

Question number	Answer	Mark
2(a)	<p>The only correct answer is C (14.7%)</p> <p><i>A is incorrect because ± 7.37 is an uncertainty based on halving the difference between the experimental and data book values and taking this as a percentage of the data book value</i></p> <p><i>B is incorrect because ± 8.65 is an uncertainty based on halving the difference between the experimental and data book values and taking this as a percentage of the experimental value</i></p> <p><i>D is incorrect because 17.3 compares the difference in values to the experimental rather than the data book value</i></p>	(1)

Question number	Answer	Mark
2(b)	<p>The only correct answer is B (lowers the error in the final value obtained)</p> <p><i>A is incorrect because increasing the specific heat capacity increases the magnitude of the final value which will then be closer to the data book value</i></p> <p><i>C is incorrect because the difference is 8.6% which is significant</i></p> <p><i>D is incorrect because 8.6% is large compared with the measurement uncertainties</i></p>	(1)

Question number	Answer	Mark
1	<p>The only correct answer is C ($2\text{Cl(g)} \rightarrow \text{Cl}_2\text{(g)}$)</p> <p><i>A is incorrect because the diagram represents an exothermic reaction and atomisation is always endothermic</i></p> <p><i>B is incorrect because the diagram represents an exothermic reaction and ionisation is always endothermic</i></p> <p><i>D is incorrect because the diagram represents an exothermic reaction and dissolving NH_4NO_3 is endothermic</i></p>	(1)

Question Number	Answer
7	<p>The only correct answer is B ($\frac{1}{2}\text{I}_2\text{(s)} \rightarrow \text{I(g)}$)</p> <p><i>A is not correct because two moles of atoms have been produced</i></p> <p><i>C is not correct because it should not be a gas on the LHS and two moles of atoms have been produced</i></p> <p><i>D is not correct because it should not be a gas on the LHS</i></p>

Question Number	Answer	Mark
3	<p>The only correct answer is D (C₉H₂₀)</p> <p><i>A is incorrect because the increment is ~630 kJ mol⁻¹ so expected enthalpy change of combustion would be -4139 kJ mol⁻¹</i></p> <p><i>B is incorrect because the increment is ~630 kJ mol⁻¹ so expected enthalpy change of combustion would be -4769 kJ mol⁻¹</i></p> <p><i>C is incorrect because the increment is ~630 kJ mol⁻¹ so expected enthalpy change of combustion would be -5399 kJ mol⁻¹</i></p>	<p>(1)</p> <p>Computer</p>

Question number	Answer	Mark
3	<p>The only correct answer is A(+491 kJ mol⁻¹)</p> <p><i>B is incorrect because the Δ_rH^o value for the formation of carbon monoxide has not been tripled</i></p> <p><i>C is incorrect because -491kJ mol⁻¹ is the enthalpy change for the reverse reaction</i></p> <p><i>D is incorrect because -713kJ mol⁻¹ is a calculation for the reverse reaction in which the Δ_rH^o value for the formation of carbon monoxide has not been tripled</i></p>	(1)

Question Number	Answer	Mark
1	<p>The only correct answer is C (CF₄(g) → C(g) + 4F(g))</p> <p><i>A is incorrect because this equation represents the bond formation of 4 CF bonds and is exothermic</i></p> <p><i>B is incorrect because this equation represents the enthalpy change of formation of CF₄ from its elements</i></p> <p><i>D is incorrect because this equation represents the enthalpy change of the reaction of CF₄ to its elements</i></p>	<p>(1)</p> <p>Computer</p>

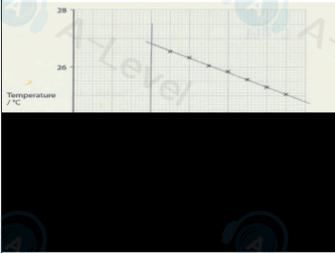
Question Number	Answer
2	<p>The only correct answer is A (letter W)</p> <p><i>B is not correct because X is the activation energy of the reverse reaction</i></p> <p><i>C is not correct because Y is the enthalpy change of the reaction</i></p> <p><i>D is not correct because Z is not a valid enthalpy change</i></p>

Question Number	Answer	Mark
2	<p>The only correct answer is A ($-554 - 394 + 1216$)</p> <p><i>B is incorrect because the sign of the enthalpy change of formation of the reactant is incorrect</i></p> <p><i>C is incorrect because the sign of the enthalpy change of formation of the products is incorrect</i></p>	(1) Computer

