Question Number	Answer
2(a)	**The only correct answer is B** (801) ***A*** *is incorrect because only one oxygen molecule has been included* ***C*** *is incorrect because only two O-H bonds have been included and only one oxygen molecule has been included* ***D*** *is incorrect because only two O-H bonds have been included*

Question Number	Answer
(b)	**The only correct answer is B** (+40) ***A*** *is incorrect because this is the value for the enthalpy change of condensation* ***C*** *is incorrect because this is the value for the enthalpy change of condensation for two moles of water* ***D*** *is incorrect because this is the value for the enthalpy change of vaporisation for two moles of water*

Question Number	Answer
3	**The only correct answer is D** ($Cu(s) + C(s) + 1½O_2(g) \rightarrow CuCO_3(s)$) ***A*** *is not correct because the oxygen is not in its standard state* ***B*** *is not correct because the equation has been doubled* ***C*** *is not correct because the copper and carbon are not in their standard states*

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

Question Number	Answer	Mark
2	**The only correct answer is A** (−554 − 394 + 1216) ***B*** *is incorrect because the sign of the enthalpy change of formation of the reactant is incorrect* ***C*** *is incorrect because the sign of the enthalpy change of formation of the products is incorrect*	**(1)** **Computer**

Question Number	Answer	Mark
3	**The only correct answer is A** ((0.5 × 436 + 0.5 × 242) − 431) ***B*** *is not correct because the bond enthalpies of the reactants have been subtracted from the bond enthalpy of the product and this is for the formation of two moles of HCl* ***C*** *is not correct because the bond enthalpies of the reactants have been subtracted from the bond enthalpy of the product* ***D*** *is not correct because this is for the formation of two moles of HCl*	**(1)**

Question Number	Answer
4	**The only correct answer is B** (391 kJ mol^{-1}) ***A*** *is not correct because 46* kJ mol^{-1} *has been deducted instead of added* ***C*** *is not correct because the value of the N ≡ N has not been divided by 2* ***D*** *is not correct because the value has not been divided by 3 to get the bond energy*

Question number	Answer	Mark
3	**The only correct answer is A**(+491 kJ mol^{-1}) **B** *is incorrect because the* $\Delta_r H^\ominus$ *value for the formation of carbon monoxide has not been tripled* **C** *is incorrect because* $-491 kJ\ mol^{-1}$ *is the enthalpy change for the reverse reaction* **D** *is incorrect because* $-713 kJ\ mol^{-1}$ *is a calculation for the reverse reaction in which the* $\Delta_r H^\ominus$ *value for the formation of carbon monoxide has not been tripled*	**(1)**

Question Number	Answer	Mark
2	**The only correct answer is A** ($\frac{1}{2}Br_2(l) \rightarrow Br(g)$) ***B*** *is not correct because bromine is a liquid in its standard state* ***C*** *is not correct because this shows the formation of two moles of gaseous bromine atoms* ***D*** *is not correct because bromine is a liquid in its standard state and this shows the formation of two moles of gaseous bromine atoms*	**(1)**

Question Number	Answer
6(a)	**The only correct answer is D** $\left(\frac{-\Delta T \times 4.2 \times 50}{2.5 \times 10^{-3}}\right)$ *A is not correct because it has the wrong sign, and the wrong number of moles* ***B*** *is not correct because it has the wrong sign and the incorrect mass of solution* ***C*** *is not correct because it has the wrong number of moles*

Question Number	Answer
6(b)	**The only correct answer is D** (25 cm^3 pipette) *A is not correct because the burette has to be read twice so the % uncertainty is 0.4%* ***B*** *is not correct because the % uncertainty is 2 %* ***C*** *is not correct because the % uncertainty is 0.4 %*

Question number	Answer	Mark
1	**The only correct answer is C** ($2Cl(g) \rightarrow Cl_2(g)$) ***A*** *is incorrect because the diagram represents an exothermic reaction and atomisation is always endothermic* ***B*** *is incorrect because the diagram represents an exothermic reaction and ionisation is always endothermic* ***D*** *is incorrect because the diagram represents an exothermic reaction and dissolving NH_4NO_3 is endothermic*	**(1)**

Question Number	Answer
7	**The only correct answer is B** ($\frac{1}{2}I_2(s) \rightarrow I(g)$) ***A*** *is not correct because two moles of atoms have been produced* ***C*** *is not correct because it should not be a gas on the LHS and two moles of atoms have been produced* ***D*** *is not correct because it should not be a gas on the LHS*

