Mark Scheme (Results)

Summer 2024

Pearson International Advanced Subsidiary Level In Chemistry (WCH12)
Paper 01R: Energetics, Group Chemistry, Halogenoalkanes and Alcohols

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Section A

Question Number	**Answer**	**Mark**
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*	(1)

Question Number	**Answer**	**Mark**
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*	**(1)**

Question Number	**Answer**	**Mark**
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*	**(1)**

Question Number	Answer	Mark
3(a)	**The only correct answer is C** (pressure of the system) ***A*** *is not correct because concentration will affect the reaction rate* ***B*** *is not correct because particle size will affect the reaction rate* ***D*** *is not correct because temperature will affect the reaction rate*	**(1)**

Question Number	Answer	Mark
3(b)	**The only correct answer is C** ($1.50\ cm^3\ s^{-1}$) ***A*** *is not correct because the time has been divided by the volume* ***B*** *is not correct because this is the final volume divided by the time the reaction finishes* ***D*** *is not correct because this is using the values at 20 seconds*	**(1)**

Question Number	Answer	Mark
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* $N \equiv N$ *has not been divided by 2* ***D*** *is not correct because the value has not been divided by 3 to get the bond energy*	**(1)**

Question Number	Answer	Mark
5	**The only correct answer is D** (2.59×10^{25}) ***A*** *is not correct because 58 has been divided by 2500* ***B*** *is not correct because kg has not been converted to g* ***C*** *is not correct because 58 has been divided by 2.5 and kg has not been converted to g*	**(1)**

Question Number	Answer	Mark
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*	**(1)**

Question Number	Answer	Mark
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 %*	**(1)**

Question Number	Answer	Mark
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*	**(1)**

Question Number	Answer	Mark
8	**The only correct answer is D** (they all show variable oxidation states in their compounds) ***A*** *is not correct because they all exist as diatomic molecules* ***B*** *is not correct because electronegativity decreases down the group* ***C*** *is not correct because reactivity increases up the group*	**(1)**

Question Number	Answer	Mark
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*	**(1)**

Question Number	**Answer**	**Mark**
10	**The only correct answer is C** (sulfuric acid acts as an oxidising agent) ***A*** *is not correct because bromide ions are oxidised* ***B*** *is not correct because hydrogen sulfide is not formed* ***D*** *is not correct because hydrogen sulfide is not formed*	**(1)**

Question Number	**Answer**	**Mark**
11	**The only correct answer is C** (the solubility of the hydroxides increases and the solubility of the sulfates decreases) ***A*** *is not correct because the solubility of the sulfates decreases* ***B*** *is not correct because the solubility of the hydroxides increases* ***D*** *is not correct because the solubility of the hydroxides increase and the solubility of the sulfates decreases*	**(1)**

Question Number	**Answer**	**Mark**
12	**The only correct answer is B** (KNO_3) ***A*** *is not correct because* $LiNO_3$ *gives off brown fumes* ***C*** *is not correct because* $Ca(NO_3)_2$ *gives off brown fumes* ***D*** *is not correct because* $Ba(NO_3)_2$ *gives off brown fumes*	**(1)**

Question Number	Answer	Mark
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*	**(1)**

Question Number	Answer	Mark
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*	**(1)**

Question Number	Answer	Mark
15	**The only correct answer is A** (XWZY) ***B*** *is not correct because bromoalkanes have higher boiling temperatures than alkanes* ***C*** *is not correct because straight-chained molecules have higher boiling temperatures than branched ones.* ***D*** *is not correct because straight-chained molecules have higher boiling temperatures than branched ones.*	**(1)**

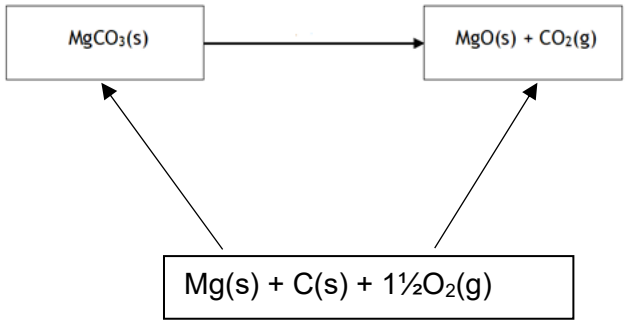
Question Number	Answer	Mark
16	**The only correct answer is B** (5) ***A*** *is not correct because there are 5 isomers* ***C*** *is not correct because there are 5 isomers* ***D*** *is not correct because there are 5 isomers*	**(1)**

