

CHEMISTRY AS PAPER 2 MARKSCHEME

Question Number	Answer	Additional Guidance	Mark
1(a)		Every atom and every bond must be shown	1
1(b)	C_2H_5		1
1(c)	B		1
1(d)	C		1
1(e)	<ul style="list-style-type: none"> re-arrangement of $pV = nRT$ equation conversion of volume and substitution evaluation of number of moles of alkane calculation of M_r, using number of moles and mass of alkane to identify it 	<p>Correct answer, no working scores 4 marks</p> <p>Example of calculation</p> $n = \frac{pV}{RT}$ $= \frac{100\,000 \times (83 \times 10^{-6})}{8.31 \times 425}$ $= 0.00235... \text{ (moles)}$ $M_r = 0.235 / 0.00235... = 99.99 \text{ or } 100$ <p>i.e. this is heptane</p>	4

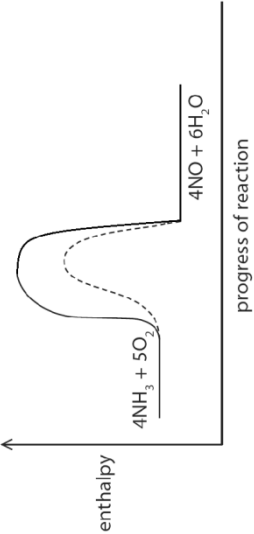
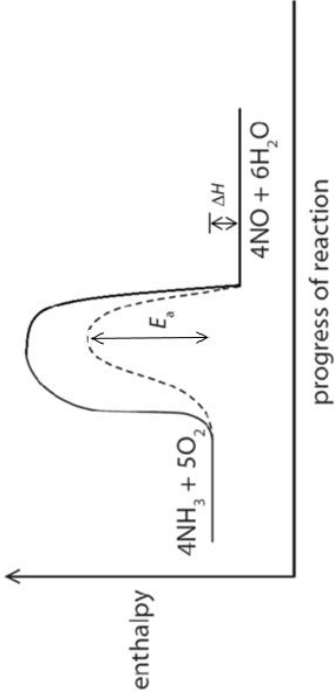
(Total for Question 1 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • (all equations) show oxygen/O₂ as a reactant/on the left (1) • (all) $\Delta_r H^\ominus$ values are negative / (all) reactions are exothermic (1) 		2
2(b)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • reaction 2 is not, because there is more than 1 product (1) • reaction 3 is not, because 2 moles of product are formed (1) 	Accept because methane/CH ₄ is not an element	2
2(c)	B		1
2(d)	D		1

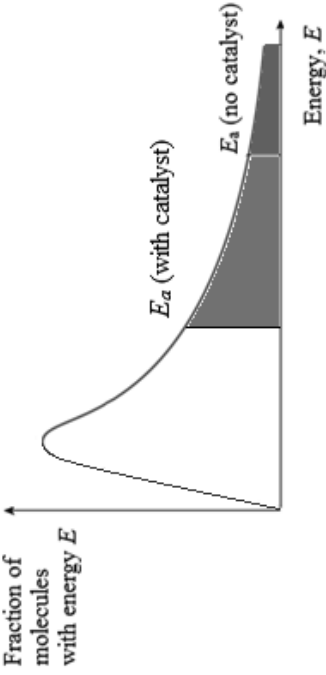
(Total for Question 2 = 6 marks)

Question Number	Answer	Additional Guidance	Mark												
*3(a)	<p>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table border="1" data-bbox="595 1379 991 1839"> <thead> <tr> <th data-bbox="595 1626 810 1839">Number of indicative marking points seen in answer</th> <th data-bbox="595 1379 810 1626">Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr> <td data-bbox="810 1626 847 1839">6</td> <td data-bbox="810 1379 847 1626">4</td> </tr> <tr> <td data-bbox="847 1626 884 1839">5-4</td> <td data-bbox="847 1379 884 1626">3</td> </tr> <tr> <td data-bbox="884 1626 920 1839">3-2</td> <td data-bbox="884 1379 920 1626">2</td> </tr> <tr> <td data-bbox="920 1626 957 1839">1</td> <td data-bbox="920 1379 957 1626">1</td> </tr> <tr> <td data-bbox="957 1626 991 1839">0</td> <td data-bbox="957 1379 991 1626">0</td> </tr> </tbody> </table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0	<p>Guidance on how the mark scheme should be applied:</p> <p>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).</p> <p>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).</p>	6
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5-4	3														
3-2	2														
1	1														
0	0														

