Question Number	Answer
12	**The only correct answer is B** (4-methylhexan-3-ol) ***A*** *is not correct because the compound is 4-methylhexan-3-ol* ***C*** *is not correct because the compound is 4-methylhexan-3-ol* ***D*** *is not correct because the compound is 4-methylhexan-3-ol*

Question Number	Answer	Mark
7	**The only correct answer is A** (VO^{2+}) ***B*** *is not correct because the oxidation number of vanadium is +5 in this ion* ***C*** *is not correct because the oxidation number of vanadium is +5 in this ion* ***D*** *is not correct because the oxidation number of vanadium is +5 in this ion*	**(1)**

Question Number	Answer	Mark
6	**The only correct answer is B** (HF > HI > HBr > HCl) ***A*** *is not correct because the trend in boiling temperature of the hydrogen halides depends on the strength of the London forces as well as polarity* ***C*** *is not correct because HF has hydrogen bonding and a higher boiling temperature than HI* ***D*** *is not correct because HF has hydrogen bonding and the highest boiling temperature*	**(1)**

Question Number	Answer	Mark
10	**The only correct answer is D** (40) ***A*** *is not correct because a mole ratio of 2:1 instead of 1:2 has been used and the volume is in* dm^3 ***B*** *is not correct because this is the correct volume in* dm^3 ***C*** *is not correct because a mole ratio of 2:1 instead of 1:2 has been used*	**(1)**

Question number	Answer	Mark
12	**The only correct answer is B** (2.97 g) ***A*** *is incorrect because 1.48 g does not take into account that 2 mol* $Mg(NO_3)_2$ *decompose* ***C*** *is incorrect because 7.42 g does not take into account that 2 mol* $Mg(NO_3)_2$ *decompose or that 5 mol of gas form* ***D*** *is incorrect because 14.8 g does not take into account that 5 mol of gas form*	**(1)**

Question Number	Answer
5	**The only correct answer is A** (calcium carbonate) ***B*** *is not correct because it would give off a brown gas* ***C*** *is not correct because it would give a yellow flame and not thermally decompose* ***D*** *is not correct because it would give off a brown gas*

15	**The only correct answer is C** (0.683 mol dm^{-3}) ***A*** *is incorrect because this is the number of moles in the sample* ***B*** *is incorrect because this is double the number of moles in the sample* ***D*** *is incorrect because this is double the value of the concentration*

Question Number	Answer	Mark
7	**The only correct answer is A** ($Br_2 + F_2 \rightarrow 2BrF$) ***B*** *is not correct because chlorine is reduced and fluorine does not change oxidation state* ***C*** *is not correct because fluorine is reduced only* ***D*** *is not correct because this is not a redox reaction*	**(1)**

Question Number	Answer	Mark
17(a)	**The only correct answer is B** (all molecules possess some energy) ***A*** *is not correct because all molecules possess some energy* ***C*** *is not correct because the temperature cannot be 0 K* ***D*** *is not correct because this relates to the activation energy, and rate, for a chemical reaction*	**(1)**

Question Number	Answer	Mark
17(b)	**The only correct answer is B** (decreases, shifts to the left) ***A*** *is not correct because the area under the curve decreases (as there are fewer molecules)* ***C*** *is not correct because the area under the curve decreases (as there are fewer molecules) and the peak shifts to the left (as the molecules have less energy)* ***D*** *is not correct because the peak shifts to the left (as the molecules have less energy)*	**(1)**

(Total for Section A = 20 marks)

Question number	Answer	Mark
10	**The only correct answer is C** (the sodium ion has a larger ionic radius than the lithium ion) ***A*** *is incorrect because the greater reactivity of sodium does not lead to the formation of a peroxide* ***B*** *is incorrect because the lower first ionisation energy of sodium does not affect the oxide formed* ***D*** *is incorrect because thelithium ion has a higher charge density than the sodium ion*	**(1)**

