

GCE

Chemistry A

H432/03: Unified chemistry

Advanced GCE

Mark Scheme for June 2019

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





This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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Annotations available in RM Assessor

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
	Benefit of doubt given
	Contradiction
	Rounding error
	Error in number of significant figures
	Error carried forward
	Level 1
	Level 2
	Level 3
	Benefit of doubt not given
	Noted but no credit given
	Ignore

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
()	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions**INTRODUCTION**

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

Question	Answer	Marks	AO element	Guidance
1 (a)	<p>Polar bonds F (atom) is more electronegative (than C atom) OR F is very/the most electronegative ✓</p> <p>No overall dipole (CF₄ is) symmetrical OR tetrahedral OR dipoles cancel OR dipoles act in opposite directions ✓</p>	2	AO1.1 ×2	<p>Mark independently ALLOW C and F have different electronegativities OR the atoms have different electronegativitiesBUT DO NOT ALLOW C is more electronegative</p> <p>ALLOW C–F shown with correct dipole, i.e. C^{δ+}–F^{δ-}.</p> <p>IGNORE square planar</p> <p>IGNORE polar bonds cancel BUT ALLOW polarities cancel</p> <p>IGNORE charges cancel</p>
(b)	<p>(Molecules) contain</p> <ul style="list-style-type: none"> • ²H OR deuterium/D • ³H OR tritium/T <p>OR O/H atoms have more neutrons (than ¹H) OR (different) O/H isotopes are present OR (Molecules are) D₂O ✓</p>	1	AO1.2	<p>ALLOW Molecules contain ¹⁸O</p> <p>Idea of isotopes is criticalBUT DO NOT ALLOW isotopes of elements different from H and O (e.g. C)</p>
(c)	<p>$p(\text{O}_2) = 0.21 \times 1.00 \times 10^5$</p> <p>= 21,000 / 2.1 × 10⁴ (Pa) ✓</p>	1	AO2.2	

Question	Answer	Marks	AO element	Guidance
(d)	<p>FIRST, CHECK ANSWER IF answer = 231 000, award 2 marks</p> <p>-----</p> <p>$n(\text{C}_3\text{H}_8)$ $n(\text{C}_3\text{H}_8) = \frac{42.0 \times 10^3}{24.0}$ OR $\frac{42.0 \times 10^6}{24\ 000}$ OR 1750 (mol) ✓</p> <p>Mass of CO₂ mass CO₂ = 3 × 1750 × 44 = 231 000 / 2.31 × 10⁵ (g) ✓</p> <p>ALLOW 2 SF, e.g. 230 000</p>	2	AO2.2 AO2.6	<p>ALLOW use of ideal gas equation with a sensible temperature (20–25°C) and pressure (100/101 kPa) At 20°C and 100 kPa, $n(\text{C}_3\text{H}_8) = \frac{100 \times 10^3 \times 42.0}{8.314 \times 293} = 1724\dots$ (mol) → ~ 227586 (g) (dependent on roundings) At 25°C and 100 kPa, $n(\text{C}_3\text{H}_8) = \frac{100 \times 10^3 \times 42.0}{8.314 \times 298} = 1695\dots$ (mol) → ~ 223767 (g) (dependent on roundings) ALLOW use of 8.31 for <i>R</i> ALLOW ECF from $n(\text{C}_3\text{H}_8)$</p> <p>-----</p> <p>Common errors from 24.0 dm³ 231 → 1 mark <i>No conversion of m³ to dm³</i> 0.231 → 1 mark <i>Confusion of cm³ and dm³</i> 77 000 → 1 mark <i>No 3 × for CO₂</i></p>
(e)	<p>Initial rate = $10^{-2} \times 2.4 \times 10^{-3} \text{ s}^{-1}$ = 2.4 × 10⁻⁵ (mol dm⁻³ s⁻¹) ✓</p>	1	AO2.2	
(f)	<p>FIRST, CHECK ANSWER IF answer = 9.03 × 10²², award 2 marks</p> <p>-----</p> <p>$n(\text{P}_2\text{O}_5) = \frac{4.26}{142.0}$ OR 0.03(00) (mol) ✓</p> <p>O atoms = 5 × 0.0300 × 6.02 × 10²³ = 9.03 × 10²² ✓ Minimum 3 SF required</p>	2	AO2.2	<p>Alternative approach $n(\text{O atoms}) = \frac{4.26}{142.0} \times 5 = 0.15$ ✓ O atoms = 0.15 × 6.02 × 10²³ = 9.03 × 10²² ✓</p> <p>ALLOW ECF from incorrect $n(\text{P}_2\text{O}_5)$ ALLOW use of 6.022 × 10²³</p> <p>-----</p> <p>Common error 1.806 × 10²² OR 1.81 × 10²² → 1 mark No × 5</p>
	Total	9		

