ [3]
alternative for last 2 marks: $\Delta H \sim 0$ [1], therefore only a slight effect on equilibrium [1]

8 max 7

3(a) (i) the enthalpy change when **1 mole** of compound/substance/element/molecule ✓

is **completely** burned *or* burned in **an excess** of oxygen ✓

at 1 atm + 298 K (*or* "a stated temperature" – in words)
or under **standard conditions** (of T and P) ✓ [3]

(ii) $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$ (balancing for 1 mole propane) ✓
(st. symbols, as long as oxygen is used) ✓ [2]

(b) (i) C(s) + $H_2(g)$ do not easily combine (at 298K) *or* E_{act} is too high
or if they did, different hydrocarbons (e.g. CH_4) would be produced as well ✓ [1]
[do NOT allow "isomers are formed"]

(ii) $\Delta H^{e}_{f} = 3 \times \Delta H_c(C) + 4 \times \Delta H_c(H_2) - \Delta H_c(C_3H_8)$

$= -1182 - 1144 + 2220$

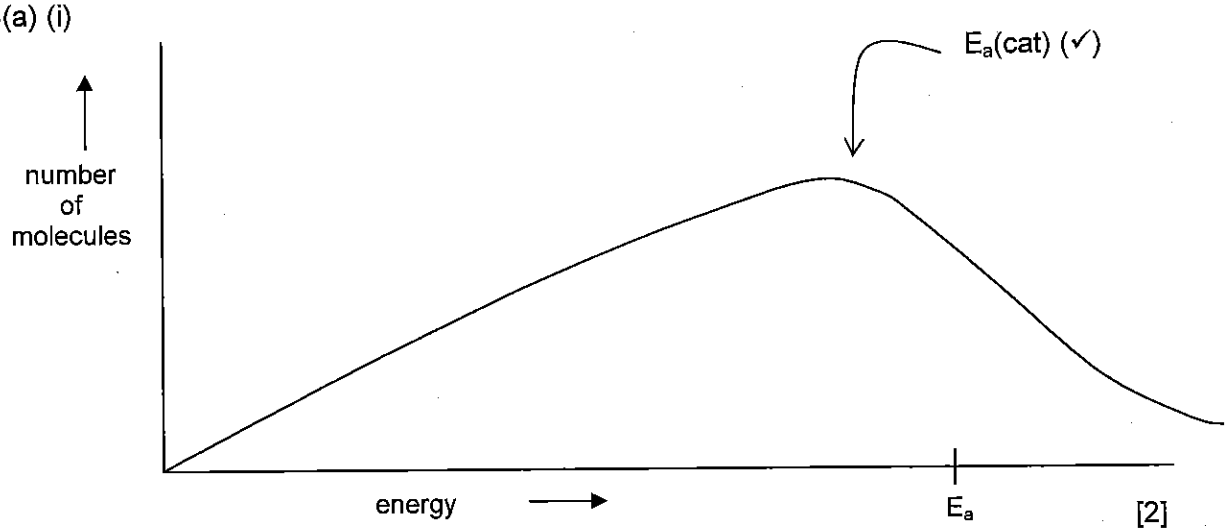
$= -2326 + 2220 =$ **-106** kJ mol^{-1} (e.c.f. see below) ✓✓✓ [3]

possible e.c.f values: +106 *or* -1250 *or* +1540 *or* ± 4546 [2]
+1250 *or* -1540 *or* ± 2112 *or* ± 2182 *or* ± 2258 [1]

for other answers see if you can award any of the following "working" marks

allow "working marks" for use of the correct multipliers (3,4,1) ✓
use of the correct ΔH^{e}_{c} values **and** the correct signs ✓
last mark is for "left – right" correctly calculated ✓

4(a) (i)



[2]

curve starts at (0,0) and then peaks ✓ then falls off more gradually ✓
(it should NOT be symmetrical *or* meet the x-axis)

(ii) the (minimum) energy required by the reacting molecules in order for them to react ✓ [1]

or (minimum) energy for a reaction to take place
or (minimum) energy to produce a reaction
or energy barrier to a reaction [NOT *just* the energy needed to break bonds]