Question Number	Answer
12(a)	**The only correct answer is C** (butan-2-ol) ***A** is incorrect because it would not have a peak at m/z 74* ***B** is incorrect because it would not have a peak at m/z 74* ***D** is incorrect because it would not have a peak at m/z 45*

Question Number	Answer
12(b)	**The only correct answer is C** (butan-2-ol) **A** *is incorrect because it is a ketone* **B** *is incorrect because it is an aldehyde which forms a carboxylic acid when oxidised* **D** *is incorrect because it is a tertiary alcohol*

Question Number	Answer
12(c)	**The only correct answer is B** (butanal) ***A** is incorrect because it is a ketone and not an aldehyde* ***C** is incorrect because it is an alcohol and not an aldehyde* ***D** is incorrect because it is an alcohol and not an aldehyde*

Question Number	Answer
1(a)	**The only correct answer is D** (Letter S) ***A** is not correct because P is the number of molecules with the modal energy* ***B** is not correct because Q is the number of molecules with the mean energy of the molecules* ***C** is not correct because R is the modal energy of the molecules*

Question Number	Answer
1(b)	**The only correct answer is B** (the peak becomes higher and further to the left) ***A** is not correct because the peak should become further to the left* ***C** is not correct because the peak should become higher and further to the left* ***D** is not correct because the peak should become higher*

Question Number	Answer
9	**The only correct answer is A** (sodium chloride, sodium chlorate(I) and water) ***B** is not correct because sodium chlorate(V) is not a product at room temperature* ***C** is not correct because sodium chloride is also formed* ***D** is not correct because water is also formed*

Question Number	Answer
14	**The only correct answer is D** (Na_2CO_3) ***A** is not correct because the oxidation number of Cr is +6* ***B** is not correct because the oxidation number of Mn is +6* ***C** is not correct because the oxidation number of S is +6*

Question Number	Answer	Mark
8	**The only correct answer is C** (bromine, hydrogen bromide and sulfur dioxide only) *A is incorrect because hydrogen bromide is oxidised by concentrated sulfuric acid*	**(1)** **Computer**
	B is incorrect because the bromide ions reduce the sulfuric acid to sulfur dioxide *D is incorrect because the bromide ions are not strong enough reducing agents to further reduce the sulfuric acid*	

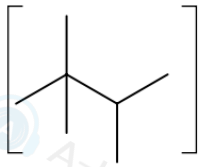
Question Number	Answer	Mark
9	**The only correct answer is C** ($Sr(NO_3)_2$) *A is not correct because LiCl would not form a precipitate when mixed with a solution of potassium sulfate* *B is not correct because $NaNO_3$ produces a yellow flame colour and would not form a precipitate when mixed with a solution of potassium sulfate* *D is not correct because $BaCl_2$ produces a green flame colour*	**(1)**

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
9	**The only correct answer is C** (increases, no change) ***A*** *is incorrect because the surface area of the magnesium has increased so the rate would increase* ***B*** *is incorrect because the surface area of the magnesium has increased so the rate would increase and magnesium is the limiting reagent* ***D*** *is incorrect because the magnesium is the limiting reagent*

Question Number	Answer	Mark
15	**The only correct answer is D** (1-iodobutane) ***A*** *is not correct because the carbon-halogen bond enthalpy decreases down the group* ***B*** *is not correct because the carbon-halogen bond enthalpy decreases down the group* ***C*** *is not correct because the carbon-halogen bond enthalpy decreases down the group*	**(1)**

Question number	Answer	Mark
4	**The only correct answer is D**  **A** *is incorrect because the alkane with the most carbon atoms will always have the highest boiling temperature* **B** *is incorrect because the alkane with the most carbon atoms will always have the highest boiling temperature* **C** *is incorrect because the alkane with the most carbon atoms will always have the highest boiling temperature*	**(1)**