Question		Answer	Marks	AO element	Guidance
2	(a)	$\text{CO}_3^{2-} + \text{H}_2\text{O} \rightarrow \text{OH}^- + \text{HCO}_3^-$ OR $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightarrow 2\text{OH}^- + \text{CO}_2$ ✓	1	AO1.2	<p>ALLOW $\text{CO}_3^{2-} + 2\text{H}_2\text{O} \rightarrow 2\text{OH}^- + \text{H}_2\text{CO}_3$</p> <p>IGNORE state symbols</p> <p>ALLOW inclusion of Na^+ as spectator ion, e.g. $2\text{Na}^+ + \text{CO}_3^{2-} + \text{H}_2\text{O} \rightarrow 2\text{OH}^- + 2\text{Na}^+ + \text{CO}_2$</p> <p>IGNORE $\text{Na}_2\text{CO}_3 + \text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{CO}_2$ <i>Ionic equation required</i></p> <p>IGNORE equation with H^+ or H_3O^+ e.g. $\text{CO}_3^{2-} + \text{H}^+ \rightarrow \text{OH}^- + \text{CO}_2$ <i>Question asks for reaction with H_2O</i></p>
	(b)	Acid/ H^+ /HCl reacts with OR protonates <ul style="list-style-type: none"> • benzoate / $\text{C}_6\text{H}_5\text{COO}^-$ • carboxylate / salt (to form benzoic acid) ✓	1	AO2.3	<p>ALLOW suitable equation, e.g. $\text{C}_6\text{H}_5\text{COO}^- + \text{H}^+ \rightarrow \text{C}_6\text{H}_5\text{COOH}$</p> <p>IGNORE responses purely in terms of neutralisation of alkali, e.g. Acid/H^+/HCl neutralises / reacts with/removes alkali / OH^- / CO_3^{2-} / Na_2CO_3</p>
	(c)	$\text{C}_6\text{H}_5\text{CH}_2\text{OH} + 2[\text{O}] \rightarrow \text{C}_6\text{H}_5\text{COOH} + \text{H}_2\text{O}$ ✓	1	AO2.6	<p>ALLOW molecular, structural, displayed formulae, etc e.g. molecular: $\text{C}_7\text{H}_8\text{O} + 2[\text{O}] \rightarrow \text{C}_7\text{H}_6\text{O}_2 + \text{H}_2\text{O}$</p>

Question	Answer	Marks	AO element	Guidance
(d)	<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 33.8 OR 33.9 (%) award 3 marks</p> <hr style="border-top: 1px dashed blue;"/> <p>Theoretical moles $n(\text{C}_6\text{H}_5\text{COOH})$ OR $n(\text{C}_6\text{H}_5\text{CH}_2\text{OH})$ $= \frac{4.00 \times 1.04}{108.0}$ OR 0.0385..... (mol) ✓</p> <p>Actual moles $n(\text{C}_6\text{H}_5\text{COOH}) = \frac{1.59}{122.0}$ OR 0.013(0).... (mol) ✓</p> <p>% yield = $\frac{0.0130...}{0.0385....} \times 100 = 33.8\%$ OR 33.9 (3 sig fig) ✓ <i>Answer depends on some intermediate roundings to 3SF</i></p>	3	<p>AO2.8 ×1</p> <p>AO2.8 ×1</p> <p>AO1.2</p>	<p>ALLOW ECF for each step</p> <p>Calculator = 0.03851851852</p> <p>Calculator = 0.01303278689</p> <hr style="border-top: 1px dashed black;"/> <p>Alternative method using mass</p> <ol style="list-style-type: none"> Theoretical moles = 0.0385 mol Mass = 0.0385 × 122.0 = 4.70 g % yield = $\frac{1.59}{4.70} \times 100 = 33.8\%$ <hr style="border-top: 1px dashed black;"/> <p>Common errors</p> <p>35.2% → 2 marks</p> <ul style="list-style-type: none"> From $\frac{4.00}{108} = 0.0370$ <i>(no use of density)</i> <hr/> <p>36.5 OR 36.6% → 2 marks</p> <ul style="list-style-type: none"> $\frac{4.00/1.04}{108} = \frac{3.846}{108} = 0.0356$ <i>(÷ density instead of × density)</i>

