Pearson

Mark Scheme (Results)

October 2025

Pearson Edexcel International Advanced
Subsidiary Level in Chemistry
WCH12/01A

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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.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.

Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities. Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Section A

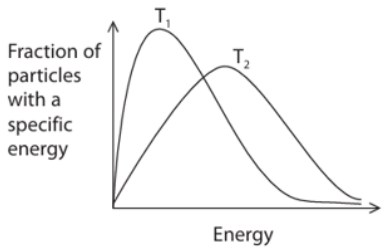
Question Number	Answer	Mark
1	**The only correct answer is A** (X) ***B*** *is incorrect because Y represents the activation energy of the reverse reaction* ***C*** *is incorrect because X−Y is the enthalpy change for the reaction* ***D*** *is incorrect because X+Y is the sum of the activation energies*	**(1)**

Question Number	Answer	Mark
2	**The only correct answer is C** (hydrogen ions act as oxidising agents) ***A*** *is incorrect because magnesium atoms lose electrons* ***B*** *is incorrect because hydrogen molecules are a product* ***D*** *is incorrect because chloride ions do not gain or lose electrons*	**(1)**

Question Number	Answer	Mark
3	**The only correct answer is C** (300 cm^3) ***A*** *is incorrect because the stoichiometry has not been considered* ***B*** *is incorrect because the stoichiometry and the differences in concentration have not been considered* ***D*** *is incorrect because the stoichiometry has not been considered and the ratio of concentrations has been used the wrong way round*	**(1)**

Question Number	Answer	Mark
4	**The only correct answer is B** ($300\ cm^3$) ***A*** *is incorrect because this assumes that the ratio of magnesium nitrate to gaseous products is 1:5* ***B*** *is incorrect because this assumes the only gaseous product is* NO_2 ***D*** *is incorrect because this assumes the ration of magnesium nitrate to gaseous products is 1:1*	**(1)**

Question Number	Answer	Mark
5	**The only correct answer is D** (NH_4Cl) ***A*** *is incorrect because* Be^{2+} *does not produce an alkaline gas when warmed with sodium hydroxide solution* ***B*** *is incorrect because* Ca^{2+} *does not produce an alkaline gas when warmed with sodium hydroxide solution* ***C*** *is incorrect because* Mg^{2+} *does not produce an alkaline gas when warmed with sodium hydroxide solution*	**(1)**

Question Number	Answer	Mark
6	 **The only correct answer is B** ( ) ***A*** *is incorrect because the height of the peak for T_2 should be lower than that for T_1 so that the area under the curve remains the same* ***C*** *is incorrect because the height of the peak for T_2 should be lower than that for T_1 and not higher so that the area under the curve remains the same* ***D*** *is incorrect because the peak for T_2 should be to the right of that for T_1 so that the distribution of energies of the particles reflects an increase in energy due to the higher temperature*	**(1)**

Question Number	Answer	Mark
7	**The only correct answer is A** (thermal stability of Group 2 nitrates increases) ***B*** *is incorrect because the thermal stability of carbonates increases going down Group 2* ***C*** *is incorrect because the solubility of sulfates decreases going down Group 2* ***D*** *is incorrect because the solubility of hydroxides increases going down Group 2*	**(1)**

Question Number	Answer	Mark
8(a)	**The only correct answer is B** (iodide ions reduce chlorine) ***A*** *is incorrect because the chlorine is reduced* ***C*** *is incorrect because the iodide ions are oxidised* ***D*** *is incorrect because the iodide ions are oxidised and the chlorine is reduced*	**(1)**

Question Number	Answer	Mark
8(b)	**The only correct answer is A** (the upper layer is purple) ***B*** *is incorrect because cyclohexane is less dense than water* ***C*** *is incorrect because iodine forms a purple (monomolecular) solution in cyclohexane* ***D*** *is incorrect because iodine is considerably more soluble in cyclohexane than in water*	**(1)**

Question Number	Answer	Mark
9	**The only correct answer is A** ((0.80 x 15.1) ÷ 60)) ***B*** *is incorrect because mass does not equal density ÷ volume* ***C*** *is incorrect because moles does not equal* M_r *÷ mass* ***D*** *is incorrect because mass does not equal volume ÷ density*	**(1)**