(iii) see E_a(cat) on graph above: E_a(cat) must be to the left of E_a ✓ [1]

(b) catalysts offer an alternative route [*or* binds substrate *or* adsorbs reactant] ✓
of lower activation energy ✓
so more molecules have $E > E_a$ *or* more molecules can react
or more collisions are successful in bringing about a reaction ✓
homogeneous - same phase/state, *heterogeneous* - different phases/states ✓

examples: (*in the examples accept unbalanced equations as long as the starting materials and products are (virtually) correct)*

(homogeneous) e.g. $Cl^•$ in the stratosphere ✓
catalysing $2O_3 \longrightarrow 3O_2$ (*or* two propagation equations) ✓

or e.g. H^+ during esterification
catalysing $RCO_2H + ROH \longrightarrow RCO_2R + H_2O$

or enzymes/zymase in fermentation
catalysing $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$

(heterogeneous) e.g. Pt in catalytic converters ✓
catalysing $NO + CO \longrightarrow \frac{1}{2}N_2 + CO_2$ ✓

or e.g. Fe in Haber
catalysing $N_2 + 3H_2 \longrightarrow 2NH_3$

(in general: identity of catalyst ✓ equation ✓)
(deduct [1] if the stated catalysts are not described in the right homo-heterogeneous context)
8 marking points max[7]

Q of w C:At least two clauses/sentences that express a logical sequence of ideas. ✓ [1]

2813/01 How Far? How Fast?/Experimental Skills 1 Written Paper

Question No		Max Mark
1) (a)	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ ✓	[1]
(b)	energy = $mc\Delta T$/ 150 x 4.18 x 42 ✓	
	=26.3 (kJ) ✓	[2]
(c)	number of moles = $\frac{0.600}{16}$ = 0.0375 ✓	[1]
(d)	enthalpy = $\frac{26.3}{0.0375}$ = 701 (kJ mol^{-1}) ✓	
	ΔHc = - 701 (kJ mol^{-1}) ✓ negative sign can be scored as stand-alone mark	[2]
		[Total: 6]

Question No		Max Mark
2(a)(i)	the (total) enthalpy change (for a reaction) is independent of the route taken owtte ✓	[1]
(ii)	$N_2(g) + 2H_2(g) \rightarrow N_2H_4(l)$ ✓	[1]
(iii)	cycle ✓ $\Delta H + 51 = 2(-241)$ ✓ $\Delta H = -533$ (kJ) ✓	[3]
(iv)	products are non-toxic/ not greenhouse gases/ occur naturally in the atmosphere/ no carbon dioxide is formed ✓	[1]
(b)(i)	any 2 from reaction is occurring in a closed system ✓ rate of forward reaction = rate of reverse reaction ✓ macroscopic properties/ suitable named macroscopic property remains constant ✓	[2]
(ii)	bonds broken = 2(C=O) + 4(H-H) = 3354 (kJ) ✓ bonds made = 4(C-H) + 4(O-H) = 3508 (kJ) ✓ enthalpy change = -154 (kJ) ✓	[3]
(iii)	low temperature ✓ because the (forward) reaction is exothermic ✓ (ecf possible from (ii)) high pressure ✓ because there are more moles (of gas) on the LHS ✓	[4] [Total: 15]

Question No		Max Mark
3(a)	a proton donor/ an H^+ donor ✓	[1]
(b)(i)	$CuO(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l)$/ $CuO(s) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(l)$/ $O^{2-} + 2H^+(aq) \rightarrow H_2O(l)$ all formulae and balancing ✓ $Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$/ $Na_2CO_3(s) + 2H^+(aq) \rightarrow 2Na^+(aq) + CO_2(g) + H_2O(l)$/ $CO_3^{2-} + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$ all formulae and balancing ✓ state symbols in both equations (ignore ss on CuO and Na_2CO_3) ✓	[3]
(ii)	high activation energy/ strong ionic bonds present (in copper oxide)/ high lattice enthalpy (in copper oxide) ✓	[1]
(iii)	bubbling/ effervescence ✓ solid disappears/solid dissolves/ blue or green solution formed ✓	[2]
(c)(i)	completely dissociated/ completely ionised ✓	[1]
(ii)	$HClO_4 \rightarrow H^+ + ClO_4^-$ ✓	[1]
(iii)	$Mg + 2H^+ \rightarrow H_2 + Mg^{2+}$ ✓	[1]
(iv)	no difference in rate ✓ the concentration of H^+ is the same ✓	[2] [Total: 12]

