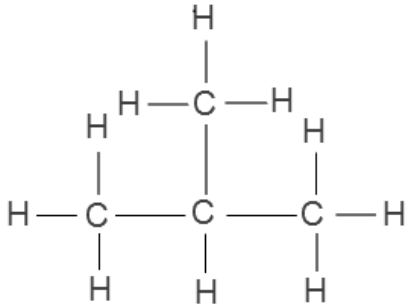
## CHEMISTRY AS PAPER 2 MARKSCHEME

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **1(a)** |  (1) | Every atom and every bond must be shown | **1** |
| **1(b)** | $C_2H_5$ (1) | | **1** |
| **1(c)** | B | | **1** |
| **1(d)** | C | | **1** |
| **1(e)** | • re-arrangement of $pV = nRT$ equation (1)<br>• conversion of volume and substitution (1)<br>• evaluation of number of moles of alkane (1)<br>• calculation of $M_r$, using number of moles and mass of alkane to identify it (1) | Correct answer, no working scores 4 marks<br><br>Example of calculation<br>$n = \frac{pV}{RT}$<br><br>$= \frac{100\,000 \times (83 \times 10^{-6})}{8.31 \times 425}$<br><br>= 0.00235… (moles)<br><br>Mr = 0.235 / 0.00235… = 99.99 **or** 100<br>i.e. this is heptane | **4** |

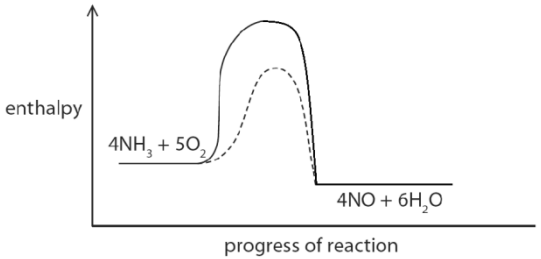
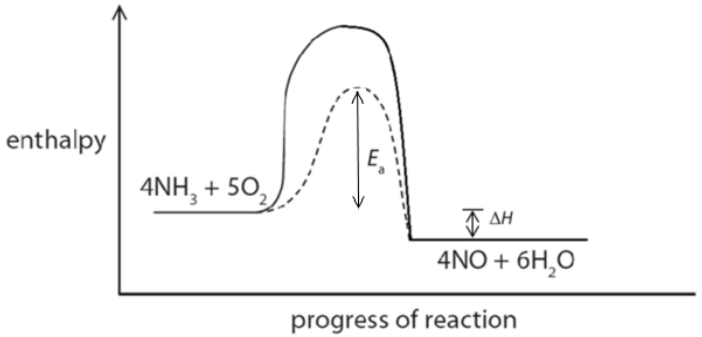
**(Total for Question 1 = 8 marks)**

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **2(a)** | An answer that makes reference to the following points:<br>• (all equations) show oxygen/$O_2$ as a reactant/on the left (1)<br>• (all) $\Delta_r H^{\ominus}$ values are negative /(all) reactions are exothermic (1) | | **2** |
| **2(b)** | An answer that makes reference to the following points:<br>• reaction 2 is not, because there is more than 1 product (1)<br>• 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** |

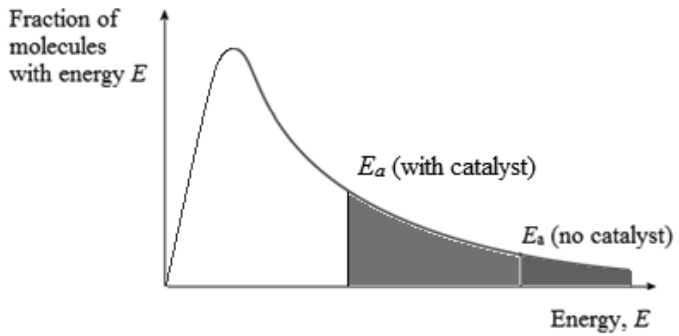
**(Total for Question 2 = 6 marks)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*3(a)</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.<br><br>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.<br><br>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></td><td>Guidance on how the mark scheme should be applied:<br><br>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).<br><br>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>6</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*3(a) cont.</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.<br><br>
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></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>
<br>Indicative content:<br><br>
• temperature decrease lowers the rate of the reaction<br>
• because there are fewer molecules/particles with $E \geq E_a$<br>
• <u>and</u> therefore there are fewer <u>successful</u> collisions <u>per second</u><br>
• temperature decrease increases the yield (of the product)<br>
• because the (forward) reaction is exothermic<br>
• 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.</td><td>Accept slows down the reaction<br><br>Accept shifts the position of equilibrium to the right/in forward direction</td><td></td></tr>
</table>

