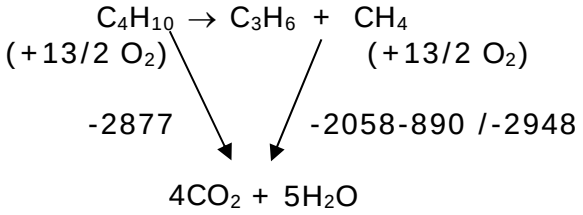
Question Number	Acceptable Answers	Reject	Mark
1(a)(i)	(Different) boiling temperatures/ boiling points ALLOW Range of boiling temperatures		**(1)**

Question Number	Acceptable Answers	Reject	Mark
1(a)(ii)	: breaking of carbon chain (in a hydrocarbon/ alkane) to give shorter chain hydrocarbon(s)/ smaller molecules OR breaking a hydrocarbon/ alkane to give smaller molecules OR Breaking an alkane to give an alkene **and** (a smaller) alkane/ hydrogen (1) **Reforming**: converting straight chain to a (more) branched chain/ ring/ arene / aromatic compound ALLOW Specific examples (1) IGNORE Makes more useful compounds Converting low octane (fuels) into high octane (fuels)	Just “Breaking a hydrocarbon” Just “Breaking a molecule” Breaking a hydrocarbon to form branched chains or ring structures	**(2)**

Question Number	Acceptable Answers	Reject	Mark
1(a)(iii)	Look at final answer: **+71** (kJ mol^{-1}) scores **3** marks **-71 / 71** (kJ mol^{-1}) scores **2** marks **-5825** (kJ mol^{-1}) scores **1** mark Method:  **MP1** Labelled cycle OR use of $\Delta H = \sum \Delta H_{combustion}$ reactants - $\sum \Delta H_{combustion}$ products (1) **MP2** ΔH = (-2877 -(-2058+ (-890)) (1) **MP3** = **+**71 (kJ mol^{-1}) (1)	Incorrect units	**(3)**

Question Number	Acceptable Answers	Reject	Mark
1(a)(iv)	$C_4H_{10} \rightarrow C_2H_6 + C_2H_4$ OR $C_4H_{10} \rightarrow C_4H_8 + H_2$ OR $C_4H_{10} \rightarrow 2C_2H_4 + H_2$ ALLOW Breakdown of multiple butanes Ignore state symbols, even if incorrect	$C_4H_{10} \rightarrow C_3H_6 + CH_4$ Charged products eg $C_2H_5^+$ Free radicals eg $C_2H_5^{\bullet}$	**(1)**

Question Number	Acceptable Answers	Reject	Mark
1b(i)	Look at final answer: **-2050** (kJ mol^{-1}) or anything correctly rounded from −2046.528 **(-2047, -2046.5, -2046.53)** scores **3** marks **+2050/ 2050** (kJ mol^{-1}) scores **2** marks Incorrect rounding scores 2 marks Correct value without sign scores 2 marks Energy transferred = (200 x 4.18 x 34.0) =28424 (J) IGNORE Sign if given (1) Mol pentane =(1.0/72) = 0.01389 / 0.0139 (1) ΔH = − (-28424 ÷ (1/72 x 1000)) = −2046.528 (kJ mol^{-1}) ALLOW TE from MP 1 and 2 provided moles of pentane is not taken as 1 (1) NOTE Use of 0.0139 mol gives -2044.9 (kJ mol^{-1}) giving 3 marks Use of 0.0138 mol gives -2059.7 (kJ mol^{-1}) giving 2 marks Use of 0.014 mol gives -2030.29 (kJ mol^{-1}) giving 2 marks Ignore SF except one or two		**(3)**

Question Number	Acceptable Answers	Reject	Mark
1(b)(ii)	Incomplete combustion OR Loss of pentane by evaporation ALLOW Volume of water too large to heat evenly Water not stirred evenly Small change in mass inaccurate Heat capacity of /energy needed to heat calorimeter not included	Incomplete reaction Loss of water by evaporation Heat losses Conditions not standard Measuring errors Pentane impure	**(1)**

Question Number	Acceptable Answers	Reject	Mark
1(b)(iii)	Pentane is **very** volatile/ has low boiling temperature so risk of explosion OR Has **high** flammability IGNORE Reaction is very exothermic	Just "it is flammable" Vapour is toxic Combustion products/ CO toxic	**(1)**

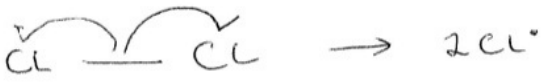
Question Number	Acceptable Answers	Reject	Mark
1(c)(i)	$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$ Allow multiples Ignore state symbols even if incorrect		**(1)**

