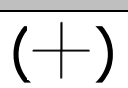
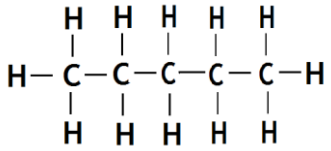
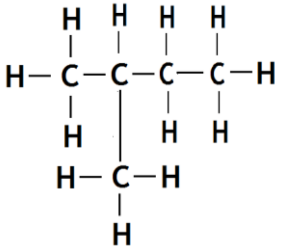
Question number	Answer	Additional Guidance	Mark
1(a)(i)	• C_5H_{12}		**1**

Question number	Answer	Additional Guidance	Mark
1(a)(ii)	**B** 		**1**

Question number	Answer	Additional Guidance	Mark
1(b)	**C** (2-methylbutane)		**1**

Question number	Answer	Additional Guidance	Mark
1(c)	 (1)  (1)		**2**

(Total for Question 1 = 5 marks)

Question number	Acceptable Answer	Additional guidance	Mark
2(a)	An explanation that makes reference to the following points • the decrease in temperature causes a decrease in rate (1) • because fewer collisions between reactant molecules will have energy ≥ activation energy (1) • and the decrease in temperature causes a shift in equilibrium (position) to the reactants / lowers the yield of hydrogen / shifts the equilibrium (position) to the left (1) • because the (forward) reaction is endothermic (1)	Allow the back reaction is exothermic	**4**

Question number	Answer	Additional Guidance	Mark
2(b)	An explanation that makes reference to the following points • the increase in pressure causes a shift in equilibrium (position) to the reactants / lowers the yield of hydrogen/ shifts the equilibrium (position) to the left (1) • because there are fewer gas moles on the reactant side (1)	Allow molecules for moles	**2**

Question number	Answer	Additional Guidance	Mark
2(c)	**C** $\left(K_c = \frac{[CO][H_2]^3}{[CH_4][H_2O]}\right)$		**1**

(Total for Question 2 = 7 marks)

Question number	Acceptable Answer	Additional Guidance	Mark
3(a)(i)	• writing of correct chemical equation	$CH_3CH_2SH + 4.5O_2 \rightarrow 2CO_2 + SO_2 + 3H_2O$ Accept multiples Ignore state symbols	**1**

Question number	Acceptable Answer	Additional Guidance	Mark
3(a)(ii)	• selection of correct values from table and relevant numbers of bonds for reactant molecules (1) • selection of correct values from table and relevant numbers of bonds for product molecules (1) • calculation with correct final answer with sign (1)	<u>Example of calculation:</u> bond enthalpies of reactants = 347 + 5(413) + 259 + 364 + 4.5(498) (= 5276) bond enthalpies of products = 4(805) + 2(523) + 6(464) (= 7050) $\Delta_c H$ (= 5276 – 7050) = –1774 (kJ mol^{-1}) Allow TE from (a)(i) to (a)(ii) and within (a)(ii) calculation Correct final answer with no working scores full marks	**3**

Question number	Answer	Additional Guidance	Mark
3(b)(i)	**A** (O_2(g) is an element)		**1**

Question number	Acceptable Answer	Additional Guidance	Mark
3(b)(ii)	• substitution of correct values (in equation or Hess cycle), with coefficients and signs (1) • correct answer with sign (1)	<u>Example of calculation:</u> ($\Sigma\Delta_f H$ (products) – $\Sigma\Delta_f H$ (reactants)) 2(–394) + (–297) + 3(–242) – (–46) = –1765 (kJ mol^{-1}) Correct final answer with no working scores full marks	**2**

Question number	Acceptable Answer	Additional Guidance	Mark
3(c)	An answer that makes reference to the following point: • bond energies vary in different (chemical) environments		**1**

(Total for Question 3 = 8 marks)

Question number	Acceptable Answer	Additional Guidance	Mark
4(a)	An answer that makes reference to the following points: • -ane means molecule is saturated but a cycloalkane does not have the same general formula as an alkane (1) • cyclobutane does have the general formula C_nH_{2n} but it is not an alkene (1)	Accept is an alkane for molecule is saturated Accept does not contain (C=C) double bonds Allow 1 mark for the two errors in the statements without discussion of the merits of the statements	**2**