Question Number	Answer	Mark
10	**The only correct answer is D** (83.3 g) ***A*** *is incorrect because the scaling of the reacting amount to take into account the yield of 36 % is incorrect* ***B*** *is incorrect because the reacting amount has not been scaled to take into account the yield of 36 %* ***C*** *is incorrect because the scaling of the reacting amount to take into account the yield of 36 % is incorrect*	**(1)**

Question Number	Answer	Mark
11	**The only correct answer is D** ($\frac{1}{2}H_2(g) + \frac{1}{2}I_2(s) \rightarrow HI(g)$) ***A*** *is incorrect because neither element is in its molecular form* ***B*** *is incorrect because 2 mol of hydrogen iodide is formed* ***C*** *is incorrect because iodine is not in its standard state*	**(1)**

Question Number	Answer **W**	Mark
12(a)	**The only correct answer is A** (increase rate decrease yield) ***B*** *is incorrect because an increase in temperature would increase rate* ***C*** *is incorrect because the equilibrium position would move to the left, i.e. endothermic direction* ***D*** *is incorrect because an increase in temperature would increase the rate and the equilibrium position would move to the left, i.e. endothermic direction*	**(1)**

Question Number	Answer	Mark
12(b)	**The only correct answer is C** (increase rate increase yield)) ***A*** *is incorrect because an increase in pressure would increase the yield* ***B*** *is incorrect because an increase in pressure would increase the rate and the yield* ***D*** *is incorrect because an increase in pressure would increase the rate*	**(1)**

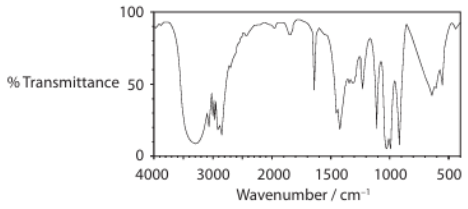
Question Number	Answer	Mark
13	**The only correct answer is C** (-93) ***A*** *is incorrect because this is the use of only 3 x N-H instead of 6x* ***B*** *is incorrect because this is the use of 2 x N≡N instead of 1x* ***D*** *is incorrect because this is the use of only 2 x H-H instead of 3x*	**(1)**

Question Number	Answer	Mark
14	***The only correct answer is D*** *(use of non-standard conditions)* ***A*** *is incorrect because there will be significant heat loss* ***B*** *is incorrect because there will be significant incomplete combustion* ***C*** *is incorrect because there will be loss of ethanol by evaporation with a greater impact on the enthalpy change value than the use of non-standard conditions*	**(1)**

Question Number	Answer	Mark
15	***The only correct answer is D*** *(the carbon-halogen bond strength)* ***A*** *is incorrect because the trend in electronegativity differences is opposite to the reactivity trend and thus is not the most significant factor in reaction rate* ***B*** *is incorrect because the trend in bond enthalpy between carbon and the halogen is the most significant factor and not the ionisation energy which is of the unbonded element* ***C*** *is incorrect because the trend in bond enthalpy between carbon and the halogen is the most significant factor and not the oxidising ability of the halogen*	**(1)**

Question Number	Answer	Mark
16(a)	**The only correct answer is B** (29) ***A*** *is incorrect because propanone would be expected to have a fragment ion peak at m / z = 15* ***C*** *is incorrect because propanone would be expected to have a fragment ion peak at m / z = 43* ***D*** *is incorrect because propanone would be expected to have a molecular ion peak at m / z = 58*	**(1)**

Question Number	Answer	Mark
16(b)	***The only correct answer is C*** *(warm with acidified potassium dichromate(VI) turns green no change)* ***A*** *is incorrect because propanone does not give a positive result with Fehling's solution* ***B*** *is incorrect because neither propanal nor propanone contains an OH group* ***D*** *is incorrect because neither propanal nor propanone contains a COOH group*	**(1)**

Question Number	Answer	Mark
17	 **The only correct answer is C (** **)** ***A*** *is incorrect because this shows no absorbance for the C=C stretch* ***B*** *is incorrect because this shows no absorbance for the O−H stretch or C=C stretch* ***C*** *is incorrect because this shows no absorbance for the O−H stretch*	**(1)**