Question Number	Answer
14(a)	**The only correct answer is D** (propanone) ***A*** *is not correct because propan-1-ol would give a colour change with acidified potassium dichromate(VI)* ***B*** *is not correct because propan-2-ol would give a colour change with acidified potassium dichromate(VI)* ***C*** *is not correct because propanal would give a colour change with acidified potassium dichromate(VI)*

Question Number	Answer
14(b)	**The only correct answer is A** (propan-1-ol) ***B*** *is not correct because propan-2-ol would not give a peak at m/z 31* ***C*** *is not correct because propanal would not give a peak at m/z 31or m/z 60* ***D*** *is not correct because propanone would not give a peak at m/z 31or m/z 60*

Question number	Answer	Mark
18(a)	**The only correct answer is C** (phosphoric(V) acid) ***A*** *is incorrect because 50% sulfuric acid is not concentrated enough to effect dehydration* ***B*** *is incorrect because ethanolic potassium hydroxide cannot effect elimination of alcohols, only of halogenoalkanes* ***D*** *is incorrect because red phosphorus is used with iodine to bring about a substitution reaction*	**(1)**

Question number	Answer	Mark
18(b)	**The only correct answer is A**(elimination) ***B*** *is incorrect because water is a product not a reactant* ***C*** *is incorrect because both hydrogen and oxygen are lost* ***D*** *is incorrect because no atom or group is replaced*	**(1)**

TOTAL FOR SECTION A = 20 MARKS

Question Number	Answer	Mark
6	**The only correct answer is D** (CH_4) ***A*** *is not correct because the oxidation state of F is –1 in HF* ***B*** *is not correct because the oxidation state of H is –1 in NaH* ***C*** *is not correct because the oxidation state of O is –1 in* H_2O_2	**(1)**

Number	
2(a)	**The only correct answer is D** (rate decreases, yield decreases) ***A*** *is not correct because the rate and yield would decrease* ***B*** *is not correct because the rate would decrease* ***C*** *is not correct because the yield would decrease*

Question Number	**Answer**
2(b)	**The only correct answer is B** (rate increases, yield decreases) ***A*** *is not correct because the yield would decrease* ***C*** *is not correct because the rate would increase and the yield decrease* ***D*** *is not correct because the rate would increase*

Question Number	**Answer**
2(c)	**The only correct answer is C** (416) ***A*** *is not correct because only one* H_2 *has been included in the calculation* ***B*** *is not correct because a value of – 206 was used as the enthalpy change* ***D*** *is not correct because only one O-H bond has been included in the calculation*

Question Number	**Answer**
13	**The only correct answer is A** (LiCl) ***B*** *is not correct because NaCl would give a yellow flame test* ***C*** *is not correct because NaBr would give a yellow flame test and a cream ppt with silver nitrate* ***D*** *is not correct because RbBr would give a cream ppt with silver nitrate*

12(a)	**The only correct answer is D** (0.702 mol dm^{-3}) ***A*** *is incorrect because the stoichiometry has been used incorrectly* ***B*** *is incorrect because volumes have been used the wrong way around* ***C*** *is incorrect because the stoichiometry has not been used*

Question Number	Answer
12(b)	**The only correct answer is D** (0.68%) ***A*** *is incorrect because this is the error of a burette in cm^3 times two* ***B*** *is incorrect because this is the error if only one reading is taken* ***C*** *is incorrect because this is the error using the pipette value*