Question Number	Acceptable Answers	Reject	Mark
1(c)(ii)	Bonds broken are four C-C twelve C-H eight O=O (1) Bonds made are ten C=O twelve O-H (1) ALLOW TE from (c)(i) If all five bonds are named but formulae not given eg oxygen-oxygen bonds, max 1 If all five bonds are correctly identified by formula but numbers are incorrect or missing, max 1	O-O single bonds C-O sing bonds	**(2)**

Question Number	Acceptable Answers	Reject	Mark
1(c)(iii)	The (total) bond energy of the bonds formed is greater than the bond energy of the bonds broken OR Energy released forming new bonds > energy needed to break old bonds OR The sum of the bond energies of the products is greater than the sum of the bond energies of the reactants.	Just"more bonds are made than broken" Answers referring to energy needed to make bonds Energy contained by bonds in reactants> energy contained by bonds in products	**(1)**

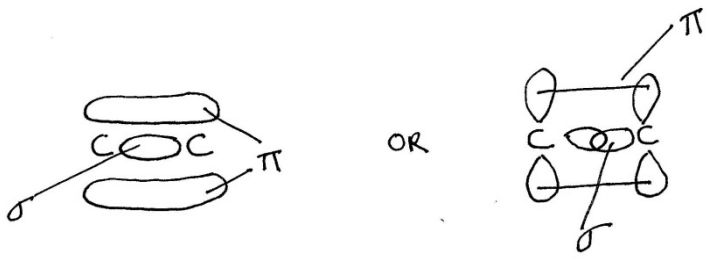
(Total for question = 16 marks)

Question Number	Acceptable Answers	Reject	Mark
2(a)(i)	Species/ atom/ molecule/ particle with an **unpaired electron** ALLOW An element with an **unpaired electron** IGNORE Reference to neutral species /lack of charge	Just "with a single electron" A lone electron Charged particle with an unpaired electron	**(1)**

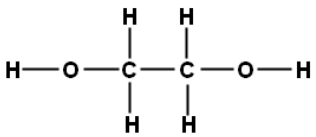
Question Number	Acceptable Answers	Reject	Mark
2(a)(ii)	 Half arrows going from bond to Cl or just beyond **and** product 2Cl• / Cl• + Cl•	Cl without •	**(1)**

Question Number	Acceptable Answers	Reject	Mark
2(iii)	$C_2H_6 + Cl• \rightarrow C_2H_5• + HCl$ ALLOW Structural formulae e.g. CH_3CH_3 OR displayed IGNORE Production of C_2H_5Cl from $C_2H_5•$ if first step is correct (1) Propagation (1) The second mark is independent of the first	$C_2H_5^+$	**(2)**

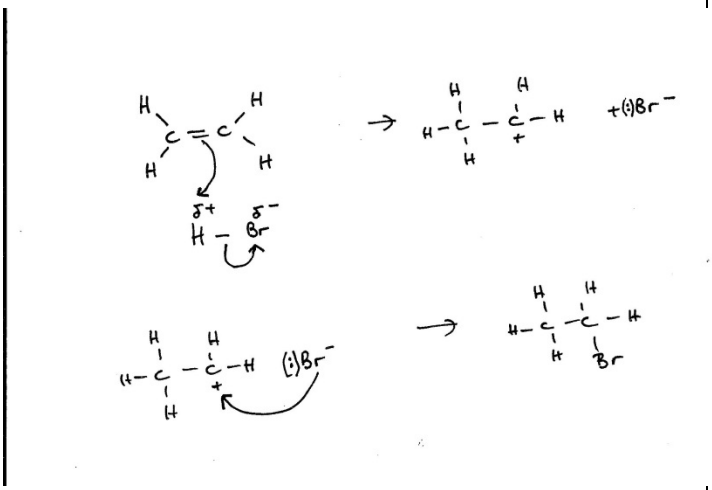
Question Number	Acceptable Answers	Reject	Mark
2(iv)	$C_2H_5\bullet + C_2H_5\bullet \rightarrow C_4H_{10}$ ALLOW Structural formulae e.g. $CH_3CH_2\bullet$ / $\bullet CH_3CH_2$ OR displayed IGNORE $Cl\bullet + Cl\bullet \rightarrow Cl_2$	Methyl or propyl radicals	**(1)**