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **3(b)(i)** |  <br>• curve starting at reactants level, ending at products level, and peaking lower than original curve (1) | | **1** |
| **3(b)(ii)** |  <br>• $\Delta_r H$ shown as the approximately vertical distance between reactants and products (1)<br>• $E_a$ 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)** | $K_c = \frac{[NO(g)]^4[H_2O(g)]^6}{[NH_3(g)]^4[O_2(g)]^5}$ (1) | State symbols not essential | **1** |

**(Total for Question 3 = 10 marks)**

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **4(a)(i)** |  (1) | Line needs to be to the left of $E_a$ (no catalyst) but to the right of the hump in the curve<br><br>Shading not required but can be included and used in (a)(ii) | **1** |
| **4(a)(ii)** | An explanation that makes reference to the following points:<br><br>• the area under the curve to the right of the activation energy represents the fraction of molecules that have $E \geq E_a$ (1)<br><br>• 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)<br><br>• (therefore) there are more successful collisions (per second per unit vol.) (1) | Accept description that involves shaded areas under the curve<br><br>Accept more molecules have enough energy to react | **3** |

| Question Number | Answer | | Additional Guidance | Mark |
|---|---|---|---|---|
| **4(b)** | • calculation of total bonds formed | (1) | Correct answer, no working scores 3 marks | **3** |
| | • re-arrangement of $\Delta_r H$ expression | (1) | Example of calculation | |
| | • evaluation of final answer | (1) | $\Sigma$(bonds formed) = $E$(N≡N) + 3$E$(H–H)<br>= 944 + (3 x 436) = 2252 (kJ mol$^{-1}$) | |
| | | | $\Delta_r H^{\ominus}$ = $\Sigma$bonds broken – $\Sigma$(bonds formed),<br>so $\Sigma$(bonds formed) = $\Sigma$bonds broken – $\Delta_r H^{\ominus}$ | |
| | | | 6$E$(N–H) = 2252 – (-92)<br>$E$(N–H) = (+) 391 (kJ mol$^{-1}$) | |
| | | | Accept 390.7 | |

**(Total for Question 4 = 7 marks)**

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **5(a)** | • calculation of temperature change and substitution into $Q = mc\Delta T$ (1)<br>• conversion to kJ (1)<br>• calculation of amount of copper(II) sulfate (1)<br>• use of $\Delta H = -\frac{Q}{n}$ (1)<br>• correct answer with sign and to 3. s.f (1) | Allow ecf for steps in calculation; including for final answer dependent on rounding in steps of the calculation.<br><br>Correct answer with sign, to 3.s.f and no working scores 5 marks<br><br>Mark consequentially on incorrect temperature change<br><br><u>Example of calculation</u><br><br>Q = 50.0 x 4.18 x 7.2 (J) = 1504.8 (J)<br><br>Q = $\frac{1504.8}{1000}$ = 1.5048 (kJ)<br><br>moles of copper(II) sulfate<br>= 4.70 ÷ 159.6<br>= 0.029449 mol<br><br>$\Delta H = -\frac{Q}{n} = -1.5048 \div 0.029449$<br><br>= (– 51.099) = – 51.1 (kJ $mol^{-1}$) | **5** |