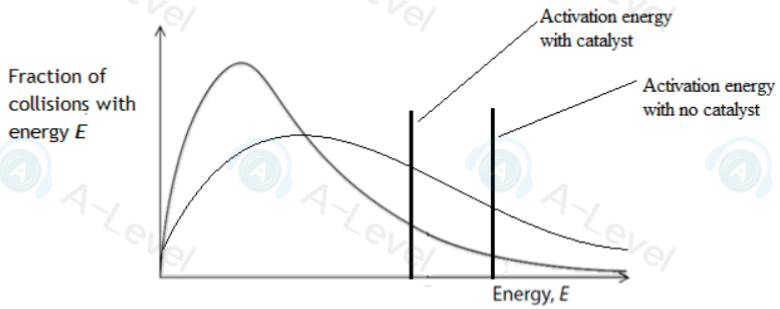
Question Number	Answer
8	**The only correct answer is B** (9×10^{22}) ***A*** *is not correct because the number of moles has not been multiplied by 3* ***C*** *is not correct because the number of moles has been multiplied by 4* ***D*** *is not correct because the number of moles has been multiplied by 5*

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
10	**The only correct answer is A** (an increase in reaction temperature) ***B*** *is incorrect because at a lower temperature a smaller proportion of particles have sufficient energy to react* ***C*** *is incorrect because an increase in reactant concentration does not change the proportion of particles that have sufficient energy to react* ***D*** *is incorrect because a decrease in reactant concentration does not change the proportion of particles that have sufficient energy to react*

Question number	Answer	Additional guidance	Mark
21(a)(i)	A diagram showing the following • new line starting at the origin **and** lower maximum **and** peak moved to the right **and** asymptotic line above the original	Do not award if any part of the curve to the right of the peak is below the 300°C line Do not award if asymptote finishes higher than 25% the height of the new peak	**(1)** **clip with (a)(ii)**

Example of Maxwell-Boltzmann distribution



Question number	Answer	Additional guidance	Mark
21(a)(ii)	An answer that makes reference to the following EITHER • Increasing the temperature increases the (average kinetic) energy of collisions **and** so more collisions have energy greater than the activation energy (1) • adding a catalyst lowers the activation energy **and** so more collisions have energy greater than the activation energy (1) OR • (rate increases when) more collisions have an energy greater than (or equal to) the activation energy (1) • the area under the curve beyond E_a is increased when the temperature is increased **and** when E_a becomes E_{cat} (1)	Allow particles / molecules / atoms for collisions throughout Allow just 'increasing the temperature increases the number of collisions with energy greater than E_a' Standalone mark Allow particles / molecules / atoms for collisions In no other mark is scored increasing the temperature increases the (average kinetic) energy of collisions **and** adding a catalyst lowers the activation energy scores (1) M2 may be scored by clear labelling of the relevant areas under the curves	**(2)** **clip with (a)(i)**

Question number	Answer	Additional guidance	Mark
21(b)	An answer that makes reference to the following • Advantage: hydrogen is a useful by-product (1) • Disadvantage: higher temperature means higher energy costs (1)	Allow higher atom economy Ignore higher temperature gives higher rate Ignore oxygen not needed Allow higher temperature is more expensive Allow the energy required is more expensive Allow higher temperature needs more expensive equipment Allow more energy is required Ignore just 'more expensive' Ignore reference to yield Do not award the hazards of hydrogen	**(2)**

Question number	Answer	Additional guidance	Mark
21(c)	An answer that makes reference to the following • (methanol) O—H stretch wavenumber range 3750-3200 (cm^{-1})(1) • (methanal) C=O stretch wavenumber range 1740-1720 (cm^{-1}) or (methanal) C—H stretch wavenumber range 2900-2820 (cm^{-1}) or (methanal) C—H stretch wavenumber range 2775-2700 (cm^{-1}) (1)	Allow OH or CO Ignore ROH / CH_3OH / HCHO Both wavenumber ranges without bonds scores (1) Specific wavenumbers within the ranges or wavenumber ranges within the Data Booklet ranges scores max (1) If more than one wavenumber is given for methanal all must be correct Ignore alkyl C—H stretch wavenumber ranges	(2)

(Total for Question 21 = 7 marks)