Question Number	Answer
3	<p>The only correct answer is D ($\text{Cu(s)} + \text{C(s)} + 1\frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{CuCO}_3\text{(s)}$)</p> <p><i>A is not correct because the oxygen is not in its standard state</i></p> <p><i>B is not correct because the equation has been doubled</i></p> <p><i>C is not correct because the copper and carbon are not in their standard states</i></p>

Question Number	Answer	Additional Guidance	Mark
18(a)(i)	<p>An answer that makes reference to the following point:</p> <p>1. balanced ionic equation</p>	<p>$\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$</p> <p>Accept</p> <p>$\text{H}_3\text{O}^+ + \text{OH}^- \rightarrow 2\text{H}_2\text{O}$</p> <p>Accept multiples</p> <p>Ignore full equation as working</p> <p>Ignore state symbols even if incorrect</p> <p>Do not award uncanceled spectator ions</p>	(1) Graduate

18(a)(ii)	<p>An answer that makes reference to the following points:</p> <p>1. heat energy released under standard conditions</p> <p>2. (when) 1 mol of water is produced (by the reaction of acid (1) with alkali)</p>	<p>(1) Allow enthalpy change under standard conditions</p> <p>Allow for standard conditions 1 atm / 1.01×10^5 Pa and a stated temperature / 298K / 25°C</p> <p>Ignore standard states</p> <p>Do not award energy required</p>	(2) Expert
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Question Number	Answer	Additional Guidance	Mark
18(b)(i)	An answer that makes reference to the following points: 3. two lines of best fit drawn 4. value ± 0.2	(1) Cooling may be shown as straight line or smooth curve $\Delta T = 26.8 - 22.4 = 4.4^{\circ}\text{C}$ (1) Accept value between 4.2°C and 4.6°C from a correct vertical extrapolation at 120s Example of extrapolation 	(2) Expert

18(b)(ii)	An answer that makes reference to the following points: 5. energy transferred to solutions 6. moles of water formed 7. enthalpy change of neutralisation with negative sign and units	<u>Example of calculation:</u> (1) $0.05 \times 4.2 \times 4.4 = 0.924 \text{ (kJ)}$ $50 \times 4.2 \times 4.4 = 924 \text{ (J)}$ (1) $(25 \div 1000) \times 0.8 = 0.02 \text{ (mol)}$ (1) $0.924 \div 0.02 = -46.2 \text{ kJ mol}^{-1} / -46,200 \text{ J mol}^{-1}$ TE on b(i) and throughout b(ii) Ignore SF except 1 SF	(3) Expert
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Question Number	Answer	Additional Guidance	Mark
18(b)(iii)	An explanation that makes reference to the following points: 1. (because the calculation has not taken into account the) energy required to heat the calorimeter/ the (total) heat capacity would be greater 2. the value(of the enthalpy change of neutralisation) would be more exothermic/more negative	(1) Ignore references to the relative heat capacity of copper/water(solution) (1) Allow higher/ increase/ greater	(2) Expert

Question Number	Answer	Additional Guidance	Mark
18(c)(i)	An answer that makes reference to the following points: nucleophilic and substitution(reaction)	Allow nucleophile substitution	(1) Clerical

Question Number	Answer	Additional Guidance	Mark
18(c)(ii)	An answer that makes reference to the following points: 3. dipole on C-Br bond 4. lone pair on O of OH 5. curly arrow from lone pair to C of C-Br . If no lone pair shown, allow curly arrow from O 6. arrow from C-Br to Br or just beyond 7. organic product 8. Br ⁻	<u>Example of mechanism</u>  Allow product as structural formula Allow NaBr Ignore Na ⁺ Do not award HBr 6 points correct scores (3) 4 / 5 points correct scores (2)	(3) Expert

		2 / 3 points correct scores (1) Ignore intermediate/ transition state if shown	
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Question Number	Answer	Additional Guidance	Mark
18(c)(iii)	An answer that makes reference to the following points: 1. elimination 2. ethanol / alcohol	(1) Do not award addition/substitution/dehydration/acid/base (1) Allow ethanolic /alcoholic solution	(2) Graduate

(Total for Question 18 = 16 marks)

Section B

Question Number	Answer	Additional Guidance	Mark
16(a)(i)	An answer that makes reference to the following point: • heat to constant mass / heat until no change in mass	Allow weight for mass Ignore just constant mass Ignore until no more steam is given off Ignore heat for a long time Ignore any test for water Ignore dry with a filter paper Do not award any drying agent	(1)