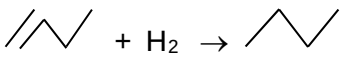
Question Number	Acceptable Answers	Reject	Mark
2b(i)	 σ bond between C atoms shown as 2 overlapping orbitals/ one electron cloud/ single bond (1) π bond above and below σ bond shown as two electron clouds/ overlapping p orbitals/ p orbitals linked by a line / a curved line above and below single bond (1) Both bonds must be labelled for 2 marks.		**(2)**

Question Number	Acceptable Answers	Reject	Mark
***2b (ii)**	σ bond remains ALLOW The product contains σ bonds only (1) **MP2** π bonds break because they are weaker (than σ bonds) ALLOW π bonds break because σ bonds are stronger (1) **MP3** Breaking the π bond results in carbocation intermediate / positively charged carbon forming OR π orbital overlap is lateral/ sideways /between parallel orbitals (making π bonds break/ weak) OR The σ bonds are much stronger (than the π bond) because of more effective (orbital) overlap (1)		**(3)**

Question Number	Acceptable Answers	Reject	Mark
2(b)(iii)	From: Purple/ pink (solution) To: colourless (1)  (1) Any orientation Don't penalise undisplayed OH Don't penalise bonds going to middle of undisplayed OH	To brown Molecular/ structural/ skeletal formulae C bonded to H of OH	**(2)**

Question Number	Acceptable Answers	Reject	Mark
2(b)(iv)	Second mark depends on use of bromine/ solution of bromine for test. EITHER Test: add bromine water / Br_2**(aq)** ALLOW Add bromine in organic solvent/ bromine dissolved in hexane/ bromine in 1,1,1-trichloroethane (1) From: brown/ red-brown/orange/ yellow To: colourless (1) OR Add bromine / Br_2 (1) From: brown/ red-brown To: colourless (1)		**(2)**

Question Number	Acceptable Answers	Reject	Mark
2(b)(v)	 Dipole on HBr (1) Curly arrow from C=C double bond to $H^{\delta+}$ of HBr **and** curly arrow from H-Br bond to Br (1) Correct intermediate with + charge (1) Curly arrow from Br^- to C^+ and formula of product ALLOW Curly arrow from anywhere on Br, including the − sign or lone pair (which is optional) (1)	Half arrows	**(4)**

Question Number	Acceptable Answers	Reject	Mark
2(c)	 (1) Suitable catalyst nickel/ platinum/ palladium (1) Ignore references to temperature, pressure, uv light	Use of H, H^+ Zeolite catalyst	**(2)**

Question Number	Acceptable Answers	Reject	Mark
3 (a)(i)	(Compound of) carbon and hydrogen **ONLY/ENTIRELY/PURELY**	"**Mixture** of carbon and hydrogen only"	**1**

Question Number	Acceptable Answers	Reject	Mark
3 (a)(ii)	(Contains) **only** (C—C) single bonds/ **only** σ bond(s) OR (Contains) no (C=C) double bond(s)/no triple bond(s) OR Cannot undergo addition (reactions) ALLOW Has maximum number of hydrogen atoms / has maximum amount of hydrogen /can form no more bonds IGNORE references to alkanes		**1**

Question Number	Acceptable Answers	Reject	Mark
3 (b)(i)	**Boiling** point(s) / **boiling** temperatures / **boiling** ranges ALLOW Different sizes of molecules / different chain lengths / different numbers of carbon atoms IGNORE References to melting points / melting temperatures / condensing	**Just** 'different temperatures' Breaking of hydrocarbon chains	**1**

Question Number	Acceptable Answers	Reject	Mark
3 (b)(ii)	Save fossil fuels / saves finite resources / saves petrol / saves diesel OR More sustainable OR Uses renewable resources / biodiesel made from 'natural resources' OR Biodiesel is a renewable fuel OR Plants (more) carbon neutral / use of plants improves carbon footprint (of fuel) OR Biodiesel has smaller carbon footprint / zero carbon footprint OR Biodiesel (more) carbon neutral ALLOW Reverse argument for petrol / 'normal' diesel (eg crude oil is non-renewable) IGNORE Less impact on the environment / references to 'environmentally friendly' / less polluting / acid rain IGNORE References to 'global warming' or 'Greenhouse Effect' or 'climate change'.		**1**

Question Number	Acceptable Answers	Reject	Mark
3 (c)(i)	**C_9H_{20}** IGNORE Any structures drawn out		**1**