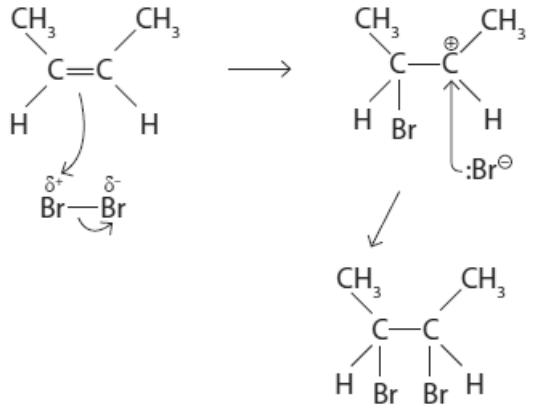
| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **5(b)** | A description that makes reference to the following points:<br><br>• record temperature at timed intervals (after adding the solid) (1)<br><br>• plot these temperature values (on a graph) (1)<br><br>• extrapolate the line of best fit to the time of adding the solid (1) | | **3** |
| **5(c)** | • use of Hess cycle or expression<br>e.g. $\Delta_r H = \Delta_r H_2 - \Delta_r H_1$<br>or $\Delta_r H = \Delta H_{solution}$(anhydrous) – $\Delta H_{solution}$(hydrated) (1)<br><br>• correct final answer with sign (– 49.5 kJ $mol^{-1}$) (1) | Correct answer with sign and no working scores 2 marks | **2** |
| **5(d)** | An explanation that makes reference to the following points:<br><br>• (the pale blue colour shows that) anhydrous copper (II) sulfate is partially hydrated (1)<br><br>• therefore less anhydrous copper (II) sulfate reacts with water / some of the (blue) solid reacts endothermically (1)<br><br>• therefore less thermal energy transferred / heat energy released during experiment<br>**or**<br>(experimental value) has a smaller negative value (1) | | **3** |

**(Total for Question 5 = 13 marks)**

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **6(a)(i)** | • (pale) yellow (1) | | **1** |
| **6(a)(ii)** | • conversion to seconds and use of $\frac{1}{\text{time in sec}}$ (1)<br>• divide by lowest to get whole number ratio (1) | Example of calculation<br>$\frac{1}{1250} : \frac{1}{555} : \frac{1}{5}$<br>or $8.00 \times 10^{-4} : 1.80 \times 10^{-3} : 0.20$<br>1 : 2.25 : 250 | **2** |
| **6(a)(iii)** | An explanation that makes reference to the following points:<br>• the C–Cl bond is shorter than the C–I bond / the Cl atom is smaller than the I atom (1)<br>• therefore, the C–Cl bond is stronger than the C–I bond (1)<br>• therefore, the C–Cl bond needs more energy to break, and so the reaction is slower (1) | Allow reverse argument throughout | **3** |

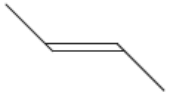
| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **6(b)(i)** | D | | **1** |
| **6(b)(ii)** | • **H**/ $(CH_3)_3$ CBr (1)<br><br>• because C of C–Br is joined to 3 alkyl groups/joined to 3 carbon atoms (1) | | **2** |
| **6(b)(iii)** | • number prefix used should be as low as possible / bromine atom is on the first carbon atom of the chain (1) | | **1** |

