

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

Question Number	Acceptable Answers	Reject	Mark
<b>1(a)(ii)</b>	: 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 <b>and</b> (a smaller) alkane/ hydrogen (1)  <b>Reforming:</b> 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	<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>1(a)(iii)</b>	<p>Look at final answer:  <b>+71</b> (kJ mol<sup>-1</sup>) scores <b>3</b> marks  <b>-71/ 71</b> (kJ mol<sup>-1</sup>) scores <b>2</b> marks  <b>-5825</b> (kJ mol<sup>-1</sup>) scores <b>1</b> mark</p> <p>Method:</p> $  \begin{array}{ccc}  \text{C}_4\text{H}_{10} & \rightarrow & \text{C}_3\text{H}_6 + \text{CH}_4 \\  (+13/2 \text{ O}_2) & & (+13/2 \text{ O}_2) \\  \swarrow & & \searrow \\  -2877 & & -2058-890 / -2948 \\  & \searrow & \swarrow \\  & 4\text{CO}_2 + 5\text{H}_2\text{O} &  \end{array}  $ <p><b>MP1</b>  Labelled cycle  OR  use of  <math>\Delta H = \sum \Delta H_{\text{combustion}} \text{ reactants} - \sum \Delta H_{\text{combustion}} \text{ products}</math> (1)</p> <p><b>MP2</b>  <math>\Delta H = (-2877 - (-2058 + (-890)))</math> (1)</p> <p><b>MP3</b>  = <b>+71</b> (kJ mol<sup>-1</sup>) (1)</p>	<p>Incorrect units</p>	<b>(3)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>1(a)(iv)</b>	$\text{C}_4\text{H}_{10} \rightarrow \text{C}_2\text{H}_6 + \text{C}_2\text{H}_4$ OR $\text{C}_4\text{H}_{10} \rightarrow \text{C}_4\text{H}_8 + \text{H}_2$ OR $\text{C}_4\text{H}_{10} \rightarrow 2\text{C}_2\text{H}_4 + \text{H}_2$ <p>ALLOW  Breakdown of multiple butanes</p> <p>Ignore state symbols, even if incorrect</p>	$\text{C}_4\text{H}_{10} \rightarrow \text{C}_3\text{H}_6 + \text{CH}_4$  Charged products eg $\text{C}_2\text{H}_5^+$  Free radicals eg $\text{C}_2\text{H}_5^\cdot$	<b>(1)</b>

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

Question Number	Acceptable Answers	Reject	Mark
<b>1(b)(ii)</b>	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	<b>(1)</b>

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

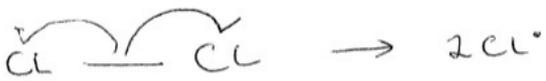
Question Number	Acceptable Answers	Reject	Mark
<b>1(c)(i)</b>	$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$ Allow multiples  Ignore state symbols even if incorrect		<b>(1)</b>

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

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

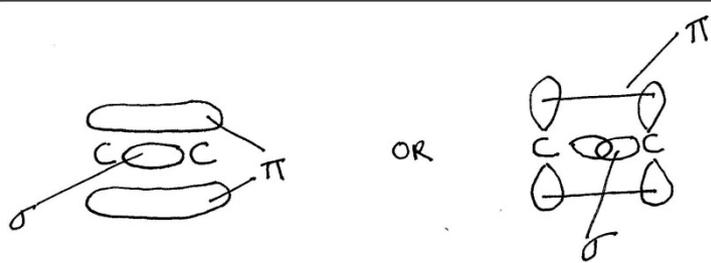
**(Total for question = 16 marks)**

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

Question Number	Acceptable Answers	Reject	Mark
<b>2(a)(ii)</b>	  Half arrows going from bond to Cl or just beyond <b>and</b> product $2\text{Cl}\cdot$ / $\text{Cl}\cdot + \text{Cl}\cdot$	Cl without •	<b>(1)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>2(iii)</b>	$\text{C}_2\text{H}_6 + \text{Cl}\cdot \rightarrow \text{C}_2\text{H}_5\cdot + \text{HCl}$ ALLOW Structural formulae e.g. $\text{CH}_3\text{CH}_3$ OR displayed  IGNORE Production of $\text{C}_2\text{H}_5\text{Cl}$ from $\text{C}_2\text{H}_5\cdot$ if first step is correct (1)  Propagation (1)  The second mark is independent of the first	$\text{C}_2\text{H}_5^+$	<b>(2)</b>