TOTAL FOR SECTION A = 20 MARKS

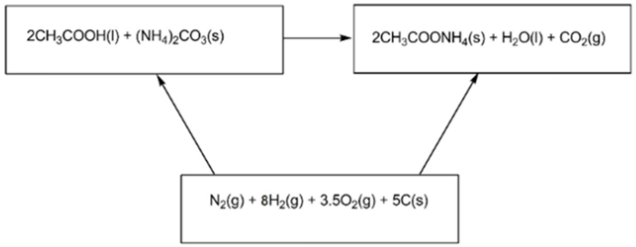
Section B

Question Number	Answer	Additional Guidance	Mark
18(a)(i)	• calculation of Q **(1)** • calculation of moles of CaO needed **(1)** • calculation of mass of CaO needed **(1)**	<u>Example of calculation</u> Q = (200 x 4.18 x 40 =) 33440 (J) Accept 33.440 **kJ** Ignore any sign n = (33440 ÷ 65100 =) 0.51367 (mol) m = (0. 51367 x 56.1 =) 28.817 / 28.82 / 28.8 (g) Correct answer with no working scores (3) TE throughout Use of 40 for Ca Ar gives 28.77 (g) scores 3 Ignore SF except 1SF	**(3)**

Question Number	Answer	Additional Guidance	Mark
18(a)(ii)	An answer that makes reference to two of the following points: • (reason 1) to keep the drink at the required temperature / to minimise heat loss / reduce energy transfer to surroundings **(1)** • (reason 2) to allow the can to be handled safely **(1)** • (reason 3) high thermal conductivity of the can **(1)**	Allow to keep the drink warm/hot Allow to prevent hands from being burnt Ignore reference to the can exploding	**(2)**

Question Number	Answer		Additional Guidance	Mark
18(b)	An answer that makes reference to the following points: • correct completion of top 2 boxes of Hess cycle • correct completion of bottom box of Hess cycle • inclusion of multiples of 2 for $\Delta_r H^\ominus$ [$CH_3COOH(l)$] **and** $\Delta_r H^\ominus$ [$CH_3COONH_4(s)$] • evidence of correct manipulation of Hess cycle to find $\Delta_r H^\ominus$ (products − reactants) • calculation of final answer	**(1)** **(1)** **(1)** **(1)** **(1)**	Penalise omission/incorrect state symbols once only in M1 and M2 Allow $H_2CO_3(aq)$ for $H_2O(l)$ and $CO_2(g)$ <u>Example of calculation</u> (2 x –586.3) **and** (2 x −484.5) Do not award if multiples applied to other enthalpy changes $\Delta_r H^\ominus$ = [((2x–586.3) + (−285.8) + (−393.5))] – [(2x–484.5) + (−939.9)] $\Delta_r H^\ominus$ = (+) 57 (kJ mol^{-1}) Correct answer with no working scores M3, M4 and M5 −57(kJ mol^{-1}) scores M3 and M5 (+)158.8 (kJ mol^{-1}) scores M4 and M5 −158.8 (kJ mol^{-1}) scores M5 Units if given must be correct. No TE from an incorrect Hess cycle but allow TE from M3	**(5)**

Example of completed diagram



Question Number	Answer	Additional Guidance	Mark
18(c)	An answer that makes reference to the following points: Either • calculation of mass of ammonium carbonate in 1 dm^3 of solution **(1)** • calculation of concentration of solution **(1)** or • calculation of moles of ammonium carbonate **(1)** • calculation of concentration of solution **(1)**	<u>Example of calculation</u> m = (3.60 x 5=) 18.0 (g) c = (18 ÷ 96 =) 0.1875 (mol dm^{-3}) n = (3.60 ÷ 96 =) 0.0375 (mol) c = (0.0375 ÷ 0.200 =) 0.1875 (mol dm^{-3}) Correct answer with no working scores (2) TE from M1 to M2 Ignore SF except 1SF	**(2)**

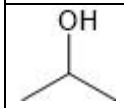
(Total for Question 18 = 12 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>19(a)</td><td>An answer that makes reference to the following points:

• correct skeletal formulae (1)

• correct names (1)

• correct classifications (1)</td><td>Accept rows in any order

<u>Example of table</u>
<table><tr><th>Skeletal formula</th><th>Name</th><th>Classification</th></tr><tr><td></td><td>Propan-1-ol</td><td>Primary / 1°</td></tr><tr><td></td><td>Propan-2-ol</td><td>Secondary /2°</td></tr></table>
Ignore bond angles, bond lengths
Allow (1) for one correct row if no other mark awarded
Do not award propanol for propan-1-ol
Do not award propane-1-ol or propane-2-ol
Do not award prop-1-ol or prop-2-ol
Classification is dependent on correct name or formula or near miss</td><td>(3)</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>19(b)(i)</td><td>• species (1)

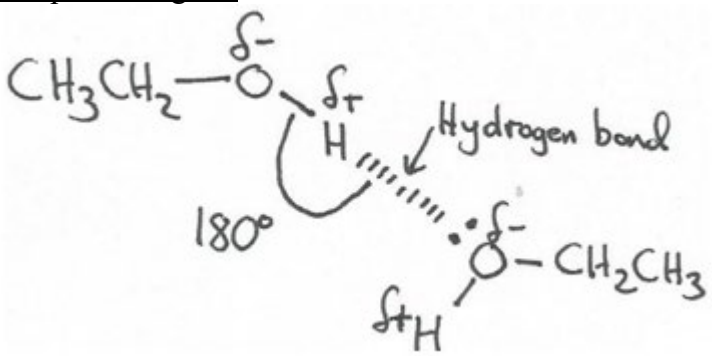
• balancing (1)</td><td><u>Example of equation</u>

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

M2 dependent on M1

Ignore state symbols even if incorrect</td><td>(2)</td></tr>
</table>

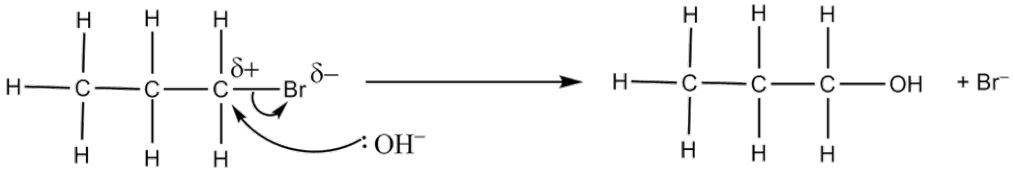
Question Number	Answer	Additional Guidance	Mark
19(b)(ii)	An answer that makes reference to the following point: • any ethanal (that evaporates) is condensed back into the flask to be further oxidised (to ethanoic acid)	Allow any indication that a liquid is returning to the flask / mixture Ignore just (reflux) prevents any ethanal vapour from escaping Ignore any reference to ethanol	**(1)**

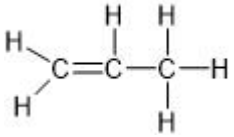
Question Number	Answer	Additional Guidance	Mark
19(b)(iii)	An answer that makes reference to the following points: • (bp1) diagram showing two **ethanol** molecules correctly aligned • (bp 2) (with) a stated bond angle of ~180° • (bp 3) hydrogen bond shown as hash or dotted line drawn between H of OH and O of a separate OH **only** • (bp4) lone pair on relevant O atom correctly aligned with the hydrogen bond • (bp5) dipole on the two atoms involved in the hydrogen bond (showing both δ+ and δ−) • (bp6) dipole on the two atoms bonded to the atoms involved in the hydrogen bond (showing both δ+ and δ−)	<u>Example of diagram</u>  6 correct points scores (3) 4-5 correct points scores (2) 2-3 correct points scores (1) Incorrect structures for ethanol loses bp 1 Ignore dipoles on any other than O or H atoms Ignore additional lone pairs on the oxygen atom(s) Ignore other bond angles given, even if incorrect	**(3)**