Question No		Max Mark
4)	a catalyst provides an alternative pathway that has a lower activation energy ✓ more particles/ collisions exceed the activation energy/ more successful collisions occur ✓ diagram to show 2 profiles with initial and final energies together ✓ two different energy humps with catalysed labelled as lower curve ✓ E_a labelled on both/ labelled on one and statement E_a (cat) < E_a ✓ equation ✓ catalyst named ✓ equation ✓ catalyst named ✓ examples include $N_2 + 3H_2 \rightarrow 2NH_3$ ✓ iron ✓ any alkene + H_2 → corresponding alkane ✓ nickel/platinum ✓ $2SO_2 + O_2 \rightarrow 2SO_3$ ✓ vanadium(V) oxide ✓ $2CO + 2NO \rightarrow 2CO_2 + N_2$/ $4CO + 2NO_2 \rightarrow N_2 + 4CO_2$ ✓ platinum/ palladium/rhodium ✓ equation for cracking/ reforming/ isomerisation of any alkane ✓ platinum/ zeolites ✓ adsorption ✓ bonds weakened ✓ products desorbed ✓	[2] [3] [4] [3] [Total: 12]

2813/01 How Far? How Fast?/Experimental Skills 1 Written Paper

Question			Expected Answers	Marks	Additional Guidance
1	(a)	i	enthalpy/energy change to break 1 mole of a (covalent) bond ✓ in the gaseous state ✓	2	do **not** allow first mark: • if **energy released** • if **break and make** • if **ionic** • if **heat** 2nd mark stand alone ignore 'under standard conditions'
		ii	bonds broken = 1 (C–C) + 5(C–H) + 1(C–O) + 1(O–H) + 3 (O=O) = 4728 (kJ) ✓ bonds formed = 4(C=O) + 6(O–H) = 6004 (kJ) ✓ ΔH_c = 1276 (kJmol^{-1}) ✓ **Alternative** if 1(O–H) cancelled on both sides the values are bonds broken = 4264 (kJ) ✓ bonds formed = 5540 (kJ) ✓ ΔH_c = –1276 (kJmol^{-1}) ✓	3	no working necessary -**allow one mark** for each value **allow ecf** on values for final answer but sign must be consistent with their values no working necessary -**allow one mark** for each value **allow ecf** on values for final answer but sign must be consistent with their values
	(b)	i	cycle/ $\Delta H_r = \Sigma\Delta H$ (products) – $\Sigma\Delta H$(reactants) ✓ 1273 + ΔH_c = 6394) + 6(286) ✓ ΔH_c = 2807 (kJ mol^{-1}) ✓	3	cycle need not be drawn correctly/drawn at all 2807 **scores 3** common errors and their effect –5353, –1377, –837, 181, 625, 1921, 2807 **score 2** –3923, –3637, –3383, –2989, –1921, –625, –181, 593, 837 **score 1**

					–1953, –593 **score 0** if these answers are seen, score appropriately any other answers **must be checked** one error **scores 2**, two errors **scores 1**
		ii	respiration	1	no other answer is acceptable **ignore** qualification eg exothermic, aerobic, anaerobic
			Total	**9**	