Question Number	Answer	Mark
17	**The only correct answer is D (** **)**  ***A*** *is not correct because this is oxidised to a ketone* ***B*** *is not correct because this is oxidised to a ketone* ***C*** *is not correct because it cannot be oxidised*	**(1)**

(Total for Section A = 20 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: • 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	**(3)**
	• 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)

Question Number	Answer	Additional Guidance	Mark
19(a)(i)	An answer that makes reference to the following points: • the mixture will turn darker/more blue **(1)** • equilibrium moves in the **endothermic** direction (to the right) **(1)**	 Allow turns blue Allow more blue gas formed Ignore just colour changes Allow favours Allow just forward reaction is **endothermic** Ignore any reference to rate	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(a)(ii)	An answer that makes reference to the following points: • the mixture will turn darker/more blue **(1)** • equilibrium moves to the side with fewer (gaseous) moles/molecules/particles (to the right) **(1)**	 Allow turns blue Allow more blue gas formed Ignore just colour changes Allow just fewer moles/molecules/particles on the right or more moles/molecules/particles on the left Allow gets more blue/darker because the molecules are more concentrated / take up less volume (score 2) Ignore any reference to rate	**(2)**

Question Number	Answer		Additional Guidance	Mark
19(b)	An answer that makes reference to the following points: • (ozone is an) oxidising agent/oxidant • S goes from $^{-}2$ (in H_2S) to +6 (in sulfuric acid) **and** is oxidised • O goes from 0 (in ozone) to – 2 (in sulfuric acid) **and** is reduced	**(1)** **(1)** **(1)**	Look at the equation as the oxidation numbers may be written by the species Allow ozone oxidises the sulfur Allow sulfide goes from $^{-}2$ to +6 (in sulfuric acid) **and** is oxidised If reduction and oxidation are not stated or incorrect, one mark can be scored the correct oxidation numbers of S and O.	**(3)**

Question Number	Answer		Additional Guidance	Mark
19(c)	• calculation of mass of water in the pool • calculation of ppm	**(1)** **(1)**	<u>Example of calculation</u> $375\,000 \times 1000 = 375\,000\,000 / 3.75 \times 10^8$ (g) $15\text{ (g)} \div 375\,000\,000\text{ (g)} \times 10^6 = 0.04$ or 4×10^{-2} or $\frac{1}{25}$ (ppm) Correct answer with no working scores 2	**(2)**

(Total for Question 19 = 9 marks)

Question Number	Answer		Additional Guidance	Mark
20(a)(i)	• calculation of percentage of oxygen	**(1)**	<u>Example of calculation</u> 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 ÷ 44 = 2 **and** molecular formula = $C_4H_8O_2$	Allow any suitable use of 44 e.g. 2 × 44 = 88 Allow 88 ÷ (2 × 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	
	• (acetoin reacted with potassium dichromate(VI) solution so must) contain a 1^o or 2^o alcohol	**(1)**	Allow not a tertiary alcohol Allow an alcohol that can be oxidised	

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>20(b)(ii)</td><td>
<table>
<tr><th></th><th>Bond</th><th>Wavenumber range / cm $^{-1}$</th></tr>
<tr><td>Absorption present in acetoin but not in an aldehyde</td><td>C=O</td><td>1720-1700</td></tr>
<tr><td>One absorption present in an aldehyde but not in acetoin</td><td>C=O
Or
C-H</td><td>1740-1720

2900-2820 or 2775-2700</td></tr>
<tr><td>Another absorption present in an aldehyde but not in acetoin</td><td>C-H</td><td>2900-2820 or 2775-2700</td></tr>
</table>
(1)

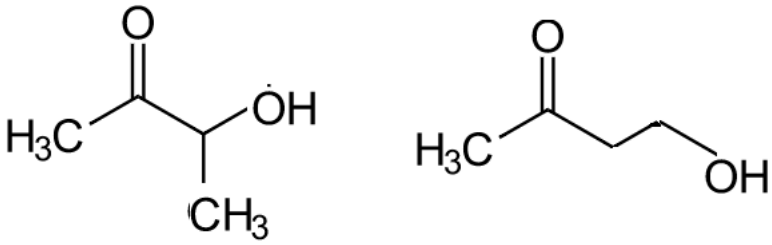
(1)

(1)
</td><td>Both bond and wavenumber range required for each mark

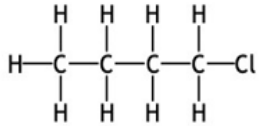
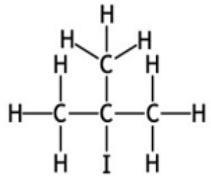
Do not award 1700 – 1680