**(Total for Question 6 = 10 marks)**

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **7(a)** | (red-)brown to colourless (1) | Allow orange for red-brown<br>Do not allow clear for colourless | **1** |
| **7(b)(i)** | electrophilic (addition) (1) | | **1** |
| **7(b)(ii)** |  <br>• partial charges on Br atoms (1)<br>• curly arrow from C=C bond to (δ+) Br atom AND curly arrow from Br–Br bond to (δ–) Br atom (1)<br>• structure of carbocation with + charge (1)<br>• 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 | **4** |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **7(c)(i)** | • calculation of % by mass of Br (1)<br>• evaluation of number of moles of C, H, and Br (1)<br>• final empirical formula based on whole number ratio (1) | Example of calculation<br>%Br = 100 – 34.9 – 6.60 = 58.5%<br>C $\frac{34.9}{12}$ = 2.91 H $\frac{6.60}{1}$ = 6.60 Br $\frac{58.5}{79.9}$ = 0.732<br>$\frac{2.91}{0.732}$ = 3.98 $\frac{6.60}{0.732}$ = 9.02 $\frac{0.732}{0.732}$ = 1<br>i.e. $C_4H_9Br$ | **3** |
| **7(c)(ii)** | • 2–bromobutane (1) | | **1** |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **7(d)** | An answer that includes at least one similarity and one difference to gain maximum marks:<br><br>Similarities:<br>• both involve the overlap of two (atomic) orbitals (each containing a single electron) (1)<br><br>• both involve an electrostatic attraction between a <u>bonding</u> pair of electrons and two nuclei (1)<br><br>Differences:<br>• the σ bond represents electron density/electrons between the two carbon atoms/nuclei/end-on overlapping of atomic orbitals (1)<br><br>• the π bond represents electron density/electrons above and below the σ bond/ sideways overlapping of orbitals (1)<br><br>• the $\sigma$ bond is formed by the overlap of a single lobe from one (atomic) orbital with a single lobe from the another (atomic) orbital (1)<br><br>• the $\pi$ bond is formed by the overlap of two lobes from one (atomic) orbital with two lobes of another (atomic) orbital (1) | Accept electrostatic attraction between a <u>shared</u> pair of electrons and two nuclei<br><br>Accept end-to-end/head-on/axial overlapping | **3** |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **7(e)** |  (1) | Do not accept a structural or displayed formula. | **1** |

**(Total for Question 7 = 14 marks)**

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **8(a)** | • **P** $CH_3CH_2CH_2CH_2CH_2OH$ (1)<br>• **Q** $(CH_3)_2CHCH(OH)CH_3$ (1)<br>• **R** $(CH_3)_2C(OH)CH_2CH_3$ (1) | Accept displayed formulae | **3** |
| **8(b)** | • *m/z* = 45 is due to $CH_3CH(OH)^+$ (1)<br>• *m/z* = 43 is due to $CH_3CH_2CH_2^+$ (1)<br>• therefore the structure is $CH_3CH_2CH_2CH(OH)CH_3$ (1) | Penalise the lack of a plus sign once only<br>$(CH_3)_2CHCH(OH)CH_3$ not allowed as it is Q | **3** |
| **8(c)(i)** | An answer that makes reference to the following points:<br>• **Y** is a ketone because the spectrum contains an absorption for C=O (carbonyl group) 1700 – 1720 $cm^{-1}$ (1)<br>• **Z** is a carboxylic acid because the spectrum contains absorptions for C=O 1725-1700 $cm^{-1}$ AND O–H (acids) 3300 – 2500 $cm^{-1}$ (1) | Absence of bonds or absence of wavenumber ranges maximum 1<br>Allow values within the ranges | **2** |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **8(c)(ii)** | • calculation of mass of carbon from mass of $CO_2$ (1)<br>• calculation of mass of hydrogen from mass of $H_2O$ (1)<br>• subtraction to find mass of O, and evaluation of number of moles of C, H and O (1)<br>• confirm whole number ratio (1) | Example of calculation<br>Mass of carbon = $(\frac{12}{44} \times 5.89) = 1.606$ g<br>Mass of hydrogen = $(\frac{2}{18} \times 2.44) = 0.271$ g<br>Mass of oxygen = 2.74 – 1.606 – 0.271<br>= 0.863 g<br>C $\frac{1.606}{12} = 0.134$<br>H $\frac{0.271}{1} = 0.271$<br>O $\frac{0.863}{16} = 0.054$<br>Ratio = 2.48 : 5.02 : 1 = 5 : 10 : 2 | **4** |

**(Total for Question 8 = 12 marks)**