TOTAL FOR SECTION B = 39 MARKS

Question Number	Answer	Additional Guidance	Mark
18(a)	• conversion of temperature to K **and** conversion of kPa to Pa **(1)** • conversion of cm^3 to m^3 **(1)** • rearrangement of ideal gas equation **(1)** • calculation of n **(1)** • calculation of relative molecular mass **(1)**	Example of calculation: $95 + 273 = 368$ $99 \times 1000 = 99000$ (Pa) $81 \times 10^{-6} = 8.1 \times 10^{-5}$ (m^3) $n = \frac{pV}{RT}$ $\frac{99000 \times 8.1 \times 10^{-5}}{8.31 \times 368} = 2.6222 \times 10^{-3}$ (mol) $\frac{0.12}{2.6222 \times 10^{-3}} = 45.763$ (g mol^{-1}) TE throughout Ignore intermediate rounding Ignore SF except 1 Correct answer with some working scores 5	(5)

Question Number	Answer	Additional Guidance	Mark
18(b)	An answer that makes reference to the following point: • ethanol/ CH_3CH_2OH/C_2H_5OH/C_2H_6O	Accept methoxymethane/CH_3OCH_3 Allow dimethyl ether Allow TE from (a) provided it is a formula that could exist	(1)

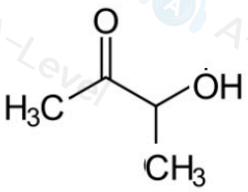
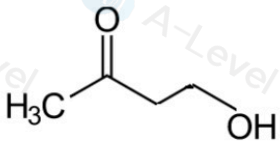
(Total for Question 18 = 6 Marks)

Question Number	Answer		Additional Guidance	Mark
20(a)(i)	• calculation of percentage of oxygen	(1)	Example of calculation 100 – 54.5 – 9.1 = 36.4 (%)	(3)
	• calculation of **moles** of C, H and O in 100 g	(1)	C = 54.5/12 = 4.5417 H = 9.1/1 = 9.1 O = 36.4/16 = 2.275	
	• (divide by the lowest number to get the ratio) **and** correct empirical formula	(1)	O: 2.275/2.275 = 1 H: 9.1/2.275 = 4 C: 4.5417/2.275 = 1.9964 C_2H_4O	

Question Number	Answer	Additional Guidance	Mark
20(a)(ii)	• C_2H_4O = 44 $88 \div 44 = 2$ **and** molecular formula = $C_4H_8O_2$	Allow any suitable use of 44 e.g. $2 \times 44 = 88$ Allow $88 \div (2 \times 12 + 4 + 16)$ No TE from (a)(i)	(1)

Question Number	Answer		Additional Guidance	Mark
20(b)(i)	An answer that makes reference to the following points:			(3)
	• (acetoin reacted with PCl_5) so must) contain an OH group	(1)	Allow contains and alcohol or a carboxylic acid Ignore hydroxyl group Do not award it just alcohol or carboxylic acid are stated on their own	
	• (acetoin did not react with sodium hydrogencarbonate so) it is not a carboxylic acid / it is an alcohol	(1)	Allow not COOH Allow not a tertiary alcohol	
	• (acetoin reacted with potassium dichromate(VI) solution so must) contain a 1° or 2° alcohol	(1)	Allow an alcohol that can be oxidised	

Question Number	Answer			Additional Guidance	Mark
20(b)(ii)		Bond	Wavenumber range / cm^{-1}	Both bond and wavenumber range required for each mark	(3)
	Absorption present in acetoin but not in an aldehyde	C=O	1720-1700	Do not award 1700 – 1680	(1)
	One absorption present in an aldehyde but not in acetoin	C=O Or C-H	1740-1720 2900-2820 or 2775-2700	Allow boxes 2 and 3 to both contain the C-H bond but different wave numbers	(1)
	Another absorption present in an aldehyde but not in acetoin	C-H	2900-2820 or 2775-2700	The full range is required as they are quoting from the data book. Ranges can be reversed d e.g. 1700-1720	(1)