Allow boxes 2 and 3 to both contain the C-H bond but different wave numbers

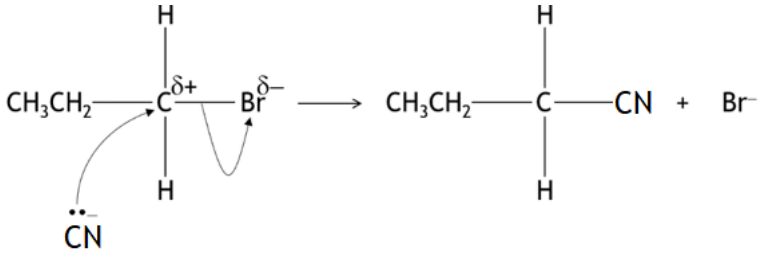
The full range is required as they are quoting from the data book.
Ranges can be reversed d e.g. 1700-1720</td><td>(3)</td></tr>
</table>

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

(Total for Question 20 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
21(a)	An answer that makes reference to the following points: •  **(1)** •  **(1)** • one mark for **both** names 1-chlorobutane **and** 2-iodo-(2)-methylpropane **(1)**	Penalise non-displayed formulae once only Ignore connectivity of the Cl e.g. Cl- Penalise missing Hs once only Allow 2-methyl-2- iodopropane Allow 2-iodomethylpropane Allow methyl-2- iodopropane Accept 2,2-iodomethylpropane Accept 2,2-methyiodolpropane Ignore missing hyphens. Ignore any spaces or commas	**(3)**

Question Number	Answer	Additional Guidance	Mark
21(b)	An answer that makes reference to the following points: • **C-I** bond is weaker (than C-Cl bond) **(1)** • tertiary halogenoalkanes react faster than primary **(1)**	Allow less energy needed to break the C-I bond Allow C-I bond is longer than C-Cl bond Allow reverse argument Ignore just iodine/iodide has a weaker bond Ignore any reference to bond polarity/ electronegativity even if wrong Allow tertiary faster/ fastest Ignore just tertiary Ignore any reference to S_N1/ stability of carbocations	**(2)**

Question Number	Answer	Additional Guidance	Mark
21(c)	An answer that makes reference to the following points: **(3)**  Comment The first curly arrow must come from the lone pair or be able to be traced back to **any point across the width** of the lone pair. The second curly arrow must come from the C- Br bond or be able to be traced back to **any point** of the bond. If CN bonds shown it must be triple	There are 6 marking points lone pair on C of CN^- dipole on C-Br curly arrow from lone pair to C curly arrow from bond to Br Final organic product Br^- 6 = 3 marks 4-5 = 2 2-3 = 1 If the lone pair is missing the curly arrow can come form the C and will score so we only penalise the missing lone pair once Ignore intermediate carbocation Ignore intermediate with both CN and Br attached as long as it has a negative charge Ignore lone pair on the bromide ion	**(3)**

(Total for Question 21 = 8 marks)
(Total for Section B = 40 marks)

Section C

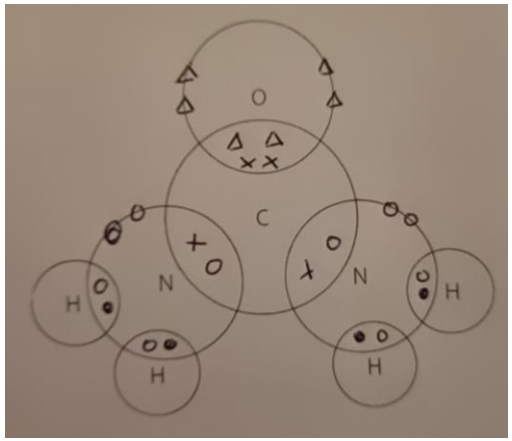
Question Number	Answer		Additional Guidance	Mark
22(a)	An explanation that makes reference to the following points: • method 2 is more sustainable because it does not use methane/fossil fuels • methane/fossil fuels are a finite resource / solar power is renewable • because it does not produce CO_2 / does not produce greenhouse gases / contribute to global warming	**(1)** **(1)** **(1)**	Allow reverse arguments for all points Allow method 2 is more sustainable as method 1 uses methane/fossil fuels Ignore it produces oxygen Allow methane is a finite energy (resource) Allow water is renewable if related to method 2 Ignore clean energy from solar power Ignore solar is a sustainable resource Ignore good for the environment Ignore any reference to atom economy etc Ignore any reference to intermolecular forces etc Penalise wrong chemistry only once	**(3)**