Question Number	Answer	Additional Guidance	Mark
16(a)(ii)	<ul style="list-style-type: none"> calculation of mass and moles of H₂O calculation of moles of MgSO₄ calculation of 1:1 ratio so x = 1 <p>Alternative calculations</p> <p>6.04 ÷ 120.4 = 0.05017 (mol)</p> <p>6.92 ÷ 0.05017 = 137.94 and 137.94 – 120.4 = 17.54</p> <p>17.54 ÷ 18 = 0.97454 = 1:1 so x = 1 OR 6.04 ÷ 120.4 = 0.5017 (mol)</p> <p>0.88 ÷ 0.05017 = 17.5</p> <p>17.54 ÷ 18 = 0.97454 = 1:1 so x = 1 OR 6.04 ÷ 120.4 = 0.05017 (mol)</p> <p>6.92 ÷ 0.05017 = 137.94 and 120 + 18x = 137.94</p> <p>x = 1</p>	<p><u>Example of calculation:</u></p> <p>6.92 – 6.04 = 0.88 g</p> <p>(1) 0.88 ÷ 18 = 0.048889/ 4.8889 × 10⁻² (mol)</p> <p>(1) 6.04 ÷ 120.4 = 0.050166/ 5.0166 × 10⁻² (mol)</p> <p>(1) 0.048889 ÷ 0.050166 ÷ = 0.97454 = 1:1 so x = 1 Or 0.050166 ÷ 0.048889 = 1.0261 = 1:1 so x = 1 Allow just 1:1</p> <p>(1) Ignore intermediate rounding to 1SF</p> <p>(1) Do not award more than 1 SF for x</p> <p>(1) Allow TE throughout</p>	(3)

Question Number	Answer	Additional Guidance	Mark
16(b)(i)	<ul style="list-style-type: none"> temperature change energy change enthalpy change per mole correct sign and units and 2 or 3 SF 	<p><u>Example of calculation:</u></p> <p>(1) 29.4 – 16.6 = 12.8 (°C)</p> <p>(1) 100 × 4.18 × 12.8 = 5350.4/5.3504 × 10³ (J)/ 5.3504 (kJ)</p> <p>(1) 5350.4 (J) ÷ 0.0628 = 85197/8.5197 × 10⁴ (J mol⁻¹) Or 5.3504 (kJ) ÷ 0.0628 = 85.197 (kJ mol⁻¹)</p> <p>(1) – 85200 J mol⁻¹/– 85000 J mol⁻¹/– 85.2 k J mol⁻¹ /– 85 k J mol⁻¹ Allow just mol⁻¹ for mol⁻¹ Allow use of 4.2 instead of 4.18 Ignore case of J TE throughout</p> <p>Correct answer with sign and units and 2-3 SF scores 4</p>	(4)

Question Number	Answer	Additional Guidance	Mark
16(b)(ii)	<p>A diagram that shows</p> <ul style="list-style-type: none"> both arrows pointing down (1) correct species and states in the bottom box (1) 	<p>Example of diagram</p> <p>Allow ions separated e.g. $\text{Mg}^{2+}(\text{aq})$ and $\text{SO}_4^{2-}(\text{aq})$ Ignore any additional water in the bottom box eg $7\text{H}_2\text{O}$ Ignore the values on arrow even if incorrect Do not award $\text{MgSO}_4 + (\text{aq})$</p>	(2)

Question Number	Answer	Additional Guidance	Mark
16(b)(iii)	<ul style="list-style-type: none"> correct use of data (1) correct sign and answer (1) 	<p>Example of calculation:</p> <p>$(+) - 85.2 \text{ (kJ mol}^{-1}\text{)} (-) + 15.8 \text{ (kJ mol}^{-1}\text{)}$</p> <p>$- 101 \text{ (kJ mol}^{-1}\text{)}$</p> <p>$+ 101 \text{ (kJ mol}^{-1}\text{)}$ score 1</p> <p>Ignore units unless wrong and if mixed units are used max 1. Ignore SF TE on (b)(i) but no TE on an incorrect cycle in (b)(ii)</p>	(2)