Question number	Acceptable Answer	Additional Guidance	Mark
4(b)	• $C_4H_6 + H_2 \rightarrow C_4H_8$	Accept skeletal formulae Ignore state symbols	**1**

Question number	Acceptable Answer	Additional Guidance	Mark
4(c)	• $C_{10}H_{14}$		**1**

Question number	Answer	Additional Guidance	Mark
4(d)	**D** (a species with an odd number of outer electrons)		**1**

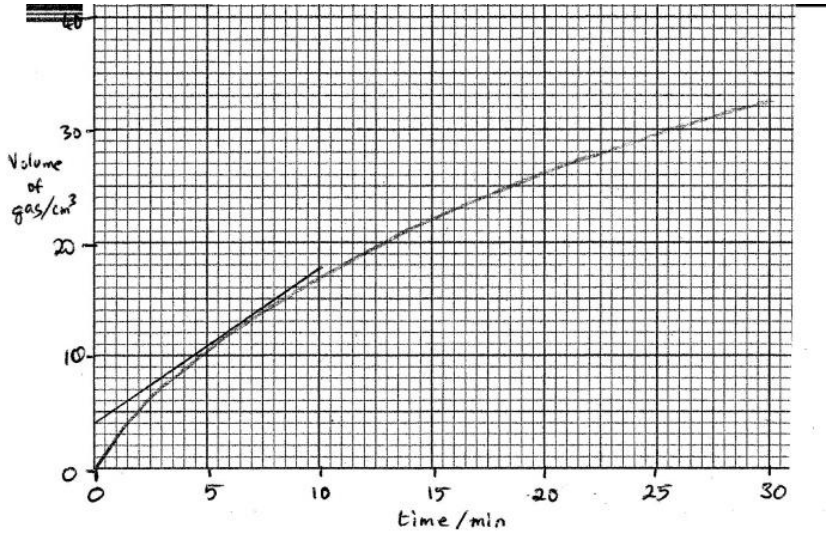
Question number	Acceptable Answer	Additional Guidance	Mark
4(e)(i)	• $Br_2 \rightarrow 2Br\bullet$ (1) • $C_2H_6 + Br\bullet \rightarrow C_2H_5\bullet + HBr$ (1) • $C_2H_5\bullet + Br_2 \rightarrow C_2H_5Br + Br\bullet$ (1) • $C_2H_5\bullet + Br\bullet \rightarrow C_2H_5Br$ (1)	Max 3 if equations in the wrong order Penalise omission of radical dots once only	**4**

Question number	Answer	Additional Guidance	Mark
4(e)(ii)	**D** (homolytic fission and radical substitution)		**1**

Question number	Acceptable Answer	Additional Guidance	Mark
4(e)(iii)	An explanation that makes reference to the following points: • C_4H_{10} is formed when two C_2H_5• radicals react (1) • but C_3H_8 cannot be formed because there are no CH_3• radicals (1)		**2**

(Total for Question 4 = 12 marks)

Question number	Answer	Additional Guidance	Mark
5(a)	**C** $(Ni(s) + 2HCl(aq) \rightarrow NiCl_2(aq) + H_2(g))$		**1**

Question number	Acceptable Answer	Additional Guidance	Mark
5(b)(i)	• drawing of tangent (1) • rate at t_1 (6.5 min) (1) • calculation of rate and units (1)	 Example of calculation rate = $\frac{18 - 4}{10}$ 1.4 cm^3 min^{-1} Allow a final answer between 1.3 and 1.5 cm^3 min^{-1}	**3**

Question number	Acceptable Answer	Additional Guidance	Mark
5(b)(ii)	An answer that makes reference to the following points: • The hydrogen ion concentration decreases / there are fewer hydrogen ions present (1) • therefore less frequent collisions (between them) (1)	Allow at t_2 there are fewer reactant particles	**2**

<table>
<tr><th>Question number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*5c</td>
<td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td>
<td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td>
<td></td>
</tr>
</table>