Question Number	Answer	Additional Guidance	Mark
22(b)(i)	• calculation of % N	Example of calculation: $28 \div 80 \times 100 = 35\%$ Correct answer with no working scores 1	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(b)(ii)	An answer that makes reference to the following points: • advantage: ammonia has a high % N **(1)** • disadvantage: ammonia is a gas (so hard to apply) **(1)**	Allow just contains more N Allow ammonia (as it is a gas) will escape Allow ammonia is a base/alkali/will increase the pH Allow it is toxic Allow it is corrosive Allow it will evaporate Allow (as it is a gas) it is harder to transport/store Ignore it has a bad smell Ignore it is a greenhouse gas Ignore any reference to cost/atom economy	**(2)**

Question Number	Answer	Additional Guidance	Mark
22(c)(i)	• $HNO_3 + NH_3 \longrightarrow NH_4NO_3$ Or $HNO_3 + NH_4OH \longrightarrow NH_4NO_3 + H_2O$	Allow NH_4^+ and NO_3^- Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(c)(ii)	An answer that makes reference to the following points: • neutralisation (reaction)/neutralization (reaction)	Allow acid/base (reaction)	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(d)	An answer that makes reference to the following points: • correct electrons round C ie a double bond to the O and 2 singles to the Ns **(1)** • rest of the electrons correct **(1)** 	Allow all dots or crosses or any combination of any symbols	**(2)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>*22(e)</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.

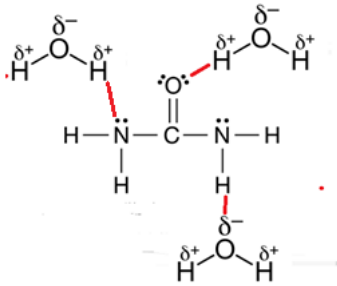
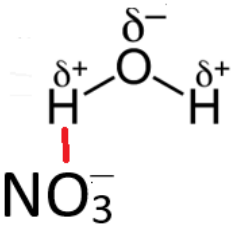
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some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

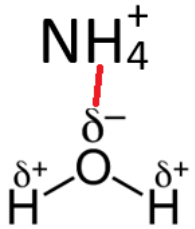
If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

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 exp</td>
</tr>
</table>

Question Number	Answer	Additional Guidance
*22(e)	**Indicative points**	
	IP1 hydrogen bonds are formed between water and urea	Allow H bonds Allow both water and urea have hydrogen bonds
	IP2 urea is soluble in water as the hydrogen bonds formed are stronger/ similar in magnitude to the intermolecular forces between the individual molecules	Allow a comparison with any intermolecular force/ London forces/dipole-dipole forces/hydrogen bonds
	IP3 diagram showing **one** hydrogen bond between urea and water Note ignore lack of lone pairs, dipoles and bond angles, including the hydrogen bond If the hydrogen bond is labelled this will score IP1 and IP3	 Ignore if multiple water molecules and hydrogen bonds are shown.
	IP4 ammonium nitrate is soluble in water as the water **hydrates** the ions (and the bonds formed are stronger/ similar in magnitude to the ionic bonds)	Allow ion- dipole interaction
	IP5 diagram showing the interaction between nitrate ions and water Ignore lack of diploes	 The H must be adjacent to the nitrate ion

	IP6 diagram showing the interaction between ammonium ions and water	The hydration attraction does not need to be shown Ignore if both Hs of a water molecule are attracted to the same ion Ignore multiple water molecules attracted to a single ion  The O must be must be adjacent to the ammonium ion The hydration attraction does not need to be shown Ignore multiple water molecules attracted to a single ion **IP3**, **5** and **6** must be scored via diagrams. **IP1** and **4** may be scored by annotated diagrams.

Question Number	Answer	Additional Guidance	Mark
22(f)	• calculation of the number of hectares **(1)** • calculation of the mass of N required **(1)** • calculation of the mass of urea required **(1)** • answer in tonnes to 2 or 3 SF **(1)**	<u>Example of calculation</u> (500 × 640) ÷ 10000 = 32 ha 32 × 160 × 1000 = 5120000 g / 5120 kg/ 5.12×10^6 (g) 5120000 (g) × 100/46.7 = 10963597 g / 1.0963597×10^7 g / 10964 kg/ 10.964 tonnes 11 (tonnes)/11.0 (tonnes) TE throughout Correct answer with no working scores 4	**(4)**

(Total for Section C = 20 marks)
TOTAL FOR PAPER = 80 MARKS

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