Question Number	Answer	Mark
1	**The only correct answer is C** ($CF_4(g) \rightarrow C(g) + 4F(g)$) ***A*** *is incorrect because this equation represents the bond formation of 4 CF bonds and is exothermic* ***B*** *is incorrect because this equation represents the enthalpy change of formation of CF_4 from its elements* ***D*** *is incorrect because this equation represents the enthalpy change of the reaction of CF_4 to its elements*	**(1)** **Computer**

Question number	Answer	Mark
2(a)	**The only correct answer is C** (14.7 %)) ***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* ***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* ***D*** *is incorrect because 17.3 compares the difference in values to the experimental rather than the data book value*	**(1)**

Question number	Answer	Mark
2(b)	**The only correct answer is B** (lowers the error in the final value obtained) ***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* ***C*** *is incorrect because the difference is 8.6% which is significant* ***D*** *is incorrect because 8.6% is large compared with the measurement uncertainties*	**(1)**

Question Number	Answer	Mark
3	**The only correct answer is D** (C_9H_{20}) ***A*** *is incorrect because the increment is ~630 kJ mol^{-1} so expected enthalpy change of combustion would be −4139 kJ mol^{-1}* ***B*** *is incorrect because the increment is ~630 kJ mol^{-1} so expected enthalpy change of combustion would be −4769 kJ mol^{-1}* ***C*** *is incorrect because the increment is ~630 kJ mol^{-1} so expected enthalpy change of combustion would be −5399 kJ mol^{-1}*	**(1)** **Computer**

Section C

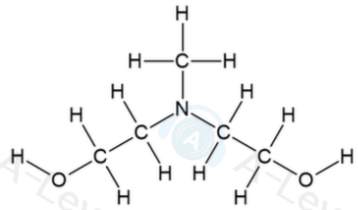
Question Number	Answer	Additional Guidance	Mark
22(a)(i)	An answer that makes reference to one of the following points: • shifts position of equilibrium to the right OR increases the (equilibrium) yield (of H_2)	Ignore to increase rate (of forward reaction) Ignore cheaper to have steam in excess Ignore to react with most of the CH_4 Allow to increase yield (of CO / products) Do not award so all of the CH_4 reacts / so reaction goes to completion Do not award to increase the moles of gas/pressure	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(a)(ii)	An answer that makes reference to the following points: • T_1 (is higher) **and** (first reaction is) endothermic	**Accept reverse argument** Allow positive enthalpy change for endothermic Allow (first reaction) absorbs (heat) energy for endothermic Ignore just +206 for endothermic Ignore correct reference to effect of temperature on equilibrium yields Do not award absorbs more energy to break (reactant) bonds	**(1)**

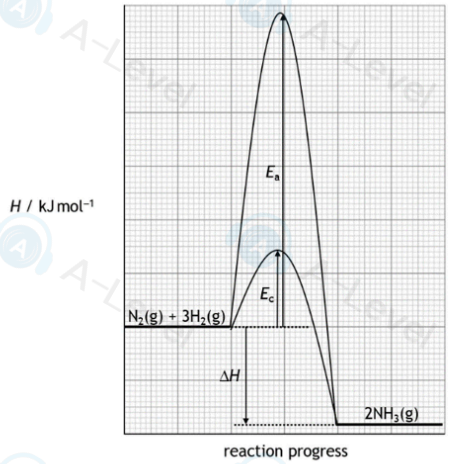
Question Number	Answer	Additional Guidance	Mark
22(a)(iii)	An answer that makes reference to the following point: • overall equation for Stage 1	Example of correct equation: $CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$ Allow ⇌ for → Allow multiples Ignore state symbols even if incorrect Ignore working Do not award uncancelled CO	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(b)(i)	An answer that makes reference to one of the following points: • to reduce greenhouse gas emissions OR to sell (to increase profit) OR to prevent poisoning of the catalyst(s) in later stages	Ignore any reference to position of equilibrium in Stage 1 reactions Allow CO_2 / it is a greenhouse gas Allow CO_2 / it causes global warming / climate change Ignore (to make the process more) carbon neutral / to reduce carbon footprint Ignore CO_2 is harmful to the environment Ignore just to reduce air pollution Do not award reference to ozone layer	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(b)(ii)	An answer that makes reference to the following point: • neutralisation	Accept acid-base Ignore addition Ignore reversible Ignore formation Do not award hydration Do not award redox	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(b)(iii)	An answer that makes reference to the following points: • displayed formula of N-methyldiethanolamine	Example of displayed formula:  Allow OH for O–H Ignore bond angles and bond lengths Do not award C–HO connectivity	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(c)	An answer that makes reference to the following points: • advantage of using high pressure **(1)** • disadvantage of using high pressure **(1)**	Examples of advantage: shifts position of equilibrium to right / products OR increases (equilibrium) yield (of NH_3) OR increases rate OR increases occupation of catalyst active sites Ignore any reference to collisions Examples of disadvantage: requires more energy OR costs more for energy/fuel OR requires expensive/specialist equipment (to withstand pressure) Ignore just expensive / costs more Ignore dangerous / risk of explosion	**(2)**