Question			Expected Answers	Marks	Additional Guidance
2	(a)	i	(becomes paler because equilibrium) moves to RHS /towards products /towards HI ✓ (because) the (forward) reaction is endothermic/ reverse reaction is exothermic ✓	2	becomes paler is in the question, **first mark** is for direction of equilibrium movement **Ignore** any discussion on number of moles/rates both marks stand alone
		ii	(becomes darker because) the molecules are pushed closer together/ space between particles decreases/ their concentration increases/ density increases/ ✓ equilibrium position does not alter ✓ because there are the same number of moles (of gas) on each side ✓	3	becomes darker is in the question, **first mark** is for comment on effect on particles all three marks are stand alone
	(b)	i	because there are <u>more</u> collisions ✓ and more of the collisions have <u>E_a</u>/ exceed <u>E_a</u> /have the required energy to react ✓	2	activation energy/ E_a / required energy to react must be mentioned for the 2nd mark
		ii	because the particles collide more (frequently) ✓	1	any mention of energy or E_a negates the mark any idea of **more particles are added** negates the mark
	(c)	i	hydrogen was added/used✓	1	**not** 'concentration of hydrogen increases'
		ii	amount of HI/products goes up/ amount of I_2 /H_2/reactants goes down/ as equilibrium moves to RHS ✓ (new) equilibrium established/reaches equilibrium again/ concentrations become constant / rate forward = rate back ✓	2	do not allow 2nd mark if restore to **original** equilibrium or if the reason given is **invalid** eg increase in temperature
			Total	11	

Question			Expected Answers	Marks	Additional Guidance
3	(a)	i	*x* axis energy ✓ *y* axis number/fraction of particles/molecules/atoms ✓	2	**not** activation energy/E_a **allow** kinetic energy/KE/speed/velocity/enthalpy **allow** 1 mark if labels both correct but on reversed axes
		ii	on diagram labelled E_a lines with and without catalyst ✓ explanation – more particles/collisions have energy greater or equal to $\underline{E_a}$ / required energy to react, with catalyst ✓	2	E_a must be labelled on one line (lines must be drawn **and** meet the curve) lines must be to RHS of hump if two graphs are drawn, first mark not awarded activation energy/ E_a /required energy to react must be mentioned for the 2nd mark
	(b)	i	gas/ hydrogen is given off/produced/formed/released ✓	1	
		ii	sketch to show line falling more steeply ✓ finishing at same horizontal level ✓	2	graph must start at the same point as the original the line need not continue very far as long as it is clearly at the same horizontal
	(c)	i	diagram to show products below reactants ✓ energy 'hump' between reactants and products ✓	2	products **must be** labelled hump can be rectangular or curved AW
		ii	ΔH labelled/ (–)120 ✓ E_a labelled/250 ✓	2	accept double headed arrows or lines single headed arrows must have arrow in correct direction
		iii	E_a = 370 (kJ mol^{-1}) ✓	1	If answer = 130, refer back to Q3(c)i **ecf** if endothermic drawn
			Total	**12**	

2813/01 How Far? How Fast?/Experimental Skills 1 Written Paper

Question			Expected Answers	Marks	Additional Guidance
1	(a)	i	reaction slows ✓	1	Not becomes constant
		ii	because there are less particles per unit volume (as the reaction proceeds)/particles further apart/ the concentration decreases ✓ (rate) of collision decreases ✓	2	marks are stand alone allow successful collisions
	(b)		sketch to show graph starting more steeply ✓ finishing at same level ✓	2	
			Total	**5**	

Question			Expected Answers	Marks	Additional Guidance
2	(a)	i	energy/enthalpy change to break 1 mole of a (covalent) bond ✓ in the gaseous state ✓	2	do **not** allow first mark: if energy released if break and make if ionic if heat 2nd mark is stand alone ignore 'under standard conditions'
		ii	energy is put in to break the bond/ energy is needed to overcome the attraction (between electrons and nuclei) in the bond ✓	1	**not** attraction between oppositely charged ions endothermic alone does not score.
	(b)		bonds broken = 1(H–H) + 1(F–F) = 436 + (F–F) **and** bonds made = 2(H–F) = 1136 ✓ 436 + (F–F) – 1136 = –542 ✓ bond enthalpy = 158 (kJ mol^{-1}) ✓	3	ecf possible
	(c)		enthalpy change is ΔH for ½ H_2 + ½ Cl_2 → HCl ✓ bonds broken = 218 + 121 = 339 and bonds made = –432 ΔH = –93 (kJ mol^{-1}) ✓	2	
	(d)	i	a weak acid is partially dissociated ✓ to form H^+ ions / protons ✓	2	allow partially ionised can be shown in an equation
		ii	the H–F bond is stronger ✓	1	accept harder to break the bond.
		iii	Na_2CO_3 + 2HF → 2NaF + CO_2 + H_2O ✓	1	ignore state symbols; allow H_2CO_3
		iv	CO_3^{2-} + $2H^+$ →. CO_2 + H_2O/ Na_2CO_3 + $2H^+$ → $2Na^+$ + CO_2 + H_2O ✓	1	ignore state symbols do not allow the inclusion of spectator ions
		v	hydrochloric acid bubbles faster / solid disappears faster ✓ concentrations (of acids) must be the same ✓	2	allow conditions must be the same
			Total	**15**	