Question		Answer	Marks	AO element	Guidance
	(e)	Dissolve in the minimum quantity of hot water/solvent ✓ Cool AND Filter AND (leave to) dry ✓ <i>All three needed</i>	2	AO3.3 ×2	ALLOW any solvent DO NOT ALLOW use of drying agent (e.g. MgSO ₄) IGNORE <ul style="list-style-type: none"> Initial filtering hot filtration to remove insoluble impurities
		Total	8		

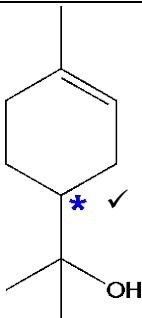
Question			Answer	Marks	AO element	Guidance
3	(a)	(i)	$4\text{Pb}_2\text{O}_3 + 3\text{CH}_4 \rightarrow 8\text{Pb} + 3\text{CO}_2 + 6\text{H}_2\text{O}$ OR $\text{Pb}_2\text{O}_3 + \text{CH}_4 \rightarrow 2\text{Pb} + \text{CO} + 2\text{H}_2\text{O}$ OR $2\text{Pb}_2\text{O}_3 + 3\text{CH}_4 \rightarrow 4\text{Pb} + 3\text{C} + 6\text{H}_2\text{O} \checkmark$	1	AO2.6	ALLOW multiples IGNORE state symbols
		(ii)	ONE Safety issue AND precaution \checkmark From: Safety issue: Compounds may be toxic/poisonous/flammable AND Precaution: Use a fume cupboard/good ventilation ----- Safety issue: Lead (compounds) is/are toxic/poisonous AND Precaution: Wear gloves ----- Safety issue: Methane is flammable AND Precaution: Keep away from flame -----	1	AO3.3	IGNORE use safety glasses, lab coat (<i>in question</i>) and tying hair back, safety screen Definite safety issue needed. Not just 'harmful' OR dangerous (Too vague). FOR OTHER SAFETY ISSUES AND PRECAUTIONS, CONTACT TEAM LEADER

Question	Answer	Marks	AO element	Guidance
(iii)	<p>Any 2 modifications ✓ ✓ from</p> <ol style="list-style-type: none"> 1. Heat to constant mass (Ensures all lead oxide has reacted) 2. Spread/stir/break up lead oxide OR increase surface area OR use powder rather than lumps (Ensures all lead oxide has reacted) 3. Pass methane/inert gas/N₂ through tube as it cools OR don't pass cold air (Prevents O₂ reacting with Pb) 4. Use excess methane OR more methane (Ensures all lead oxide has reacted) 5. Bubble (escaping) gas through lime water (Ensures all lead oxide has reacted OR ensures all CO₂ has been produced) 	2	AO3.4 ×2	<p>ALLOW response that implies heating to constant mass, e.g. Heat again until the mass does not change</p> <p>IGNORE 'heat for longer' <i>Needs link to constant mass</i></p> <p>IGNORE 'weigh straight after heating'</p> <p>IGNORE idea of repeating the experiment/ taking an average/ getting concordant results / larger sample size, etc.</p>
(iv)	<p>Masses(/g): Pb : O 3.132 AND 0.322</p> <p>OR Mole ratios: <u>3.132</u> : <u>0.322</u> 207.2 : 16.0</p> <p>OR Mole ratios: 0.0151: 0.020125 ✓</p> <p>Empirical formula Pb₃O₄ (must come from masses) ✓</p>	2	AO2.8 ×2	<p>NO ECF from incorrect masses</p>