Question Number	Answer	Additional Guidance	Mark
19(b)(iv)	An answer that makes reference to the following point: • none of the hydrogen atoms in ethanal are bonded to an oxygen atom (or another highly electronegative atom)	Allow there is no OH bond in ethanal Allow hydrogen bonds only form if H is bonded to F, O or N Ignore the CH bond in the aldehyde group is non-polar Ignore H is bonded to C if no further qualification	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(c)(i)	• correct equation	Example of equation $CH_3OH + PCl_5 \rightarrow CH_3Cl + POCl_3 + HCl$ Allow multiples Allow PCl_3O Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(c)(ii)	An answer that makes reference to the following point: • steamy **fumes** / misty **fumes** / white **fumes**	Ignore effervescence / bubbles / gets hot / PCl_5 dissolves Do not award white smoke / additional incorrect observations	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(d)(i)	An answer that makes reference to the following points: • dipole on C−Br bond • one curly arrow from the C−Br bond to Br or just beyond • lone pair on the **oxygen** of the hydroxide ion • one curly arrow (from the lone pair) to the C of the C−Br • structure of propan-1-ol product • bromide ion product with single negative charge	Accept displayed / structural / skeletal / hybrid formulae <u>Example of mechanism</u>  May be seen as an intermediate or a product 6 correct points scores (3) 4-5 correct points scores (2) 2-3 correct points scores (1) Allow S_N2 Allow NaBr / KBr as second product if NaOH / KOH used as reactant Allow 3 lone pairs on O atom of OH^- Penalise incorrect horizontal connectivity of -OH bond Fully correct mechanism using ammonia to form propylamine scores 1	**(3)**

Question Number	Answer	Additional Guidance	Mark
19(d)(ii)	An answer that makes reference to the following points: • (reaction type) elimination **(1)** • correct displayed formula **(1)**	Do not award electrophilic <u>Example of formula</u>  Allow CH_3 for methyl group Ignore bond angles, bond lengths Ignore any structural/skeletal formulae Ignore any other product even if incorrect	**(2)**

(Total for Question 19 = 17 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*20(a)</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 zero reasoning marks

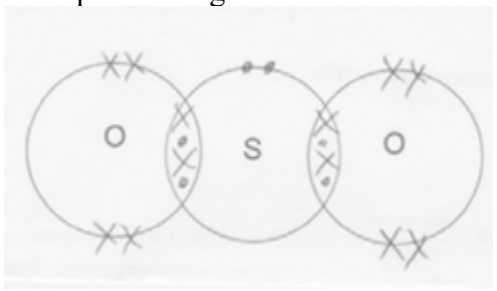
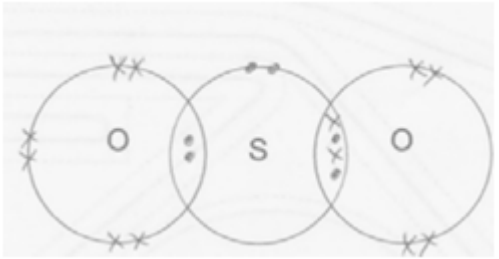
If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).</td>
<td>(6)</td>
</tr>
</table>

	Indicative content **IP1** methane has (only) London forces **IP2** London forces are weak**er** than hydrogen bonds (so boiling point of methane is lowest) **IP3** NH_3 **and** H_2O **and** HF have hydrogen bonds **IP4** London forces are same/similar as they have the same number of electrons **IP5** the hydrogen bond is strong**er** in HF than H_2O/NH_3 (so HF has a higher boiling point than ammonia) or fluorine has high**er** electronegativity than N or O / is the most electronegative element / H−F bond is the most polar **IP6** water has **more** hydrogen bonds (than ammonia / HF) (so boiling point of water is the highest)	Accept dispersion forces / Accept instantaneous dipole – induced dipole Ignore id-id Allow all have London forces (but NH_3, H_2O, HF have additional intermolecular forces) Allow van der Waals' forces Accept reverse argument Allow reference to more energy required to break H bonds All 3 must be mentioned to score IP3 Lose IP4 for incorrect statement about different numbers of electrons / any reference to differences in London forces Allow hydrogen bond is weakest in NH_3 providing the H-bond in H_2O is not referred to as "strongest" Do not award H-F bond is stronger than H-N / H-O Allow description of ratio of 2:1 in H_2O with NH_3/HF	