Question Number	Answer	Additional Guidance	Mark								
*3(a) cont.	<p>The following table shows how the marks should be awarded for structure and lines of reasoning.</p> <table border="1" data-bbox="395 954 938 1839"> <thead> <tr> <th data-bbox="395 1328 576 1839"></th> <th data-bbox="395 954 576 1328">Number of marks awarded for structure of answer and sustained line of reasoning</th> </tr> </thead> <tbody> <tr> <td data-bbox="576 1328 756 1839">Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td> <td data-bbox="576 954 756 1328">2</td> </tr> <tr> <td data-bbox="756 1328 863 1839">Answer is partially structured with some linkages and lines of reasoning</td> <td data-bbox="756 954 863 1328">1</td> </tr> <tr> <td data-bbox="863 1328 938 1839">Answer has no linkages between points and is unstructured</td> <td data-bbox="863 954 938 1328">0</td> </tr> </tbody> </table> <p>Indicative content:</p> <ul data-bbox="1050 891 1359 1794" style="list-style-type: none"> • temperature decrease lowers the rate of the reaction • because there are fewer molecules/particles with $E \geq E_a$ • and therefore there are fewer <u>successful collisions per second</u> • temperature decrease increases the yield (of the product) • because the (forward) reaction is exothermic • lower rate and increased yield are opposing factors and it is not possible to tell which has greater effect on overall yield in a given time. 		Number of marks awarded for structure of answer and sustained line of reasoning	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	<p>Accept slows down the reaction</p> <p>Accept shifts the position of equilibrium to the right/in forward direction</p>	
	Number of marks awarded for structure of answer and sustained line of reasoning										
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2										
Answer is partially structured with some linkages and lines of reasoning	1										
Answer has no linkages between points and is unstructured	0										

Question Number	Answer	Additional Guidance	Mark
3(b)(i)	 <ul style="list-style-type: none"> curve starting at reactants level, ending at products level, and peaking lower than original curve (1) 		1
3(b)(ii)	 <ul style="list-style-type: none"> $\Delta_r H$ shown as the approximately vertical distance between reactants and products (1) E_a shown as the approximately vertical distance between reactants and peak of drawn curve for catalysed reaction (1) 	ecf from candidate's curve	2
3(c)	$K_c = \frac{[\text{NO}(\text{g})]^4 [\text{H}_2\text{O}(\text{g})]^6}{[\text{NH}_3(\text{g})]^4 [\text{O}_2(\text{g})]^5}$	State symbols not essential	1

(Total for Question 3 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
4 (a) (i)	 <p>Fraction of molecules with energy E</p> <p>Energy, E</p> <p>E_a (with catalyst)</p> <p>E_a (no catalyst)</p>	<p>Line needs to be to the left of E_a (no catalyst) but to the right of the hump in the curve</p> <p>Shading not required but can be included and used in (a)(ii)</p>	1
4 (a) (ii)	<p>An explanation that makes reference to the following points: (1)</p> <ul style="list-style-type: none"> the area under the curve to the right of the activation energy represents the fraction of molecules that have $E \geq E_a$ (1) the area under the curve to the right of E_a (with catalyst) is greater than the area under the curve to the right of E_a (no catalyst) (1) (therefore) there are more <u>successful collisions</u> (<u>per second per unit vol.</u>) (1) 	<p>Accept description that involves shaded areas under the curve</p> <p>Accept more molecules have enough energy to react</p>	3

Question Number	Answer	Additional Guidance	Mark
4 (b)	<ul style="list-style-type: none"> • calculation of total bonds formed (1) • re-arrangement of $\Delta_r H$ expression (1) • evaluation of final answer (1) 	<p>Correct answer, no working scores 3 marks</p> <p><u>Example of calculation</u></p> $\Sigma(\text{bonds formed}) = E(\text{N}\equiv\text{N}) + 3E(\text{H}-\text{H})$ $= 944 + (3 \times 436) = 2252 \text{ (kJ mol}^{-1}\text{)}$ $\Delta_r H^\ominus = \Sigma(\text{bonds broken}) - \Sigma(\text{bonds formed}),$ <p>so $\Sigma(\text{bonds broken}) = \Sigma(\text{bonds broken}) - \Delta_r H^\ominus$</p> $6E(\text{N}-\text{H}) = 2252 - (-92)$ $E(\text{N}-\text{H}) = (+) 391 \text{ (kJ mol}^{-1}\text{)}$ <p>Accept 390.7</p>	3