Question	Answer	Marks	AO element	Guidance
(b)	<p>Type of lattice 2 marks</p> <ul style="list-style-type: none"> • SiO₂: Giant (covalent lattice) ✓ • CO₂: Simple molecular/covalent (lattice) ✓ <p>-----</p> <p>Explanation 2 marks</p> <p>1. Forces in CO₂</p> <ul style="list-style-type: none"> • Induced dipole–dipole interactions / London forces ✓ <hr/> <p>2. Comparison of forces with strength / melting point</p> <ul style="list-style-type: none"> • (Covalent) bonds in SiO₂ are stronger THAN intermolecular forces in CO₂ OR • More energy to break (covalent) bonds in SiO₂ THAN intermolecular forces in CO₂ ✓ <p>ORA</p>	4	<p>AO1.1 ×2</p> <p>AO1.1 ×1</p> <p>AO2.1 ×1</p>	<p>Throughout, IGNORE 'ionic' for SiO₂</p> <p>FOR SiO₂, IGNORE macromolecular DO NOT ALLOW giant metallic</p> <p>Mark explanation independently on type of lattice i.e. no ECF from incorrect lattice</p> <p>For CO₂ IGNORE</p> <ul style="list-style-type: none"> • covalent bonds • van der Waals' forces • idid • LDF <p>DO NOT ALLOW hydrogen bonds OR permanent dipole interactions</p> <hr/> <p>For SiO₂, comparison needs just 'bonds' OR 'forces'</p> <p>For intermolecular, ALLOW 'between molecules'</p> <p>For comparison, ALLOW strong in SiO₂ AND weak in CO₂</p> <p>DO NOT ALLOW responses containing intermolecular forces in SiO₂</p> <p>IGNORE 'More bonds'</p>
	Total	10		

Question		Answer	Marks	AO element	Guidance
4	(a) (i)	4-chloro-3,5-dimethylphenol ✓ CARE: Look for di methyl	1	AO1.2	ALLOW 3,5-dimethyl-4-chlorophenol ALLOW absence of hyphens or extra hyphen or space, e.g. 4 chloro 3,5 dimethylphenol ALLOW full stops or spaces between numbers e.g. 4-chloro-3.5-dimethylphenol ALLOW name based on benzene, if unambiguous e.g. 1-chloro-4-hydroxy-2,6-dimethylbenzene DO NOT ALLOW meth OR methy
	(ii)	5 ✓	1	AO2.5	
	(iii)	Functional group Phenol ✓ Test Indicator/pH paper turns red / orange OR pH < 7 OR pH meter < 7 AND No reaction with Na ₂ CO ₃ /CO ₃ ²⁻ /carbonate ✓	2	AO1.2 AO2.3	DO NOT ALLOW alcohol OR hydroxide IGNORE hydroxyl OR hydroxy IGNORE OH (<i>name asked for</i>) ALLOW Add bromine AND white precipitate ALLOW FeCl ₃ AND violet/blue colour

Question	Answer	Marks	AO element	Guidance
	<p>(iv) FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 1.71×10^{-10}, award FOUR calculation marks CARE Separate mark for equation</p> <p>-----</p> <p>Equation (1 mark) $C_8H_9ClO \rightleftharpoons H^+ + C_8H_8ClO^-$ ✓ Molecular formulae required (atoms in any order)</p> <p>[C₈H₉ClO] calculation (2 marks) Molar mass C₈H₉ClO = 156.5 (g mol⁻¹) ✓ ONLY correct answer</p> <p>$[C_8H_9ClO] = \frac{4.8 \times 10}{156.5}$ OR 0.3067..... (mol dm⁻³) ✓ Subsumes mark for molar mass = 156.5</p> <p>K_a calculation (2 marks) $[H^+] = 10^{-5.14} = 7.244..... \times 10^{-6}$ (mol dm⁻³) ✓</p> <p>$K_a = \frac{(7.244..... \times 10^{-6})^2}{0.3067.....} = 1.71 \times 10^{-10}$ (mol dm⁻³) ✓</p>	5	<p>AO1.2 ×1</p> <p>AO2.8 ×4</p>	<p>ALLOW → for ⇌</p> <p>DO NOT ALLOW C₈H₈ClOH in equation i.e. C₈H₈ClOH ⇌ H⁺ + C₈H₈ClO⁻</p> <p>If equation is omitted, ALLOW equation mark for a correct K_a expression with molecular formula i.e. $\frac{[H^+][C_8H_8ClO^-]}{[C_8H_9ClO]}$</p> <p>NO ECF from an incorrect formula in equation</p> <p>ALLOW ECF from incorrect molar mass ALLOW 0.307 up to calculator value: 0.306709265 correctly rounded</p> <p>ALLOW 7.24×10^{-6} up to calculator value: 7.244359601 × 10⁻⁶ correctly rounded</p> <p>ALLOW 2 SF ($1.7..... \times 10^{-10}$) up to calculator value, correctly rounded (but take care from acceptable intermediate rounding)</p> <p>COMMON ERRORS $2.36..... \times 10^{-5}$ 3/4 calculation marks No squaring of 7.24×10^{-6}</p>