Question Number	Answer	Additional Guidance	Mark
20(b)	An answer that makes reference to four of the following points: Any two from: (Similarities) • **both** produce hydrogen halides **(1)** • formation of hydrogen halides is protonation **(1)** • **both** give off misty/steamy/white fumes **(1)** Any two from: (Differences) • only the reaction of sodium bromide is redox / bromide ions are stronger reducing agents (than chloride ions) **(1)** • (red-) brown fumes / gas / liquid produced with sodium bromide **(1)** • sulfur dioxide (colourless choking gas) / bromine given off with sodium bromide **(1)**	Both similarities and differences can be shown in equations or with observations Accept $NaX + H_2SO_4 \rightarrow HX + NaHSO_4$ Allow $2NaX + H_2SO_4 \rightarrow 2HX + Na_2SO_4$ Do not award white smoke Do not award rotten egg smell / references to yellow solid Accept $2HBr + H_2SO_4 \rightarrow Br_2 + SO_2 + 2H_2O$ Apply list principle	**(4)**

(Total for Question 20 = 10 marks)
TOTAL FOR SECTION B = 39 MARKS

Section C

Question Number	Answer	Additional Guidance	Mark
21(a)(i)	An answer that makes reference to the following points: • one oxygen joined to a sulfur with a double bond and 8 electrons or one oxygen joined to a sulfur with a dative covalent bond and 8 electrons or arrangement of electrons around the sulfur atom matches either of the two diagrams **(1)** • all other electrons correct **(1)**	Examples of diagrams  or  Dots/crosses the wrong way round scores maximum 1 All dots/crosses scores maximum 1 Unbonded electron pairs may be at any position or inside the circles Electrons do not have to be paired	**(2)**

Question Number	Answer	Additional Guidance	Mark
21(a)(ii)	An answer that makes reference to the following point • 120 (°)	 Allow 117 to 123 (°)	**(1)**

Question Number	Answer	Additional Guidance	Mark
21(b)(i)	An answer that makes reference to the following point • two concordant titres already obtained	 Allow just titres are concordant / (last two) titres are within 0.2/0.1 cm^3 Allow only 10 cm^3 (of H_2SO_4) left so not possible to pipette a further sample Allow there is not enough sulfuric acid for a (fourth) titration Do not award **all** titres are concordant Ignore answers implying that three titres are enough/sufficient Ignore references to precision/accuracy	**(1)**

Question Number	Answer	Additional Guidance	Mark
21(b)(ii)	• calculation of NaOH moles in mean titre **(1)** • calculation of moles of sulfuric acid in 10 cm^3 sample **(1)** • calculation of moles of sulfuric acid in 40 cm^3 **(1)**	<u>Example of calculation</u> n = (22.10 ÷ 1000 x 0.00400 =) 8.84 x 10^{-5} (mol) n = (8.84 x 10^{-5} ÷ 2 =) 4.42 x 10^{-5} (mol) n = (4.42 x 10^{-5} x 4 =) 1.768 x 10^{-4} (mol) Accept 1.76 −1.77 x 10^{-4} (mol) Correct answer with no working scores (3) TE throughout Ignore SF except 1SF Ignore intermediate units	**(3)**

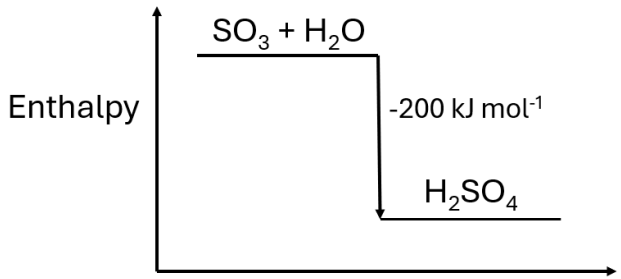
Question Number	Answer	Additional Guidance	Mark
21(b)(iii)	• same moles as (b)(ii)	n = 1.768 x 10^{-4} (mol) TE on 21(b)(ii)	**(2)**