(Total for Question 4 = 7 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)	<ul style="list-style-type: none"> • calculation of temperature change and substitution into $Q = mc\Delta T$ (1) • conversion to kJ (1) • calculation of amount of copper(II) sulfate (1) • use of $\Delta H = -\frac{Q}{n}$ (1) • correct answer with sign and to 3. s.f (1) 	<p>Allow ecf for steps in calculation; including for final answer dependent on rounding in steps of the calculation.</p> <p>Correct answer with sign, to 3.s.f and no working scores 5 marks</p> <p>Mark consequentially on incorrect temperature change</p> <p><u>Example of calculation</u></p> <p>$Q = 50.0 \times 4.18 \times 7.2 \text{ (J)} = 1504.8 \text{ (J)}$</p> <p>$Q = \frac{1504.8}{1000} = 1.5048 \text{ (kJ)}$</p> <p>moles of copper(II) sulfate $= 4.70 \div 159.6$ $= 0.029449 \text{ mol}$</p> <p>$\Delta H = -\frac{Q}{n} = -1.5048 \div 0.029449$ $= (-51.099) = -51.1 \text{ (kJ mol}^{-1}\text{)}$</p>	5

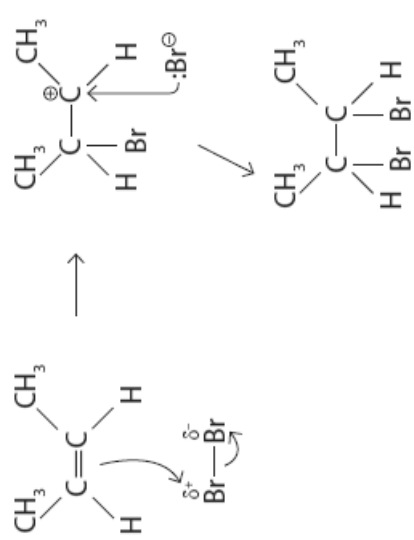
Question Number	Answer	Additional Guidance	Mark
5(b)	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> record temperature at timed intervals (after adding the solid) (1) plot these temperature values (on a graph) (1) extrapolate the line of best fit to the time of adding the solid (1) 		3
5(c)	<ul style="list-style-type: none"> use of Hess cycle or expression e.g. $\Delta_r H = \Delta_r H_2 - \Delta_r H_1$ or $\Delta_r H = \Delta H_{\text{solution}}(\text{anhydrous}) - \Delta H_{\text{solution}}(\text{hydrated})$ (1) correct final answer with sign ($-49.5 \text{ kJ mol}^{-1}$) (1) 	Correct answer with sign and no working scores 2 marks	2
5(d)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> (the pale blue colour shows that) anhydrous copper (II) sulfate is partially hydrated (1) therefore less anhydrous copper (II) sulfate reacts with water / some of the (blue) solid reacts endothermically (1) therefore less thermal energy transferred / heat energy released during experiment or (experimental value) has a smaller negative value (1) 		3

(Total for Question 5 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)(i)	<ul style="list-style-type: none"> (pale) yellow (1) 		1
6(a)(ii)	<ul style="list-style-type: none"> conversion to seconds and use of $\frac{1}{\text{time in sec}}$ (1) divide by lowest to get whole number ratio (1) 	<p>Example of calculation</p> $\frac{1}{1250} : \frac{1}{555} : \frac{1}{5}$ <p>or $8.00 \times 10^{-4} : 1.80 \times 10^{-3} : 0.20$</p> <p>1 : 2.25 : 250</p>	2
6(a)(iii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> the C–Cl bond is shorter than the C–I bond / the Cl atom is smaller than the I atom (1) therefore, the C–Cl bond is stronger than the C–I bond (1) therefore, the C–Cl bond needs more energy to break, and so the reaction is slower (1) 	Allow reverse argument throughout	3

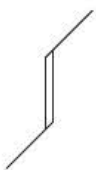
Question Number	Answer	Additional Guidance	Mark
6(b)(i)	D		1
6(b)(ii)	<ul style="list-style-type: none"> • H/ (CH₃)₃ CBr (1) • because C of C-Br is joined to 3 alkyl groups/joined to 3 carbon atoms (1) 		2
6(b)(iii)	<ul style="list-style-type: none"> • number prefix used should be as low as possible / bromine atom is on the first carbon atom of the chain (1) 		1

(Total for Question 6 = 10 marks)