Question		Answer	Marks	AO element	Guidance
(b)	(i)		1	AO2.5	<p>DO NOT ALLOW more than one *</p> <p>ALLOW a circle for *</p>
	(ii)	<p>MAXIMUM OF 4 MARKS FROM 5 MARKING POINTS</p> <p>Requirement for <i>E/Z</i> isomerism 2 marks C=C/double bond ✓ Each C (in C=C) is attached to (two) different groups/atoms ✓</p> <p>Identification as <i>E</i>- or <i>Z</i>- isomer 2 marks <i>E/Z</i> isomerism linked to (high) priority groups ✓ <i>Z</i>- isomer AND groups are on same side OR the ring carbons ✓</p> <p>Reason why other <i>E/Z</i> isomer does not exist 1 mark ring would be strained OR ring would break/deform OR Cannot form ring if high priority groups are on opposite sides OR ring locks groups on one side of C=C bond ✓</p>	4	<p>AO1.2 ×2</p> <p>AO2.5 ×2</p>	<p>IGNORE no H attached to C=C IGNORE functional', i.e. ALLOW different functional groups</p> <p>ALLOW in context of groups with largest atomic number ORA Award BOTH identification marks for: <i>Z</i>- isomer AND (high) priority groups on same side</p> <p>Mark independently of previous part</p> <p>Response MUST be linked to the ring/cyclic structure</p> <p>IGNORE just '<i>E</i> isomer is impossible'</p> <p>IGNORE C=C bond cannot rotate IGNORE Groups can't swap sides</p>

Question	Answer	Marks	AO element	Guidance
(iii)	<p>First group: Reagent AND Functional group: Alkene OR cycloalkene ✓</p> <p>Examples of reagents Br₂ or other halogen, HBr, H₂ AND Ni (catalyst), H₂O(g)/steam AND H⁺ (catalyst)</p> <p>Organic product for reagent with C=C in α-terpineol ✓ ALLOW product from H₂ or H₂O if H⁺ catalyst has been omitted from reagent.</p> <p>-----</p> <p>Second group Reagent AND Functional group: (Tertiary) alcohol ✓</p> <p>Examples of reagents NaBr/KBr/Br⁻ AND acid/H⁺ (substitution), OR HBr</p> <p>Acid/H⁺ (catalyst) (elimination),</p> <p>CH₃COOH AND acid/H⁺ (catalyst) (esterification) CH₃COOCOCH₃ (esterification) CH₃COCl (esterification)</p> <p>Organic product for reagent with OH in α-terpineol ✓ ALLOW product if catalyst omitted from reagent</p>	4	AO3.2 ×4	<p>CONTACT TEAM LEADER FOR OTHER REACTIONS ----- ALLOW GROUPS EITHER WAY ROUND IN BOXES</p> <p>Functional group MUST be named</p> <p>DO NOT ALLOW UV with halogens ALLOW H₂SO₄/H₃PO₄/acid for H⁺</p> <p>ALLOW addition of HBr/ H₂O either way across C=C</p> <p>ALLOW ANY HALIDE, i.e. Cl⁻, Br⁻, I⁻ ALLOW H₂SO₄/H₃PO₄/acid for H⁺ ALLOW HBr for H⁺ and Br⁻</p> <p>ALLOW name or formula of any carboxylic acid or acyl chloride for esterification</p> <p>ALLOW Na → product with -ONa OR -O⁻ DO NOT ALLOW Cr₂O₇²⁻/H⁺ (tertiary alcohol)</p>
	Total	18		