Question Number	Answer	Additional Guidance	Mark
16(c)(i)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <p>diagram showing the H of water molecule adjacent to the sulfate ion</p> <p>diagram showing O of the water molecule adjacent to the magnesium ion</p> 	<p>Correct dipole on water must be seen at least once and the delta + and delta- can be seen on 2 different water molecules/ 2 different diagrams</p> <p>Allow any number of water molecules</p> <p>Allow just different sized unlabelled circles for water molecules or unlabelled ball and stick diagrams </p> <p>Allow one water molecule attracted to both ions</p> <p>Penalise wrong charges on the ions only once Penalise missing dipoles or a full charge not a dipole only once Penalise labelled hydrogen bond only once</p>	(2)

Question Number	Answer	Additional Guidance	Mark
16(c)(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> (the barium ions are removed from solution by) precipitation of insoluble barium sulfate ionic equation with all state symbols 	<p>(1) Allow the barium ions precipitate out Allow insoluble barium sulfate is formed Allow solid barium sulfate is formed Ignore any reference to displacement/neutralisation reactions Ignore the non-toxicity of barium sulfate</p> <p>(1) $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \longrightarrow \text{BaSO}_4(\text{s})$</p> <p>Do not award if any other ions are present eg Mg^{2+} on both side of the equation</p>	(2)

(Total for Question 16 = 16 Marks)

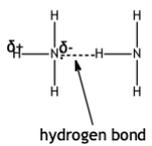
Question number	Answer	Additional guidance	Mark
20(a)(i)	<ul style="list-style-type: none"> identification and number of bonds broken and the values needed evaluation of energy required identification of bonds formed and the values needed and evaluation of energy produced evaluation of enthalpy change of combustion 	<p>Here and throughout the paper Do not penalise correct premature rounding Penalise incorrect rounding only in their final answer</p> <p>Example of calculation Bonds broken: $7 \times \text{C}-\text{C} + 18 \times \text{C}-\text{H} + 12.5 \times \text{O}=\text{O}$ $E(\text{bond breaking}) = 7 \times 347 + 18 \times 413 + 12.5 \times 498$ $= (+)16088 \text{ (kJ mol}^{-1}\text{)}$ TE only if at least 2 bonds used Bonds formed: $E(\text{bond forming}) = 16 \times \text{C}=\text{O} + 18 \times \text{O}-\text{H}$ $= 16 \times 805 + 18 \times 464$ $= (-)21232 \text{ (kJ mol}^{-1}\text{)}$ $\Delta_c H = 16088 - 21232 = -5144 \text{ (kJ mol}^{-1}\text{)}$ TE at each stage (even if final value is positive) Ignore SF except 1 SF Units are not required but if given must be correct for the final value Correct answer with some working scores (4)</p>	(4)

Question number	Answer	Additional guidance	Mark
20(a)(ii)	<p>An answer that makes reference to the following</p> <ul style="list-style-type: none"> the bond enthalpies are averaged over a (large) number of compounds bond enthalpies always refer to substances in the gas phase and octane and water are liquids when the value of $\Delta_c H^\ominus$ is obtained 	<p>Allow just bond enthalpies are average values</p> <p>Allow just octane is a liquid or water is a liquid Allow calculations using mean bond enthalpies do not include changes of state Ignore non-standard conditions Do not award explanations for experimental error such as heat loss, or incomplete combustion</p>	(2)

Question number	Answer	Additional guidance	Mark
20(a)(iii)	<ul style="list-style-type: none"> calculation of molar mass of octane <p>(1)</p> <ul style="list-style-type: none"> conversion of kJ mol^{-1} to MJ kg^{-1} <p>and</p> <ul style="list-style-type: none"> calculation of percentage efficiency <p>(1)</p>	<p>Example of calculation</p> $M = 8 \times 12 + 18 = 114 \text{ g mol}^{-1}$ <p>Allow mol octane = $1000 \div (8 \times 12 + 18 \times 1) = 8.772$</p> <p>Ignore just $(8 \times 12 + 18 \times 1)$</p> $1000 \times 5470 \div 114 = 47982 \text{ kJ kg}^{-1} = 47.982 \text{ MJ kg}^{-1}$ <p>Efficiency = $100 \times 11 \div 47.982 = 22.925 / 22.9 / 23\%$</p> <p>Allow conversion of MJ kg^{-1} to kJ mol^{-1}</p> $= 114 \times 11 \times 1000 \div 1000 = 1254 \text{ (kJ mol}^{-1}\text{)}$ <p>and</p> $\text{Efficiency} = 100 \times 1254 \div 5470 = 22.925 / 22.9 / 23\%$ <p>Ignore SF except 1 SF</p> <p>TE unless % efficiency > 100</p> <p>Correct answer with no working scores (2)</p> <p>Allow calculation using $\Delta_c H^\ominus$ from mean bond enthalpy data ($-5144 \text{ kJ mol}^{-1}$):</p> $\text{Efficiency} = 24.378\%$ <p>Allow calculation using stated incorrect $\Delta_c H^\ominus$ from mean bond enthalpy data unless % efficiency > 100</p>	(2)