Question Number	Answer	Mark	Additional Guidance
7 (a)	(red-)brown to colourless	(1)	Allow orange for red-brown Do not allow clear for colourless
7 (b) (i)	electrophilic (addition)	(1)	
7 (b) (ii)		4	
	<ul style="list-style-type: none"> partial charges on Br atoms (1) curly arrow from C=C bond to ($\delta+$) Br atom AND curly arrow from Br-Br bond to ($\delta-$) Br atom (1) structure of carbocation with + charge (1) curly arrow from Br^- to C with + charge AND structure of 1, 2-dibromobutane product (1) 		Accept cyclic bromonium ion with + charge shown in centre of ring

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	<ul style="list-style-type: none"> • calculation of % by mass of Br (1) • evaluation of number of moles of C, H, and Br (1) • final empirical formula based on whole number ratio (1) 	<p><u>Example of calculation</u></p> $\%Br = 100 - 34.9 - 6.60 = 58.5\%$ $C \frac{34.9}{12} = 2.91 \quad H \frac{6.60}{1} = 6.60 \quad Br \frac{58.5}{79.9} = 0.732$ $\frac{2.91}{0.732} = 3.98 \quad \frac{6.60}{0.732} = 9.02 \quad \frac{0.732}{0.732} = 1$ <p>i.e. C₄H₉Br</p>	3
7(c)(ii)	<ul style="list-style-type: none"> • 2-bromobutane (1) 		1

Question Number	Answer	Additional Guidance	Mark
7 (d)	<p>An answer that includes at least one similarity and one difference to gain maximum marks:</p> <p>Similarities:</p> <ul style="list-style-type: none"> • both involve the overlap of two (atomic) orbitals (each containing a single electron) (1) • both involve an electrostatic attraction between a <u>bonding</u> pair of electrons and two nuclei (1) <p>Differences:</p> <ul style="list-style-type: none"> • the σ bond represents electron density/electrons between the two carbon atoms/nuclei/end-on overlapping of atomic orbitals (1) • the π bond represents electron density/electrons above and below the σ bond/ sideways overlapping of orbitals (1) • the σ bond is formed by the overlap of a single lobe from one (atomic) orbital with a single lobe from the another (atomic) orbital (1) • the π bond is formed by the overlap of two lobes from one (atomic) orbital with two lobes of another (atomic) orbital (1) 	<p>Accept electrostatic attraction between a <u>shared</u> pair of electrons and two nuclei</p> <p>Accept end-to-end/head-on/axial overlapping</p>	3

Question Number	Answer	Additional Guidance	Mark
7 (e)	 <p>(1)</p>	Do not accept a structural or displayed formula.	1

(Total for Question 7 = 14 marks)

Question Number	Answer	Additional Guidance	Mark
8(a)	• P $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$	Accept displayed formulae	3
	• Q $(\text{CH}_3)_2\text{CHCH}(\text{OH})\text{CH}_3$		
	• R $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{CH}_3$		
8(b)	• $m/z = 45$ is due to $\text{CH}_3\text{CH}(\text{OH})^+$	Penalise the lack of a plus sign once only	3
	• $m/z = 43$ is due to $\text{CH}_3\text{CH}_2\text{CH}_2^+$		
	• therefore the structure is $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$		
8(c)(i)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • Y is a ketone because the spectrum contains an absorption for C=O (carbonyl group) $1700 - 1720 \text{ cm}^{-1}$ (1) • Z is a carboxylic acid because the spectrum contains absorptions for C=O $1725-1700 \text{ cm}^{-1}$ AND O-H (acids) $3300 - 2500 \text{ cm}^{-1}$ (1) 	<p>Absence of bonds or absence of wavenumber ranges maximum 1</p> <p>Allow values within the ranges</p>	2


Question Number	Answer	Additional Guidance	Mark
8(c) (ii)	<ul style="list-style-type: none"> • calculation of mass of carbon from mass of CO₂ (1) • calculation of mass of hydrogen from mass of H₂O (1) • subtraction to find mass of O, and evaluation of number of moles of C, H and O (1) • confirm whole number ratio (1) 	<p><u>Example of calculation</u></p> <p>Mass of carbon = $(\frac{12}{44} \times 5.89) = 1.606 \text{ g}$</p> <p>Mass of hydrogen = $(\frac{2}{18} \times 2.44) = 0.271 \text{ g}$</p> <p>Mass of oxygen = $2.74 - 1.606 - 0.271$ $= 0.863 \text{ g}$</p> <p>C $\frac{1.606}{12} = 0.134$</p> <p>H $\frac{0.271}{1} = 0.271$</p> <p>O $\frac{0.863}{16} = 0.054$</p> <p>Ratio = $2.48 : 5.02 : 1 = 5 : 10 : 2$</p>	4

(Total for Question 8 = 12 marks)

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