Question			Expected Answers	Marks	Additional guidance
3	(a)		high temperature needed (to send equilibrium to RHS) ✓ since (forward) reaction is endothermic ✓ low pressure needed (to send equilibrium to RHS) ✓ since fewer moles of gas on LHS ✓	4	all stand alone marks
	(b)		high temperature (gives a fast rate of reaction) ✓ because a higher proportion of collisions exceed *E*a ✓ high pressure (gives a fast rate of reaction) ✓ because molecules are closer together **and** collide at a faster rate/ because particles are more concentrated **and** collide at a faster rate ✓	4	all stand alone marks accept because a 'higher proportion of collisions have enough energy to cause a reaction' do not accept 'more collisions' or 'more energetic collisions' not answer based on E_a
	(c)		would use high temperature – for rate **and** yield ✓ but compromise on pressure ✓ because high pressure gives a fast rate but poor yield ✓	3	compromise must be on pressure not temperature both rate and yield needed
	(d)	i	the (total) enthalpy change for a reaction is the same whichever route is taken ✓ owtte	1	
		ii	cycle/ $\Sigma\Delta H$ (products) - $\Sigma\Delta H$ (reactants) ✓ $-75 - 242 + 210 = \Delta H_f$ ✓ ΔH_f = - 107 ($kJmol^{-1}$) ✓	3	cycle need not be drawn correctly/ drawn at all –107 scores 3
			Total	**15**	

Question	Expected Answers	Marks	Additional Guidance
4 (a)	**enthalpy profile diagram**		
	y axis labelled energy/enthalpy and one curve drawn to include either horizontal lines or reactants and products labelled✓		1 max for enthalpy profile diagram if diagrams are reversed
	second curve included to start and finish at same energy level and one curve labelled (catalysed or uncatalysed) ✓		
	Boltzmann distribution		
	axes labelled *x* as energy **and** *y* as number/ fraction or % of particles/ molecules/atoms ✓		for x axis allow kinetic energy/ KE/ velocity/ enthalpy do not allow activation energy/ E_a
	shape of curve ✓		must start at 0,0 and at higher energies must not touch or cross the x axis
	catalysed and uncatalysed E_a shown as vertical lines touching or crossing the curve and labelled ✓		if 2 graphs are drawn , this mark does not score
	explanation		
	to increase the rate of reaction more collisions/particles/molecules have to exceed E_a/have enough energy to react ✓		
	a catalyst acts by lowering E_a ✓		
	by allowing the reaction to proceed via a different route ✓	8	if candidate says catalyst gives molecule more energy, this mark does not score
(b)	equilibrium position unchanged ✓		
	rate of forward and reverse reaction increased by same amount ✓	2	
	Total	**10**	