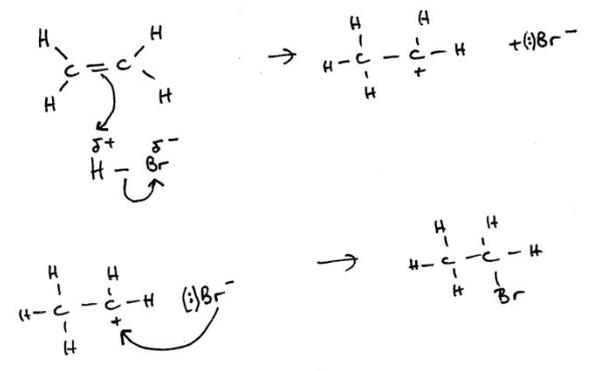
Question Number	Acceptable Answers	Reject	Mark
<b>2(iv)</b>	$C_2H_5\cdot + C_2H_5\cdot \rightarrow C_4H_{10}$  ALLOW Structural formulae e.g. $CH_3CH_2\cdot$ / $\cdot CH_3CH_2$ OR displayed  IGNORE $Cl\cdot + Cl\cdot \rightarrow Cl_2$	Methyl or propyl radicals	<b>(1)</b>

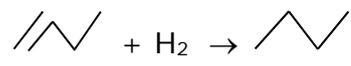
Question Number	Acceptable Answers	Reject	Mark
<b>2b(i)</b>	 <p> <math>\sigma</math> bond between C atoms shown as 2 overlapping orbitals/ one electron cloud/ single bond (1)         </p> <p> <math>\pi</math> bond above and below <math>\sigma</math> bond shown as two electron clouds/ overlapping p orbitals/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

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

Question Number	Acceptable Answers	Reject	Mark
<b>2(b)(iii)</b>	<p>From: Purple/ pink (solution) To: colourless (1)</p> $  \begin{array}{ccccccc}  & & \text{H} & & \text{H} & & \\  & &   & &   & & \\  \text{H} & - & \text{O} & - & \text{C} & - & \text{C} & - & \text{O} & - & \text{H} \\  & &   & &   & & \\  & & \text{H} & & \text{H} & &   \end{array}  $ <p>(1)</p> <p>Any orientation Don't penalise undisplayed OH</p> <p>Don't penalise bonds going to middle of undisplayed OH</p>	<p>To brown</p> <p>Molecular/ structural/ skeletal formulae</p> <p>C bonded to H of OH</p>	<b>(2)</b>

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

Question Number	Acceptable Answers	Reject	Mark
<b>2(b)(v)</b>	 <p>Dipole on HBr (1)</p> <p>Curly arrow from C=C double bond to H<sup>δ+</sup> of HBr <b>and</b> curly arrow from H-Br bond to Br (1)</p> <p>Correct intermediate with + charge (1)</p> <p>Curly arrow from Br<sup>-</sup> to C<sup>+</sup> and formula of product</p> <p>ALLOW Curly arrow from anywhere on Br, including the - sign or lone pair (which is optional) (1)</p>	Half arrows	<b>(4)</b>

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

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

Question Number	Acceptable Answers	Reject	Mark
<b>3 (a)(ii)</b>	(Contains) <b>only</b> (C—C) single bonds/ <b>only</b> $\sigma$ 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		<b>1</b>

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

Question Number	Acceptable Answers	Reject	Mark
<b>3</b> <b>(b)(ii)</b>	<p>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</p> <p>ALLOW Reverse argument for petrol / 'normal' diesel (eg crude oil is non-renewable)</p> <p>IGNORE Less impact on the environment / references to 'environmentally friendly' / less polluting / acid rain</p> <p>IGNORE References to 'global warming' or 'Greenhouse Effect' or 'climate change'.</p>		<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>3 (c)(i)</b>	<b>C<sub>9</sub>H<sub>20</sub></b> IGNORE Any structures drawn out		<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>3 (c)(ii)</b>	<p><b>First mark:</b> Any ONE of: -</p> <p>(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</p> <p>NOTE: ALLOW 'To produce fuel(s)'</p> <p style="text-align: right;"><b>(1)</b></p> <p><b>Second mark:</b> (High temperatures needed to) <b>break</b> (the C-C and / or C-H) <b>bonds</b> 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</p> <p>ALLOW To overcome the (high) activation energy / the reaction has a high activation energy / provide activation energy</p> <p>IGNORE C-C bond is stable References to increasing rate (of reaction) References to yield / equilibrium References to efficiency / producing less CO</p> <p style="text-align: right;"><b>(1)</b></p> <p><b>Marks are stand-alone</b></p>	<p><b>No 2nd mark if any of the following are mentioned:</b></p> <p><b>Separation</b> of molecules</p> <p>Breaking <b>intermolecular</b> forces</p> <p>References to (high) boiling temperatures / (high) boiling points</p> <p>References to (high) melting temperatures / (high) melting points</p>	<b>2</b>