	Indicative content: • repeat the experiment (done with nichrome A) using nichrome B (containing the same masses of nickel and chromium) • with other variables unchanged • compare the volume of hydrogen gas collected at t_1 (or a specified time) in both experiments **or** comparing the rate of reaction at a particular time **or** comparing the tangent/ slope at a particular time • if the experiment with nichrome B gives a greater volume (of gas) at a specified time (eg t_1) / greater rate then copper may act as a catalyst • after the experiment with nichrome B is complete, remove the copper, (wash and dry it) and measure its mass • if the mass is unchanged <u>and</u> there is a greater rate, then copper has acted as a catalyst	Allow reference to controlling of one variable e.g. concentration of acid, temperature Do not award mark if total volume is compared	**6**

(Total for Question 5 = 12 marks)

Question number	Acceptable Answer		Additional guidance	Mark
6(a)	• calculation of mass of carbon	(1)	Example of calculation: mass of C = $\frac{2.086 \times 12}{44}$ = 0.569 g	
	• calculation of mass of hydrogen	(1)	mass of H = $\frac{0.851 \times 2}{18}$ = 0.0946 g	
	• calculation of mass of oxygen and division of masses by atomic masses	(1)	mass of O = 0.815 – (0.569 + 0.0946) = 0.151 g and $\frac{\text{C}}{12}$ $\frac{0.569}{1}$ $\frac{\text{H}}{1}$ $\frac{0.0946}{16}$ $\frac{\text{O}}{16}$ $\frac{0.151}{1}$	
	• calculation of (whole number) mole ratio	(1)	0.0474 : 0.0946 : 0.0095 **or** 5 : 10 : 1	
	• writing of empirical formula	(1)	$C_5H_{10}O$	**5**

Question number	Acceptable Answer	Additional Guidance	Mark
6(b)	• selection of $pV = nRT$ and rearrangement to calculate n (1) • conversions of temperature and volume values to appropriate units (1) • substitution of values and calculation of amount of substance (1) • rearrangement of number of moles = mass of **Y** ÷ Molar mass and substitution of values and calculation of M including the units (1)	Example of calculation: $pV = nRT \therefore n = pV \div RT$ $V = 92 \times 10^{-6} = 9.2 \times 10^{-5}$ m^3 and $T = 110 + 273 = 383$ K $n = \frac{1.01 \times 10^5 \times 9.2 \times 10^{-5}}{8.31 \times 383} = 2.9195 \times 10^{-3}$ mol $M = m \div n = 0.250 \div 2.9195 \times 10^{-3} = 85.6$ g mol^{-1}	**4**

Question number	Acceptable Answer	Additional Guidance	Mark
6(c)	An answer that makes reference to the following point: • (molecular formula = empirical formula so) any correct structural formula (including displayed and skeletal) for $C_5H_{10}O$	likely examples are $CH_3COCH_2CH_2CH_3$ and isomers $CH_3CH_2CH_2CH_2CHO$ and isomers cyclic alcohols e.g. cyclopentanol and isomers alkenols e.g. pent-3-ene-1-ol and isomers	**1**

(Total for Question 6 = 10 marks)

Question number	Acceptable Answer	Additional Guidance	Mark
7(a)(i)	• calculation of temperature change (1) • substitution into Q = mcΔT (1) • correct answer in kJ to 3 sf (1)	<u>Example of calculation:</u> ΔT = 54.8 – 18.6 = (+)36.2(ºC) Q = 150.0 × 4.18 × 36.2 (= 22697.4 J) Q = 22.7 kJ Ignore sign	**3**

Question number	Acceptable Answer	Additional Guidance	Mark
7(a)(ii)	• it prevents evaporation of the pentane/fuel		**1**

Question number	Acceptable Answer	Additional Guidance	Mark
7(b)	• equation containing C and H_2O as products (1) • equation balanced (1)	$C_8H_{18} + 4.5O_2 \rightarrow 8C + 9H_2O$ Accept other equations containing either or both CO and CO_2 as products as well as C e.g. $C_8H_{18} + 7.5O_2 \rightarrow 4C + 2CO + 2CO_2 + 9H_2O$ Accept multiples Do not award marks for answers with H_2 as a product Ignore state symbols	**2**