Question Number	Acceptable Answers	Reject	Mark
3 (c)(ii)	**First mark:** Any ONE of:- (Greater) demand for smaller molecules / (Greater) demand for smaller alkanes / (Greater) demand for alkenes / To make more useful products / To make more reactive product / To make smaller molecules / To make shorter molecules / To make alkenes / To make shorter chains NOTE: ALLOW 'To produce fuel(s)' **(1)** **Second mark:** (High temperatures needed to) **break** (the C-C and / or C-H) **bonds** OR To break (down) the (hydrocarbon) chain(s) / To break (down) the molecule(s) / To split the molecule(s) / To break the hydrocarbon OR (Reaction is) endothermic ALLOW To overcome the (high) activation energy / the reaction has a high activation energy / provide activation energy IGNORE C-C bond is stable References to increasing rate (of reaction) References to yield / equilibrium References to efficiency / producing less CO **(1)** **Marks are stand-alone**	**No 2nd mark if any of the following are mentioned:** **Separation** of molecules Breaking **intermolecular** forces References to (high) boiling temperatures / (high) boiling points References to (high) melting temperatures / (high) melting points	**2**

Question Number	Acceptable Answers	Reject	Mark
3 (d)(i)	(Substance that) produces **energy** or produces **heat** IGNORE:- References to 'power' References to **just** 'exothermic' References to burning or combustion or heating the fuel or reference to oxygen		**1**

Question Number	Acceptable Answers	Reject	Mark
3 (d)(ii)	$C_4H_{10}(g) + 6½O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$ OR $C_4H_{10}(g) + 6.5O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$ OR $C_4H_{10}(g) + \frac{13}{2} O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$ OR $2C_4H_{10}(g) + 13\ O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$ OR Any other correct multiples Correct species **(1)** Balancing and state symbols correct **(1)** 2nd mark is dependent on the 1st mark	H_2O(**g**) C_4H_{10}(**l**)	**2**

Question Number	Acceptable Answers	Reject	Mark
3(d)(iii)	$C_4H_{10} + 4½O_2 \rightarrow 4CO + 5H_2O$ OR $C_4H_{10} + 4.5\ O_2 \rightarrow 4CO + 5H_2O$ OR $C_4H_{10} + \frac{9}{2} O_2 \rightarrow 4CO + 5H_2O$ OR $2C_4H_{10} + 9\ O_2 \rightarrow 8CO + 10H_2O$ OR Any other correct multiples IGNORE State symbols even if incorrect		**1**

Question Number	Acceptable Answers	Reject	Mark
3(d)(iv)	Limited (supply of) air / oxygen OR insufficient (supply of) air / oxygen OR Oxygen / air not in excess OR Not enough air / not enough oxygen ALLOW 'Lack of oxygen' / lack of ventilation IGNORE "It is not completely oxidized"	'**no** air' / '**no** oxygen'	**1**

Question Number	Acceptable Answers	Reject	Mark
3(d)(iii)	$C_4H_{10} + 4½O_2 \rightarrow 4CO + 5H_2O$ OR $C_4H_{10} + 4.5\ O_2 \rightarrow 4CO + 5H_2O$ OR $C_4H_{10} + \frac{9}{2} O_2 \rightarrow 4CO + 5H_2O$ OR $2C_4H_{10} + 9\ O_2 \rightarrow 8CO + 10H_2O$ OR Any other correct multiples IGNORE State symbols even if incorrect		**1**

Question Number	Acceptable Answers	Reject	Mark
3(d)(iv)	Limited (supply of) air / oxygen OR insufficient (supply of) air / oxygen OR Oxygen / air not in excess OR Not enough air / not enough oxygen ALLOW 'Lack of oxygen' / lack of ventilation IGNORE "It is not completely oxidized"	'**no** air' / '**no** oxygen'	**1**

Question Number	Acceptable Answers	Reject	Mark
***3(e)(ii)**	**First mark:** **Initiation** (step) **(1)** **Second mark:** Br—Br → Br● + Br● / Br_2 → 2Br● **(1)** **Third mark:** **Propagation** (steps) **(1)** **Fourth and fifth marks:** Br● + C_4H_{10} → C_4H_9● + HBr **(1)** Br_2 + C_4H_9● → C_4H_9Br + Br● **(1)** Allow in either order **Sixth mark:** **Termination (**step(s) **(1)** **Seventh mark:** **Any one of** Br● + Br● → Br_2 OR C_4H_9● + Br● → C_4H_9Br OR C_4H_9● + C_4H_9● → C_8H_{18} **(1)**	H● (the fourth and fifth marks cannot be awarded if H● appears in **either** propagation step)	**7**

(Total for Question = 21 marks)