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

Question Number	Acceptable Answers	Reject	Mark
<b>3 (d)(ii)</b>	$\text{C}_4\text{H}_{10}(\text{g}) + 6\frac{1}{2}\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 5\text{H}_2\text{O}(\text{l})$ OR $\text{C}_4\text{H}_{10}(\text{g}) + 6.5\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 5\text{H}_2\text{O}(\text{l})$ OR $\text{C}_4\text{H}_{10}(\text{g}) + \frac{13}{2}\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 5\text{H}_2\text{O}(\text{l})$ OR $2\text{C}_4\text{H}_{10}(\text{g}) + 13\text{O}_2(\text{g}) \rightarrow 8\text{CO}_2(\text{g}) + 10\text{H}_2\text{O}(\text{l})$ OR Any other correct multiples  Correct species <span style="float: right;"><b>(1)</b></span>  Balancing and state symbols correct <span style="float: right;"><b>(1)</b></span>  2 <sup>nd</sup> mark is dependent on the 1 <sup>st</sup> mark	$\text{H}_2\text{O}(\text{g})$ $\text{C}_4\text{H}_{10}(\text{l})$	<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>3(d)(iii)</b>	$C_4H_{10} + 4\frac{1}{2}O_2 \rightarrow 4CO + 5H_2O$ 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		<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>3(d)(iv)</b>	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'	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>3(e)(i)</b>	<p><b>First mark</b>  Calculation of the sum of the <math>M_r</math> values of all the products = <b>217.8</b>  If using Br = 80, <math>M_r</math> = 218 <b>(1)</b></p> <p><b>Second mark</b>  Calculation of % atom economy using value of total <math>M_r</math></p> <p><math display="block">\left[ = \frac{136.9}{217.8} \text{ (x 100\%)} \right]</math></p> <p>= 62.856 (%) <b>(1)</b></p> <p>NOTE  If using Br = 80, final answer = 62.844 (%)</p> <p>ALLOW  ECF for the 2nd mark on an incorrect total <math>M_r</math> value</p> <p>IGNORE  sf except 1 sf</p> <p>Correct answer with no working <b>(2)</b>  <b>Check rounding of answer</b></p> <p><b>NOTE</b>  <b>If one error only is made, (1) mark awarded</b></p>	<p>For <math>M_r</math> = <b>217.8</b>,  <b>62.8%</b> (no 2nd mark, as this is a rounding error)</p>	<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>*3(e)(ii)</b>	<p><b>First mark:</b>  <b>Initiation</b> (step) <b>(1)</b></p> <p><b>Second mark:</b>  <math>\text{Br}-\text{Br} \rightarrow \text{Br}\bullet + \text{Br}\bullet /</math>  <math>\text{Br}_2 \rightarrow 2\text{Br}\bullet</math> <b>(1)</b></p> <p><b>Third mark:</b>  <b>Propagation</b> (steps) <b>(1)</b></p> <p><b>Fourth and fifth marks:</b>  <math>\text{Br}\bullet + \text{C}_4\text{H}_{10} \rightarrow \text{C}_4\text{H}_9\bullet + \text{HBr}</math> <b>(1)</b>  <math>\text{Br}_2 + \text{C}_4\text{H}_9\bullet \rightarrow \text{C}_4\text{H}_9\text{Br} + \text{Br}\bullet</math> <b>(1)</b></p> <p>Allow in either order</p> <p><b>Sixth mark:</b>  <b>Termination</b> (step(s)) <b>(1)</b></p> <p><b>Seventh mark:</b>  <b>Any one of</b>  <math>\text{Br}\bullet + \text{Br}\bullet \rightarrow \text{Br}_2</math>  OR  <math>\text{C}_4\text{H}_9\bullet + \text{Br}\bullet \rightarrow \text{C}_4\text{H}_9\text{Br}</math>  OR  <math>\text{C}_4\text{H}_9\bullet + \text{C}_4\text{H}_9\bullet \rightarrow \text{C}_8\text{H}_{18}</math> <b>(1)</b></p>	<p>H• (the fourth and fifth marks cannot be awarded if H• appears in <b>either</b> propagation step)</p>	<b>7</b>

**(Total for Question = 21 marks)**