Question number	Acceptable Answer	Additional Guidance	Mark
7(c)	• calculation of amount of methanol (1) • substitution into $\Delta H = -\frac{Q}{n}$ and conversion to kJ (1) • answer in kJ mol^{-1} (1)	Example of calculation: $n = \frac{0.717}{32.0} = 0.022406$ mol $\Delta H = -\frac{8960}{0.022406} = 399888$ J = 399.888 kJ $\Delta H = -400$ (kJ mol^{-1}) Must have negative sign and be in kJ mol^{-1} (no need to state units) Only accept - 400	**3**

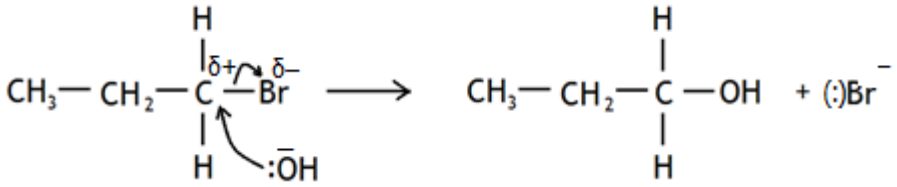
Question number	Acceptable Answer	Additional Guidance	Mark
7(d)	An answer that makes reference to the following points: • the value would be more negative / closer to the true value (1) • justification: because copper is a better conductor of heat energy than glass (1)	Allow the magnitude of $\Delta_c H$ would be greater Reject just $\Delta_c H$ would be greater	**2**

Question number	Acceptable Answer	Additional Guidance	Mark
7(e)	An answer that makes reference to the following points: • the alcohols have fewer carbon/hydrogen atoms (than the alkanes) (1) • the alcohols already contain oxygen (that cannot be combusted) / already partially oxidised (1)	Allow reverse arguments	**2**

(Total for Question 7 = 13 marks)

Question number	Answer	Additional Guidance	Mark
8(a)	**C** $((CH_3)_3CCl)$		**1**

Question number	Acceptable Answer	Additional Guidance	Mark
8(b)(i)	An explanation that makes reference to the following points: • the decreasing order of reactivity is $CH_3CH_2CH_2I > CH_3CH_2CH_2Br > CH_3CH_2CH_2Cl$ (1) • because the weakest bond to be broken is C–I / the strongest bond is C–Cl **OR** therefore the least energy is needed to break C–I / the most energy is needed to break C–Cl (1)	Allow reverse argument	**2**

Question number	Acceptable Answer	Additional Guidance	Mark
8(b)(ii)	 • partial charges on the atoms in the C–Br bond (1) • curly arrow from lone pair on the O of OH^- ion to δ+ C and curly arrow from C–Br bond to Br atom (1) • structure of propan-1-ol product and formula of Br^- ion (1)	If S_N1 mechanism is shown then allow MP1 and MP3 only	**3**

Question number	Acceptable Answer	Additional Guidance	Mark
8(c)(i)	An answer that makes reference to the following points: • **P** is propan-1-ol / $CH_3CH_2CH_2OH$ (1) Justification: • the M_r value of propan-1-ol is 60.0, therefore the peak at m/z = 60 is due to the molecular ion peak (1) • and the peak at m/z = 29 is due to $^+C_2H_5$ (formed from propan-1-ol) (1)		**3**

Question number	Acceptable Answer	Additional Guidance	Mark
8(c)(ii)	An explanation that makes reference to the following points: • product **P** has a broad absorption centred on 3400 cm^{-1} (1) • which is in the range 3750-3200 cm^{-1} for (O-H in) alcohols (1) • and product **Q** has an absorption close to the 1669-1645 cm^{-1} range (1) • which is due to C=C present in alkenes (1)	<u>Alternatives for 3rd and 4th marks</u> Allow absorption close to 3095-3010 cm^{-1} range Due to C-H bond in alkene	**4**

(Total for Question 8 = 13 marks)

TOTAL FOR PAPER = 80 MARKS