Question number	Answer	Additional guidance	Mark
20(a)(iv)	<p>An answer that makes reference to two of the following</p> <ul style="list-style-type: none"> heat loss to the surroundings <p>(1)</p> <ul style="list-style-type: none"> energy is used to bring the engine to operating temperature <p>(1)</p> <ul style="list-style-type: none"> incomplete combustion (of the fuel) <p>(1)</p>	<p>Accept specific examples such as</p> <p>Heat loss due to friction in the engine</p> <p>Heat loss via hot exhaust</p> <p>Allow just 'converted to heat'</p> <p>Allow energy loss to the surroundings</p> <p>Ignore just 'friction'</p> <p>Allow energy is used to warm up the engine</p> <p>Allow energy is used to start the engine</p> <p>Allow energy is used for aircon / electronic devices</p> <p>Allow combustion is not smooth</p> <p>Ignore inefficient combustion</p> <p>Ignore references to standard conditions</p> <p>Ignore fuel evaporates</p> <p>Ignore petrol not 100% octane</p> <p>Ignore the idea that some other force is moving the car e.g. car is going downhill</p>	(2)

Question number	Answer	Additional guidance	Mark																				
*20(b)	<p>This question assesses the 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"> <thead> <tr> <th>Number of indicative marking points seen in answer</th> <th>Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <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> </tbody> </table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning</p> <table border="1"> <thead> <tr> <th></th> <th>Number of marks awarded for structure of answer and sustained lines of reasoning</th> </tr> </thead> <tbody> <tr> <td>Answer shows a coherent 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> </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		Number of marks awarded for structure of answer and sustained lines of reasoning	Answer shows a coherent 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>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, a response 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 were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</p> <p>In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks 3 or 4 indicative points would get 1 reasoning mark 0, 1 or 2 indicative points would get 0 reasoning marks.</p> <p>If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).</p> <p>Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning</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																						
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Question	Answer	Additional guidance	Mark
*20(b) cont	<p>Indicative points</p> <p>Similarities</p> <ul style="list-style-type: none"> IP1 both hydrogen and ammonia form London / dispersion forces IP2 a temporary dipole forms in a molecule and induces a dipole in an adjacent molecule IP3 the attraction (between the temporary dipoles) is small(er) in hydrogen because the H₂ electron cloud is not easily polarised <p>Differences</p> <ul style="list-style-type: none"> IP4 ammonia forms hydrogen bonds (because nitrogen is very electronegative)  <ul style="list-style-type: none"> IP5 Accept hydrogen bond forms between the nitrogen lone pair and the (δ^+) hydrogen (of a different molecule) IP6 ammonia liquefies more easily than hydrogen because hydrogen bonds are stronger than London forces 	<p>Allow van der Waals forces</p> <p>Ignore permanent dipole-dipole forces in ammonia</p> <p>Do not award H₂ forms hydrogen bonds / permanent dipole-dipole forces</p> <p>Accept fluctuating electron clouds result in differences in electron density within the molecule</p> <p>Allow instantaneous dipole-dipole attractions between molecules</p> <p>Allow because H₂ has only two / few electrons</p> <p>Allow attraction is greater in ammonia because it has more electrons</p> <p>Do not award ammonia forms hydrogen bonds with water</p> <p>IP4 and IP5 may be scored by a diagram showing dipole and lone pair and with H bond labelled</p> <p>Allow N---H---N bond angle not equal to 180</p> <p>Allow hydrogen bond forms between the δ^- nitrogen and the δ^+ hydrogen (of a different molecule)</p> <p>Allow permanent dipole-dipole forces for H bonds here</p> <p>Ignore just 'H-bonding is the strongest IMF'</p> <p>Ignore reference to boiling temperatures</p> <p>Do not award hydrogen liquefies to form water</p> <p>Do not award energy is required to liquefy a gas</p>	6

(Total for Question 20 = 16 marks)