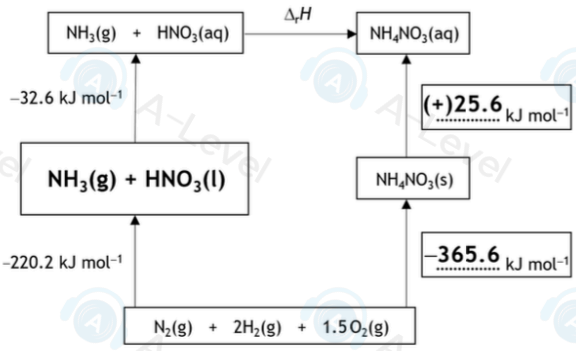
Question Number	Answer	Additional Guidance	Mark
22(d)(i)	An answer that makes reference to the following points: • ΔH labelled **and** arrow pointing downwards **(1)** • **labelled** reaction profiles for uncatalysed **and** catalysed reactions **(1)** • correct scale for activation energies **(1)**	Example of labelled reaction profile:  Allow arrows to start/end within one small square of correct placement and penalise incorrect placement once only Allow –92 / 'enthalpy change' for ΔH Do not award double headed arrow Allow any form of unambiguous labelling, eg values Allow double headed arrows Do not award downward arrows Do not award $E_{cat} > E_a$ Accept accuracy of ± one small square Ignore scale shown on y-axis	**(3)**

Question Number	Answer	Additional Guidance	Mark
22(d)(ii)	An answer that makes reference to one of the following points: • less energy (needed) / (works at a) lower temperature OR less fuel (required)	 Ignore lowers E_a Ignore catalyst can be reused Ignore reduces carbon footprint / carbon emissions	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(e)(i)	An answer that makes reference to one of the following points: • increase rate OR rate is slow at low temperature OR catalyst does not work at low temperature OR so more reactants/collisions have $E \geq E_a$ OR to break O=O/N–H bonds	Do not award to increase yield Do not award to shift position of equilibrium (to left / right) Do not award reverse reaction is endothermic Allow to increase the number of successful collisions Ignore to increase collision frequency Allow catalyst more efficient at high temperature Allow to activate the catalyst Accept (to reach) high activation energy Allow to break bonds in oxygen/ammonia/reactants	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(e)(ii)	An answer that makes reference to the following points: • (forward reaction is highly) exothermic OR (forward reaction) releases (a lot of) heat (energy)	 Ignore any reference to catalysis Allow thermal energy for heat Do not award NH_3 from Stage 2 is hot Do not award 1100 K is not very high	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(f)	An explanation that makes reference to the following points: • NO_2 removed (in second reaction) **(1)** • shifting position of equilibrium (in first reaction) to right **and** increasing the yield (of NO_2) **(1)**	 Allow (as) NO formed (in second reaction) Ignore HNO_3 is formed (in second reaction) Ignore reaction is irreversible Ignore NO_2 dissolves Allow shifting reaction to right **and** increasing yield (of NO_2)	**(2)**

Question Number	Answer	Additional Guidance	Mark
22(g)(i)	An answer that makes reference to the following points: • left hand side of enthalpy cycle **(1)** • right hand side of enthalpy cycle **(1)**	Example of completed enthalpy cycle:  Do not award omission/incorrect state symbols Do not award multiples Do not award numbers in opposite order Do not award −25.6 Do not award +365.6 / 365.6	**(2)**

Question Number	Answer	Additional Guidance	Mark
22(g)(ii)	An answer that makes reference to the following point: • calculation of $\Delta_r H$	Example of calculation: $\Delta_r H = -(-32.6) - (-220.2) + (-365.6) + 25.6$ $= -87.2 / -87$ (kJ mol^{-1}) Allow omission of units Allow kJ TE on cycle in (g)(i)	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(h)	An answer that makes reference to two of the following points: • cheaper to produce H_2/NH_3/NO/HNO_3 than to purchase (from other suppliers) **(1)** OR • (better) knowledge of chemical purity / chemical quality **(1)** OR • lower transportation / travel costs (between sites) **(1)** OR • prevents (more) chemical waste through transfer losses **(1)** OR • energy produced in exothermic reactions can be used (in endothermic processes) **(1)** OR • smaller workforce required **(1)** OR • less land required **(1)** OR • saves time so cheaper operational costs **(1)**	**Ignore just cheaper (operational costs)** **Ignore just less energy required** **Ignore just saves time / makes product faster** Ignore just chemicals need transporting Ignore just chemical lost through transportation Ignore just higher yield Do not award higher atom economy Allow lower energy costs Allow reduces carbon footprint Allow lower workforce costs Allow saves building / maintenance costs	**(2)**