Question Number	Answer		Additional Guidance	Mark
20(b)(iii)	An answer that makes reference to the following points:			(3)
	• (peak at 45) CH_3CHOH^+/ $CH_2CH_2OH^+$/$C_2H_4OH^+$/$C_2H_5O^+$	(1)	Allow displayed/ skeletal/ molecular Do not award $CH_3CH_2O^+$	
	• (peak at 43) CH_3CO^+/ $C_2H_3O^+$	(1)	Do not award $C_3H_7^+$ Do not award CH_2COH^+/ CH_2CHO^+ Penalise missing + once only	
	• a structure consistent with these peaks  	(1)	Penalise wrong connectivity to the OH- only when horizontal and only once.	

(Total for Question 20 = 13 marks)

Section B

Question Number	Answer		Additional Guidance	Mark
18(a)	An explanation that makes reference to the following points:			**(3)**
	• disproportionation (of chlorine)	**(1)**	Ignore redox Do not award disproportionation of calcium/oxygen/hydrogen	
	• (oxidation numbers of chlorine) 0 (in Cl_2) **and** (+)1 in $Ca(ClO)_2$ **and** −1 in $CaCl_2$	**(1)**	Allow annotations on the equation Allow 1− Do not award if any other element is also changing oxidation number	
	• oxidised from 0 to +1 **and** reduced from 0 to −1	**(1)**	Allow oxidation is increase in oxidation number **and** reduction is decrease in oxidation number TE on oxidation numbers given in M2, even for Ca/O/H Ignore any reference to oxidising agents / reducing agents Ignore any reference to electron transfer	

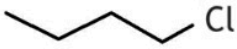
Question Number	Answer		Additional Guidance	Mark
18(b)	An answer that makes reference to the following points:		Examples of calculation:	**(2)**
	• M_r of $Ca(ClO)_2$	**(1)**	$M_r = 40.1 + 2 \times 16.0 + 2 \times 35.5 = 143.1$ Allow 143.0 / 143	
	• percentage atom economy (by mass)	**(1)**	$\frac{143.1}{(143.1 + 111.1 + 2 \times 18.0)} \times 100 = 49.311(\%)$ Allow use of 143 for M_r of $Ca(ClO)_2$ and 111 for M_r of $CaCl_2$ giving 49.310(%) OR $\frac{143.1}{(2 \times 74.1 + 2 \times 71.0)} \times 100 = 49.311(\%)$ Allow use 143 for M_r of $Ca(ClO)_2$ and 74 for M_r of $Ca(OH)_2$ giving 49.310(%) TE on M_r of $Ca(ClO)_2$ Ignore SF except 1SF Correct answer with some working scores (2)	

Question Number	Answer	Additional Guidance	Mark
18(c)(i)	• volume of swimming pool water **(1)** • mass of $Ca(ClO)_2$ = concentration × volume **(1)** • mass of $Ca(ClO)_2$ in kg **(1)**	Example of calculation: **In M1 and M2, Allow expression and/or evaluation** volume = 50 × 25 × 2.0 = 2500 (m^3) Ignore units, even if incorrect mass = 2500 ($\times 10^3$) × 4.2 ($\times 10^{-3}$) = 10500 (g) Ignore units, even if incorrect Do not award multiplication by 143.1 / 143 / molar mass 10.5 (kg) TE only if 10500 × 143.1 (or 143) in M2, giving 1502.55 (or 1501.5) (kg) Ignore SF except 1 SF Correct answer with some working scores (3)	**(3)**