2813/01 How Far? How Fast?/Experimental Skills 1 Written Paper

Question			Expected Answers	Marks	Additional Guidance
1	(a)	(i)	respiration (1)	1	**Ignore** aerobic/anaerobic
		(ii)	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ (1)	1	**ignore** state symbols **allow** $C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$ if specified aerobic/anaerobic in (i), must match in (ii)
	(b)	(i)	(enthalpy change) when 1 mole of a compound/substance/product/molecules is formed (1) from its (constituent) elements (1) in their standard states/ under standard conditions (1)	3	**reject** 1 mole of **element** **ignore** required/produced if standard conditions are quoted, they must be correct do not award this mark if standard AND gaseous
		(ii)	cycle (1) $x - 1367 = 2(-394) + 3(-286)$ (1) $x = -279$ (kJ mol $^{-1}$)	3	
		(iii)	diagram to show $2CO_2$ and $3H_2O$ at lower enthalpy than C_2H_5OH and $3O_2$ (1) E_a marked correctly (1) ΔH marked correctly (1)	3	**reject** products **ignore** state symbols for E_a and ΔH **allow** lines or double headed arrows single headed arrows must point in the correct direction
	(c)	(i)	(when pressure is increased) more ethene is converted/ equilibrium moves to RHS (1) because there are more (gas) moles on LHS/ ora (1)	2	**ignore** rate arguments **reject** volumes

		(ii)	when temperature is increased less ethene is converted/ equilibrium moves to LHS(1) (this means that the forward reaction is exothermic/produces heat/ increases the temperature) the sign of ΔH is negative (1)	2	2^{nd} mark dependent on 1^{st} mark ecf possible
		(iii)	sends equilibrium to RHS (1)	1	**allow** makes reaction goes to completion **allow** increase yield/maximum conversion
			Total	**16**	

Question			Expected Answers	Marks	Additional Guidance
3	(a)		bonds broken = 2(C=S) + 3(Cl–Cl) = 1086 + 3(Cl–Cl) (1) bonds made = 4(C–Cl) + 2(S–Cl) + (S–S) = 2084 (1) 1086 + 3(Cl–Cl) – 2084 = –272 Cl–Cl = 242 (kJ mol^{-1}) (1)	3	ecf possible on values of bonds broken and bonds made
	(b)		$C(s) + ½ F_2(g) + 1 ½ Cl_2(g) \rightarrow CFCl_3(g)$ formulae and balancing (1) state symbols (1)	2	**Allow** state symbols for species even if formula is not correct/reverse equation
	(c)	(i)	chlorine BUT NO MARK because the C–Cl bond is weaker (than the C–F bond) (1)	1	**accept** the bond enthalpy of C–Cl is less than that of C–F/ it is easier to break the C–Cl bond (than the C–F bond **reject** easier to form Cl free radical some comparison has to be made
		(ii)	homogeneous (1) because the catalyst and the reagents are in the same phase/ same physical state (1)	2	can be scored even if homogeneous not given
			Total	8	

Question			Expected Answers	Marks	Additional Guidance
4			diagram labelled with axes and E_a marked (1) curve shape correct – starting at origin and approaching x axis asymptotically (1) curve at higher temperature starting at origin and to RHS and with lower peak than the one at lower temperature (1) statement that, in order to react, the collision energy/ energy of molecules must (be equal to) or exceed E_a (1)	4	*y* axis can be number/ fraction/ percentage of molecules/ particles *x* axis can be energy/ enthalpy not allowed if E_a lowered **reject** more successful collisions **accept** more molecules have enough energy for successful collisions
			Total	**4**	

Question			Expected Answers	Marks	Additional Guidance
5	a		a strong acid is totally dissociated/ionised (1) $HNO_3 \rightarrow H^+ + NO_3^-$ (1)	2	ignore state symbols ignore equilibrium arrow
	B	(i)	$MgCO_3 + 2HNO_3 \rightarrow Mg(NO_3)_2 + CO_2 + H_2O$ (1)	1	
		(ii)	fizzing/solid disappears/ solid dissolve/ gas evolved/ gas given off (1)	1	
		(iii)	$MgCO_3 + 2H^+ \rightarrow Mg^{2+} + CO_2 + H_2O$/ $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ (1)	1	**Ignore** state symbols **reject** spectator ions
	c	(i)	ammonia is a base/ is a proton acceptor	1	**allow** is an alkali **reject** has a pair of electrons
		(ii)	M_r of NH_4NO_3 = 80 (1) %N = 35 (1)	2	ecf possible from M_r
			Total	8	