(Total for Question 22 = 21 marks)
(Total for Section C = 21 marks)
(Total for Paper = 80 marks)

Question number	Answer	Additional guidance	Mark
20(a)(i)	• identification and number of bonds broken **and** the values needed (1) • evaluation of energy required (1) • identification of bonds formed **and** the values needed **and** evaluation of energy produced (1) • evaluation of enthalpy change of combustion (1)	Here and throughout the paper Do not penalise correct premature rounding Penalise incorrect rounding only in their final answer Example of calculation Bonds broken: 7 × C─C + 18 × C─H + 12.5 × O=O E (bond breaking) = 7 × 347 + 18 × 413 + 12.5 × 498 = (+)16088 (kJ mol^{-1}) TE only if at least 2 bonds used Bonds formed: E (bond forming) = 16 × C=O + 18 × O─H = 16 × 805 + 18 × 464 = (−)21232 (kJ mol^{-1}) $\Delta_c H$ = 16088 – 21232 = −5144 (kJ mol^{-1}) 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)	**(4)**

Question number	Answer	Additional guidance	Mark
20(a)(ii)	An answer that makes reference to the following • the bond enthalpies are averaged over a (large) number of compounds (1) • 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 (1)	Allow just bond enthalpies are average values 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	**(2)**

Question number	Answer	Additional guidance	Mark
20(a)(iii)	• calculation of molar mass of octane (1) • conversion of kJ mol^{-1} to MJ kg^{-1} **and** calculation of percentage efficiency (1)	Example of calculation $M = 8 \times 12 + 18 = 114$ g mol^{-1} Allow mol octane = 1000÷(8x12 + 18x1) = 8.772 Ignore just (8x12 + 18x1) $1000 \times 5470 \div 114 = 47982$ kJ kg^{-1}= 47.982 MJkg^{-1} Efficiency = 100 x 11 ÷ 47.982 = 22.925 /22.9 / 23% Allow conversion of MJ kg^{-1} to kJ mol^{-1} = 114 x 11 x 1000 ÷ 1000 = 1254 (kJ mol^{-1}) and Efficiency = 100 x 1254 ÷ 5470 = 22.925 /22.9 / 23% Ignore SF except 1 SF TE unless % efficiency > 100 Correct answer with no working scores (2) Allow calculation using $\Delta_c H^\ominus$ from mean bond enthalpy data (−5144 kJ mol^{-1}): Efficiency =24.378% Allow calculation using stated incorrect $\Delta_c H^\ominus$ from mean bond enthalpy data unless % efficiency > 100	(2)

Question number	Answer	Additional guidance	Mark
20(a)(iv)	An answer that makes reference to **two** of the following • heat loss to the surroundings (1) • energy is used to bring the engine to operating temperature (1) • incomplete combustion (of the fuel) (1)	Accept specific examples such as Heat loss due to friction in the engine Heat loss via hot exhaust Allow just 'converted to heat' Allow energy loss to the surroundings Ignore just 'friction' Allow energy is used to warm up the engine Allow energy is used to start the engine Allow energy is used for aircon / electronic devices Allow combustion is not smooth Ignore inefficient combustion Ignore references to standard conditions Ignore fuel evaporates Ignore petrol not 100% octane Ignore the idea that some other force is moving the car e.g. car is going downhill	(2)

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*20(b)</td><td>This question assesses the 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>
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr>
<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>
</table></td><td>Guidance on how the mark scheme should be applied.

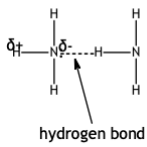
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some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

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).

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.