Question Number	Answer	Additional Guidance	Mark
18(c)(ii)	• moles $Ca(ClO)_2$ **(1)** • moles Cl_2 **(1)** • volume Cl_2 in dm^3 OR volume Cl_2 in cm^3 OR volume Cl_2 in m^3 **(1)**	Example of calculation: moles = 10500 ÷ 143.1 = 73.375 TE on mass $Ca(ClO)_2$ from (c)(i) TE on $M(Ca(ClO)_2)$ from (b) Allow 73.427 from $M(Ca(ClO)_2)$ = 143 moles = 73.375 × 2 = 146.75 TE on moles $Ca(ClO)_2$ Allow 146.85 from $M(Ca(ClO)_2)$ = 143 volume = 146.75 × 24 = 3522.0/3522/3520/3500 (dm^3) volume = 146.75 × 24000 = 3.5220/3.522/3.52/3.5 × 10^6 (cm^3) volume = 146.75 × 0.024 = 3.5220/3.522/3.52/3.5 (m^3) TE on moles Cl_2 Allow omission of units Do not award incorrect units Ignore SF except 1 SF Correct answer with some working scores (3)	**(3)**

(Total for Question 18 = 11 marks)

Question Number	Answer	Additional Guidance	Mark
17(a)(i)	An answer that makes reference to the following point: • 2-iodo-(2)-methylpropane	Allow 2-methyl-2-iodopropane Allow 2,2 iodomethylpropane Ignore missing hyphens Ignore gaps Ignore commas instead of hyphens Do not award 2-iodine -2-methylpropane Do not award 2-iodino -2-methylpropane	(1)

Question Number	Answer	Additional Guidance	Mark
17(a)(ii)	An answer that makes reference to the following point: • 	Ignore angles/ length of bonds	(1)

Question Number	Answer	Additional Guidance	Mark
17(b)(i)	An answer that makes reference to the following points: • observation with **A** yellow precipitate/ solid **(1)** • observation with **B** white precipitate/ solid **(1)**	Allow ppt/ppte or near miss spellings Allow precipitation Ignore formula even if incorrect Yellow solution and white solution score 1 Precipitation colours reversed score 1 Do not award with any other wrong observations eg steamy fumes. Ignore any further tests on the ppt e.g. addition of ammonia	(2)

Question Number	Answer		Additional Guidance	Mark
17(b)(ii)	An answer that makes reference to the following points: • **A** is a tertiary (halogenoalkane) **and B** is a primary one	(1)	Allow reverse argument for both points Accept **A** reacts via a tertiary carbocation and **B** reacts via a primary one Allow just tertiary reacts faster than primary Do not award **A** is a tertiary carbocation **and B** is a primary one Do not award tertiary halogenoalkane is more stable	(2)
	• the C-I bond is weaker than the C-Cl bond (so **A** reacts faster)	(1)	Accept C-I bond enthalpy is less than C-Cl Allow C-I bond easier to break Ignore just C-I is easy to break/weak as there must be a comparison. Ignore any references to iodine/chlorine eg electronegativity /reactivity Ignore S_N1 faster than S_N2	

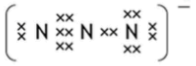
Question Number	Answer		Additional Guidance	Mark
17(c)(i)	An answer that makes reference to the following points: • $C_4H_9Cl + KCN \longrightarrow C_4H_9CN + KCl$	(1)	Allow ionic equation $C_4H_9Cl + CN^- \longrightarrow C_4H_9CN + Cl^-$ Allow displayed, molecular, full structural or skeletal formula Ignore state symbols even if incorrect	(2)
	• pentanenitrile	(1)	Allow pentane nitrile Allow pentanonitrile Allow pentane-1-nitrile Allow pentannitrile (missing the e) Allow pentanitrile (missing n and e)	

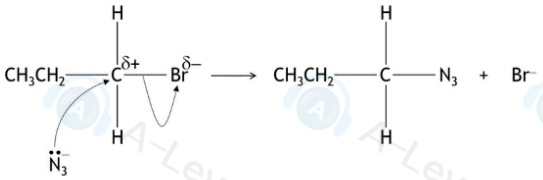
Question Number	Answer	Additional Guidance	Mark
17(c)(ii)	An answer that makes reference to the following point: • it is a way of extending the carbon chain/ adding extra carbon(s)		(1)