Question Number	Answer		Additional Guidance	Mark
21(b)(iv)	• calculation of volume of sample collected	**(1)**	<u>Example of calculation</u> V = (15 x 20 =) 300 (dm^3)	**(3)**
	• calculation of moles of gas bubbled through	**(1)**	n = (300 ÷ 24 =) 12.5 (mol)	
	• calculation of SO_2 ppm in the air	**(1)**	c = (1.768 x 10^{-4} ÷ 12.5 = 1.4144 x 10^{-5}) ppm = (1.4144 x 10^{-5} x 10^6 =) 14.144	
	or			
	• calculation of volume of SO_2 in sample	**(1)**	V = (1.768 x 10^{-4} x 24 =) 4.2432 x 10^{-3} (dm^3)	
	• calculation of volume of sample collected	**(1)**	V = (15 x 20 =) 300 (dm^3)	
	• calculation of SO_2 ppm in the air	**(1)**	c = (4.2432 x 10^{-3} ÷ 300 = 1.4144 x 10^{-5}) ppm = (1.4144 x 10^{-5} x 10^6 =) 14.144	
			Correct answer with no working scores (3) TE from (b)(iii) and throughout Ignore SF except 1SF Ignore intermediate units	

Question Number	Answer	Additional Guidance	Mark
21(c)(i)	• correct equation	Example of equation $2O_3 \rightarrow 3O_2$ Allow $2O_3 \rightarrow 2O_2 + O_2$ Allow $O_3 + O_3 \rightarrow 3O_2$ Accept multiples Ignore state symbols even if incorrect Do not award equations with uncancelled species	**(1)**

Question Number	Answer	Additional Guidance	Mark
21(c)(ii)	An answer that makes reference to two of the following points: • many ozone molecules decompose for each free radical formed / a single free radical breaks down a large number of ozone molecules **(1)** • the chlorine free radical is regenerated / recycled / does not get used up (in the reaction) **(1)** • chlorine free radicals cause a chain reaction / reaction can be repeated many times / reaction produces another free radical **(1)**	Ignore references to O_2 Must be clear that the free radical breaks down or decomposes ozone Ignore chlorine free radical acts as a catalyst Allow reaction is unstoppable Allow reaction continues (on) Ignore references to skin cancer Ignore references to global warming	**(2)**

Question Number	Answer	Additional Guidance	Mark
21(d)(i)	• sulfur oxidised from (+)4 to (+)6 **(1)** • oxygen reduced from 0 to −2 **(1)**	Award (1) for sulfur is oxidised and oxygen is reduced Award (1) for correct oxidation number changes	**(2)**

Question Number	Answer	Additional Guidance	Mark
21(d)(ii)	• reactants energy level higher than that of products with correct species on each line **(1)** • enthalpy change −200 (kJ mol^{-1}) labelled with arrow pointing downwards **(1)**	<u>Example of diagram</u>  Arrow must start/finish at the reactant/product lines Ignore transitions state/intermediate 'hump' Ignore labelling of the x axis Ignore state symbols even if incorrect Penalise missing reactant/product line Do not award just reactants and products Do not award a double headed arrow Comment Only allow an upwards arrow if enthalpy change is positive Allow arrow between extended reactant/product lines	**(2)** **Expert**

Question Number	Answer	Additional Guidance	Mark
21(d)(iii)	An explanation that makes reference to the following points: • carbon dioxide causes a rise in temperature **(1)** • (sulfur dioxide results in the formation of) sulfuric acid which causes global cooling / causes a decrease in temperature **(1)** • the effect of sulfur dioxide is greater than that of carbon dioxide (because the global temperature decreased) **(1)**	Allow carbon dioxide is a greenhouse gas/ causes global warming Ignore references to formation of carbonic acid / H_2CO_3 Allow sulfur dioxide / sulfur trioxide for sulfuric acid Ignore references to acid rain/ ozone depletion Ignore sulfur dioxide / sulfur trioxide does not cause global warming Ignore sulfur dioxide is a greenhouse gas Ignore reference to endothermic/exothermic reaction	**(3)**

(Total for Question 21 = 21 marks)
TOTAL FOR SECTION C = 21 MARKS

TOTAL FOR PAPER = 80 MARKS