If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning</td><td>6</td></tr>
</table>

Question	Answer	Additional guidance	Mark
*20(b) cont	Indicative points Similarities • **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 H_2 electron cloud is not easily polarised Differences • **IP4** ammonia forms hydrogen bonds (because nitrogen is very electronegative)  • **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	Allow van der Waals forces Ignore permanent dipole-dipole forces in ammonia Do not award H_2 forms hydrogen bonds / permanent dipole-dipole forces Accept fluctuating electron clouds result in differences in electron density within the molecule Allow instantaneous dipole-dipole attractions between molecules Allow because H_2 has only two / few electrons Allow attraction is greater in ammonia because it has more electrons Do not award ammonia forms hydrogen bonds with water IP4 and IP5 may be scored by a diagram showing dipole and lone pair and with H bond labelled Allow N----H—N bond angle not equal to 180 Allow hydrogen bond forms between the δ− nitrogen and the δ+ hydrogen (of a different molecule) Allow permanent dipole-dipole forces for H bonds here Ignore just 'H-bonding is the strongest IMF' Ignore reference to boiling temperatures Do not award hydrogen liquefies to form water Do not award energy is required to liquefy a gas	6

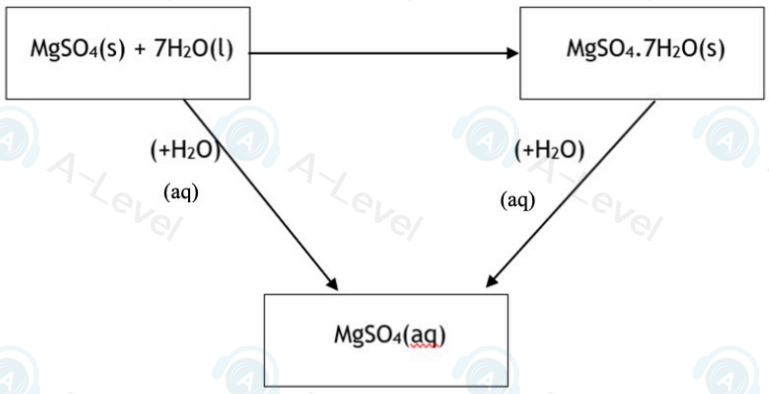
(Total for Question 20 = 16 marks)

Section B

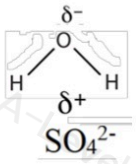
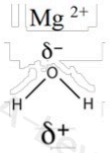
Question Number	Answer	Additional Guidance	Mark
16(a)(i)	An answer that makes reference to the following point: • **heat** to constant mass /**heat** until no change in mass	Allow weight for mass Ignore just constant mass Ignore until no more steam is given off Ignore heat for a long time Ignore any 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)	• calculation of mass **and** moles of H_2O **(1)** • calculation of moles of $MgSO_4$ **(1)** • calculation of 1:1 ratio so x = 1 **(1)** Alternative calculations 6.04 ÷ 120.4 = 0.05017 (mol) **(1)** 6.92 ÷ 0.05017 = 137.94 and 137.94 – 120.4 = 17.54 **(1)** 17.54 ÷ 18 = 0.97454 = 1:1 so x =1 **(1)** OR 6.04 ÷ 120.4 = 0.5017 (mol) **(1)** 0.88 ÷ 0.05017 = 17.5 **(1)** 17.54 ÷ 18 = 0.97454 = 1:1 so x =1 **(1)** OR 6.04 ÷ 120.4 = 0.05017 (mol) **(1)** 6.92 ÷ 0.05017 = 137.94 and 120 + 18x = 137.94 **(1)** x =1 **(1)**	Example of calculation: 6.92 – 6.04 = 0.88 g 0.88 ÷ 18 = 0.048889/ 4.8889 ×10 $^{-2}$ (mol) 6.04 ÷ 120.4 = 0.050166/ 5.0166 ×10 $^{-2}$ (mol) 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 Ignore intermediate rounding to 1SF Do not award more than 1 SF for x Allow TE throughout	**(3)**

Question Number	Answer	Additional Guidance	Mark
16(b)(i)	• temperature change **(1)** • energy change **(1)** • enthalpy change per mole **(1)** • correct sign and units and 2 or 3 SF **(1)**	Example of calculation: 29.4 – 16.6 = 12.8 (°C) 100 × 4.18 × 12.8 = 5350.4/5.3504 × 10^3 (J)/ 5.3504 (kJ) 5350.4 (J) ÷ 0.0628 = 85197/8.5197 × 10^4 (J mol $^{-1}$) Or 5.3504 (kJ) ÷ 0.0628 = 85.197 (kJ mol $^{-1}$) – 85200 J mol $^{-1}$ /– 85000 J mol $^{-1}$/– 85.2 k J mol $^{-1}$ /– 85 k J mol $^{-1}$ Allow just mol $^{-}$ for mol $^{-1}$ Allow use of 4.2 instead of 4.18 Ignore case of J TE throughout Correct answer with sign and units and 2-3 SF scores 4	**(4)**