(Total for Question 17 = 9 Marks)

Question Number	Answer	Additional Guidance	Mark
20(a)	An answer that makes reference to the following points: • hydrogen chloride / HCl((g))	Allow hydrochloric acid / HCl(aq) Ignore any reference to conditions Do not award any additional reagents	**(1)**

Question Number	Answer	Additional Guidance	Mark
20(b)	An answer that makes reference to the following points: • CH_3CH_2CN / C_2H_5CN	Accept displayed or skeletal formula Ignore any inorganic products, even if incorrect Ignore any reagents / conditions Do not award any additional organic products Do not award C_3H_5N	**(1)**

Question Number	Answer	Additional Guidance	Mark
20(c)(i)	An answer that makes reference to the following points: • 8 electrons surrounding central N atom **or** 8 electrons surrounding **both** terminal N atoms **(1)** • 8 electrons surrounding **all** N atoms **and** a total of 16 outer shell electrons **(1)**	**Mark independently** Examples of correct diagram:   Do not award incorrect charge Allow any symbols to represent outer shell electrons and allow any combination, eg  Allow bonded electrons to be shown as pairs, eg  Allow circles to indicate outer shells Ignore inner shell electrons Ignore lines representing bonds Ignore displayed diagrams	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(c)(ii)	An answer that makes reference to the following points: • lone pair on N of N_3^- **and** curly arrow from lone pair to C of C–Br **(1)** • dipole shown on C–Br **and** curly arrow from C–Br bond to (δ–)Br **(1)** • organic product **and** bromide ion **(1)**	Example of correct mechanism:  Penalise half-headed arrows once in M1 and M2 Do not award curly arrow from negative charge on N_3^- Allow $CH_3CH_2CH_2N_3$ for organic product Allow $C_3H_7N_3$ for organic product Ignore structure of N_3 group if displayed Do not award charged organic product Allow $K^{(+)}Br^{(-)}$ Ignore K^+ spectator ion Do not award K–Br Do not award Br atom Do not award any additional inorganic product	**(3)**

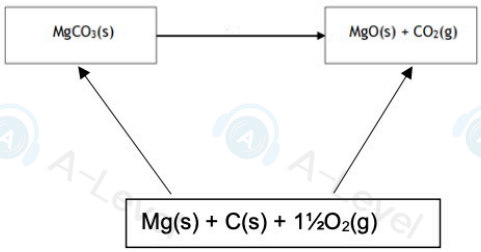
Question Number	Answer	Additional Guidance	Mark
20(d)(i)	An answer that makes reference to the following points: • alcohol (solvent) **(1)** • under (high) pressure **(1)**	Accept ethanol Allow aqueous ethanol Ignore concentrated/excess NH_3 Do not award KOH/NaOH/alkaline Allow any stated pressure above 100 kPa / 1 atm Ignore any reference to heat	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(d)(ii)	An answer that makes reference to one of the following points: • secondary amine / tertiary amine / quarternary (ammonium) salt may form	Allow further **substitution** may occur Allow product may react with 1-bromopropane Allow 1-bromopropane/haloalkane in excess Allow NH_3/ammonia not in excess Ignore just amine reacts further Ignore just side products / side reactions Do not award any reference to atom economy	**(1)**

(Total for Question 20 = 10 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	<u>Example of calculation</u> 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)**	<u>Example of calculation</u> (–)–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:			(3)
	• the enthalpy change (of calcium carbonate) would be more positive/endothermic	(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	
	• Ca^{2+} is larger than Mg^{2+}	(1)	Allow Ca ion larger than Mg ion Ignore Ca is larger than Mg Ignore atomic radius	
	• so Ca^{2+} is less polarising / CO_3^{2-} less distorted (so more heat needed to decompose it)	(1)	Ions must be mentioned at least once in M2 and M3, but only penalise once. Allow reverse argument for all points	

(Total for Question 18 = 10 Marks)