Question Number	Answer	Additional Guidance	Mark
16(b)(ii)	A diagram that shows • both arrows pointing down **(1)** • correct species and states in the bottom box **(1)**	Example of diagram  Allow ions separated e.g. Mg^{2+}(aq) and SO_4^{2-}(aq) Ignore any additional water in the bottom box eg $7H_2O$ Ignore the values on arrow even if incorrect Do not award $MgSO_4$ + (aq)	**(2)**

Question Number	Answer	Additional Guidance	Mark
16(b)(iii)	• correct use of data **(1)** • correct sign and answer **(1)**	Example of calculation: (+) – 85.2 (kJ mol $^{-1}$) (–) + 15.8 (kJ mol $^{-1}$) – 101 (kJ mol $^{-1}$) + 101 (kJ mol $^{-1}$) score 1 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)	**(2)**

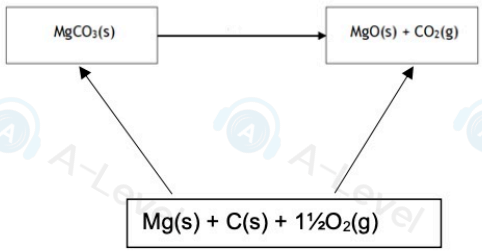
Question Number	Answer	Additional Guidance	Mark
16(c)(i)	An answer that makes reference to the following points: • diagram showing the H of water molecule adjacent to the sulfate ion  (1) • diagram showing O of the water molecule adjacent to the magnesium ion  (1)	Correct dipole on water must be seen at least once and the delta + and delta– can be seen on 2 different water molecules/ 2 different diagrams Allow any number of water molecules Allow just different sized unlabelled circles for water molecules or unlabelled ball and stick diagrams  Allow one water molecule attracted to both ions 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	(2)

Question Number	Answer	Additional Guidance	Mark
16(c)(ii)	An answer that makes reference to the following points: • (the barium ions are removed from solution by) precipitation of insoluble barium sulfate (1) • ionic equation with all state symbols (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 $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$ Do not award if any other ions are present eg Mg^{2+} on both side of the equation	(2)

(Total for Question 16 = 16 Marks)

Section B

Question Number	Answer	Additional Guidance	Mark
18(a)	• M1 calculation of change of mass **and** moles of CO_2 (1) • M2 calculation of moles of magnesium carbonate (1) • M3 % calculation (1) Alternative M2 and M3 • M2 calculation of mass MgO that decomposes • M3 % calculation	Example of calculation 4.17(g) – 2.35(g) = 1.82(g) 1.82÷44 = 0.041364/ 4.1364 ×10 $^{-2}$ (mol) 4.17÷84.3 = 0.049466/ 4.9466 ×10 $^{-2}$ (mol) 0.041364 ÷ 0.049466 × 100 = 83.620 % 0.041364 × 84.3 = 3.4870(g)) 3.4870 (g) ÷ 4.17(g) × 100 = 83.620 % Ignore SF except 1 SF	(3)

Question Number	Answer	Additional Guidance	Mark
18(b)(i)	An explanation that makes reference to the following points: • both arrows pointing up **(1)** • correct species, balanced and states in the bottom box **(1)**	 Allow C(graphite) for C(s) Allow 2 arrows on the RHS Ignore labels on the arrows	**(2)**

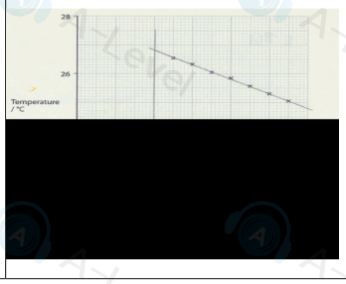
Question Number	Answer	Additional Guidance	Mark
18(b)(ii)	• correct use of data **(1)** • calculation of energy required with sign and units **(1)**	Example of calculation (–)–1095.8 – 601.7 – 393.5 = ((+) 100.6 (kJ mol^{-1})) (+) 100.6 kJ mol^{-1} kJ/mol Allow rounding to 101 kJ/mol – 100.6 kJ mol^{-1} will score 1 Correct answer with no working scores 2 No TE on wrong cycle	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(c)	An answer that makes reference to the following points: • the enthalpy change (of calcium carbonate) would be more positive/endothermic **(1)** • Ca^{2+} is larger than Mg^{2+} **(1)** • so Ca^{2+} is less polarising / CO_3^{2-} less distorted (so more heat needed to decompose it) **(1)**	Allow larger, greater or higher Allow more heat/energy needed Allow thermal decomposition greater Do not award if there is any reference to exothermic or heat given out Do not award if there is any reference London forces or any intermolecular force Allow Ca ion larger than Mg ion Ignore Ca is larger than Mg Ignore atomic radius Ions must be mentioned at least once in M2 and M3, but only penalise once. Allow reverse argument for all points	**(3)**

(Total for Question 18 = 10 Marks)

Question Number	Answer	Additional Guidance	Mark
18(a)(i)	An answer that makes reference to the following point: 1. balanced ionic equation	$H^+ + OH^- \rightarrow H_2O$ Accept $H_3O^+ + OH^- \rightarrow 2H_2O$ Accept multiples Ignore full equation as working Ignore state symbols even if incorrect Do not award uncancelled spectator ions	**(1)** **Graduate**

18(a)(ii)	An answer that makes reference to the following points: 1. heat energy released under standard conditions **(1)** 2. (when) 1 mol of **water** is produced (by the reaction of acid with alkali) **(1)**	Allow enthalpy change under standard conditions Allow for standard conditions 1 atm / 1(.01) x10^5Pa and a stated temperature / 298K / 25°C Ignore standard states Do not award energy required	**(2)** **Expert**

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 **(1)** 4. value ±0.2 **(1)**	Cooling may be shown as straight line or smooth curve $\Delta T = 26.8 - 22.4 = 4.4^oC$ Accept value between 4.2 ^oC and 4.6 ^oC 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 **(1)** 6. moles of water formed **(1)** 7. enthalpy change of neutralisation with negative sign and units **(1)**	<u>Example of calculation:</u> $0.05 \times 4.2 \times 4.4 = 0.924$ (kJ) $50 \times 4.2 \times 4.4 = 924$ (J) $(25 \div 1000) \times 0.8 = 0.02$(mol) $0.924 \div 0.02 = -46.2$ kJ mol^{-1} /−46,200 J mol^{-1} TE on b(i) and throughout b(ii) Ignore SF except 1 SF	**(3)** **Expert**

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 **(1)** 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) 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^-	Example of mechanism 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	

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

(Total for Question 18 = 16 marks)

Question Number	Answer		Additional Guidance	Mark
22(a)	An explanation that makes reference to the following points: • 1 mol of substance / compound / MgO • formed from element(s) in standard state(s)	**(1)** **(1)**	Allow 1 mol of product Ignore Mg(s) and O_2(g) / reactant(s) for element(s) Ignore normal/natural etc for standard Ignore any reference to standard conditions	**(2)**

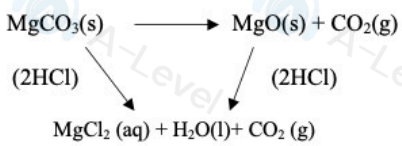
Question Number	Answer		Additional Guidance	Mark
22(b)			Here and throughout the paper: • penalise incorrect rounding once only and only if the final answer is incorrect • do not penalise correct premature rounding • penalise incorrect units once only • Allow mol^{-} for mol^{-1} Example of calculation: Correct answer to **3SF or 2SF** with some working scores (4) Ignore SF except 1SF and penalise use of 1SF once only Ignore sign in M1 and M3	**(4)**
	• calculation of energy transferred	**(1)**	energy = 25.0 × 4.18 × (28.0 – 21.5) = 679.25 (J) Allow 0.67925 (kJ)	
	• calculation of amount of MgO	**(1)**	amount = 0.189 ÷ 40.3 = 0.0046898 / 4.6898 × 10^{-3} (mol) Allow 0.004725 / 4.725 × 10^{-3} (mol) from M_r = 40	
	• calculation of Δ_rH_2	**(1)**	Δ_rH_2 = 679.25 ÷ 0.0046898 = 144830 (J mol^{-1}) Accept 144.83 (kJ mol^{-1}) Allow 143760 (J mol^{-1}) / 143.76 (kJ mol^{-1}) from M_r = 40 TE on M1 and M2	
	• negative sign and answer to 3SF or 2SF	**(1)**	–145 / –140 (kJ mol^{-1}) Allow –145000 / –140000 J mol^{-1} Allow –144 (kJ mol^{-1}) / –144000 J mol^{-1} from M_r = 40 TE on M3	

Question Number	Answer		Additional Guidance	Mark
22(c)			Example of calculation: Correct answer with some working scores (2)	**(2)**
	• correct expression for Δ_rH_1	**(1)**	Δ_rH_1 = –462 + (–286) – answer to (b)	
	• calculation of Δ_rH_1	**(1)**	Δ_rH_1 = –462 + (–286) – (–145) = –603 (kJ mol^{-1}) Ignore SF TE on answer to (b) No TE on incorrect expression from M1 Allow –604 (kJ mol^{-1}) from M_r = 40 in (b) If using –100 (kJ mol^{-1}) for answer to (b) Δ_rH_1 = –462 + (–286) – (–100) = –648 (kJ mol^{-1})	

(Total for Question 22 = 8 marks)

Question Number	Answer		Additional Guidance	Mark
17(a)	• moles of NaOH in titre	(1)	Example of calculation $27.15 \div 1000 \times 0.0960 = 2.6064 \times 10^{-3}$ / 0.0026064 / 0.00261 (mol)	(7)
	• total moles of HCl in solution after reaction with the carbonate	(1)	$0.0026064 \times 10 = 2.6064 \times 10^{-2}$ / 0.026064 / 0.0261 (mol)	
	• moles of HCl which reacted with $MgCO_3\ nH_2O$	(1)	$0.0600 - 0.026064 = 3.3936 \times 10^{-2}$ / 0.033936 / 0.0339 (mol)	
	• moles of $MgCO_3\ nH_2O$ in sample	(1)	$0.033936 \div 2 = 1.6968 \times 10^{-2}$ / 0.016968 / 0.0170 (mol)	
	• mass $MgCO_3$ in the sample	(1)	$0.016968 \times (24.3 + 12.0 + 3(16.0)) = 1.43040$ / 1.4304 / 1.43 (g)	
	• mass of water	(1)	$2.35 - 1.4304 = 0.9196$ (g)	
	• value of n to 1 SF	(1)	$(0.9196 \div 18) : 0.016968 = 3.01 = 3$ to 1 SF Allow TE throughout Ignore SF throughout	
	Alternative method for M5,6,7 • M_r hydrated salt	(1)	$2.35 \div 0.016968 = 138.500$	
	• mass of water	(1)	$138.500 - (24.3 + 12.0 + 3(16.0)) = 54.196$	
	• value of n to 1 SF	(1)	$54.196 \div 18 = 3.0109 = 3$ to nearest whole number	

Question Number	Answer		Additional Guidance	Mark
17(b)(i)	• calculation of energy produced	(1)	Example of calculation $Q = 40 \times 30.8 \times 4.18 = 5149.8$ / 5150 (J)	(3)
	• calculation of mols magnesium oxide and use in calculation	(1)	$1.92 \div (24.3 + 16) = 4.76 \times 10^{-2}$ / 0.047643 / 0.0476 / 0.048 (mol)	
	• calculation of $\Delta_r H_1$ and sign and units	(1)	$5149.8 \div 1000 \div 0.047643 = -108.09$ /– 108.1/ −108 kJ mol^{-1} Allow -108090 J mol^{-1} Ignore SF except 1 SF Correct answer with no working scores (3) Allow TE throughout +108.09 scores 2 marks	

Question Number	Answer		Additional Guidance	Mark
17(b)(ii)	• completed Hess cycle	(1)	Example of calculation  	(3)
	• $\Delta_r H = \Delta_r H_2 - \Delta_r H_1$	(1)	$3.58 - (-108.09)$	
	• answer to 2/3 SF	(1)	= (+) 111.67 / 111.7 / 112 / 110 = (+)112 / (+)110 (kJ mol^{-1}) TE from (i) Correct answer with no working scores M2 and M3	

Question Number	Answer	Additional Guidance	Mark
17(b)(iii)	An answer that makes reference to the following point: • it is difficult to measure the **temperature** of a solid/powder/ while it is being heated	Ignore references to non-standard conditions	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(c)(i)	An explanation that makes reference to the following points: • the temperature required to decompose calcium carbonate is higher (than that for magnesium carbonate)/the thermal stability of the Group 2 carbonates increases down the Group **(1)** • (because) the calcium ion is larger than magnesium ion/ the surface charge density of calcium ion is less/ magnesium ion is more polarising **(1)** • (so the) carbon - oxygen bond is less weakened **(1)**	Allow reverse arguments for M1 and M2 Do not award references to electronegativity/intermolecular forces Allow so carbon - oxygen bond is less polarised	**(3)**

Question Number	Answer	Additional Guidance	Mark
17(c)(ii)	An explanation that makes reference to the following points: • the (forward) reaction is exothermic so a low(er) temperature increases the yield of methanol **(1)** • but the rate will be too low (so a compromise temperature is used) **(1)** • there are fewer moles of gas on the RHS/products **(1)** • so high pressure will move the equilibrium position to the RHS/ increase the yield of methanol **(1)**	Allow reverse arguments Allow shifts the equilibrium position to RHS for increasing the yield of methanol Allow annotation on the equation Allow high pressure will cause more collisions / increase rate Ignore references to catalysts	**(4)**

(Total for Question 17 = 21 marks)

TOTAL FOR SECTION C = 21 MARKS
TOTAL FOR PAPER = 80 MARKS