Question	Answer	Marks	AO element	Guidance
5 (a) (i)*	<p>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</p> <p>Level 3 (5–6 marks) Calculates CORRECT enthalpy change with correct – signs for $\Delta_{\text{sol}}H(\text{CuSO}_4(\text{s}))$ for reaction 5.2 AND Δ_rH, for reaction 5.1.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Calculates a value of $\Delta_{\text{sol}}H(\text{CuSO}_4(\text{s}))$ for reaction 5.2 from the: Energy change AND Amount in mol of CuSO_4.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Processes experimental data to obtain the: Energy change from $mc\Delta T$ OR Amount in mol of CuSO_4.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p>	6	AO3.1 ×4 AO3.2 ×2	<p>Indicative scientific points may include:</p> <p>1. Processing experimental data Energy change from $mc\Delta T$</p> <ul style="list-style-type: none"> Energy in J OR kJ <i>Using 50.70 g, 50.0 g</i> $= 50.70 \times 4.18 \times 13.5 = 2861 \text{ (J) OR } 2.861 \text{ (kJ)}$ 3SF or more (2.861001 unrounded) OR $50.0 \times 4.18 \times 13.5 = 2821.5 \text{ (J) OR } 2.8215 \text{ (kJ)}$ <hr/> <p>Amount in mol of CuSO_4</p> <ul style="list-style-type: none"> $n(\text{CuSO}_4) = \frac{7.98}{159.6} = 0.0500 \text{ (mol)}$ <p>-----</p> <p>2. ± value of $\Delta_{\text{sol}}H(\text{CuSO}_4(\text{s}))$ for reaction 5.2</p> <p>From $m = 50.70 \text{ g}$ $= \pm \frac{2.861}{0.0500} = \pm 57.22 \text{ (kJ mol}^{-1}\text{)}$ (–57.22002 unrounded)</p> <p>From $m = 50.0 \text{ g}$ $= \pm \frac{2.8215}{0.0500} = \pm 56.43 \text{ (kJ mol}^{-1}\text{)}$</p> <p>-----</p> <p>3. CORRECT enthalpy changes for reactions 5.2 and 5.1 with signs (using 50.70 g ONLY)</p> <p>Reaction 5.2 $= -57.22 \text{ (kJ mol}^{-1}\text{)}$ 3SF or more with correct – sign</p> <p>Reaction 5.1 $\Delta_rH = \Delta_{\text{sol}}H(\text{CuSO}_4(\text{s})) - \Delta_{\text{sol}}H(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s}))$ $= -57.22 - 8.43 = -65.65 \text{ (kJ mol}^{-1}\text{)}$ 3SF or more with correct – sign</p> <p>NOTE: A clear and logically structured response would include an energy cycle ALLOW omission of trailing zeroes ALLOW minor slips</p>

Question	Answer	Marks	AO element	Guidance
	0 marks – No response or no response worthy of credit.			
(a) (ii)	Temperature change = $0.2 \times \frac{100}{20} = 1(.0)^{\circ}\text{C}$ ✓	1	AO2.8	IGNORE direction of temperature change Working NOT required
(b)	<p>FIRST CHECK THE ANSWER IN ON ANSWER LINE If answer = (+)156 (J K⁻¹ mol⁻¹) award 4 marks</p> <hr/> <p>Part 1: Calc of $\Delta_r S$ Use of 298 K (seen anywhere) 1 mark ✓ <ul style="list-style-type: none"> e.g. $-16.1 = -55.8 - 298 \times \Delta S$ </p> <hr/> <p>CORRECT use of Gibbs' equation 1 mark <ul style="list-style-type: none"> using candidate's temperature (e.g. 298) with -16.1 AND -55.8 to calculate ΔS in kJ OR J ✓ </p> <hr/> <p>Part 2: Calc of $S(\text{Na}_2\text{S}_2\text{O}_3)$ 1 mark CORRECT use of standard S data in question ✓ Seen anywhere (could be within an expression) e.g. <ul style="list-style-type: none"> $372.4 - [S(\text{Na}_2\text{S}_2\text{O}_3) + (5 \times 69.9)]$ OR $372.4 - (5 \times 69.9)$ OR $372.4 - 349.5$ OR 22.9 </p> <p>IGNORE sign, i.e. ALLOW -22.9, etc</p> <hr/> <p>CORRECT calculation of $S(\text{Na}_2\text{S}_2\text{O}_3)$ using candidate's calculated ΔS in Part 1 to 3 SF 1 mark ✓</p>	4	AO2.4 ×4	<p>Using 298 K, $\Delta S = \frac{-55.8 - (-16.1)}{298} = \frac{-39.7}{298}$ $= -0.133\dots(\text{kJ K}^{-1}\text{mol}^{-1})$ OR -133... (J K⁻¹mol⁻¹) Sign required IGNORE units</p> <p>Calculator: -0.133221 (kJ K⁻¹ mol⁻¹) -133.221 (J K⁻¹ mol⁻¹)</p> <p>ALLOW ECF from incorrect temperature.</p> <hr/> <p>Using -133: $S(\text{Na}_2\text{S}_2\text{O}_3) = 372.4 - 349.5 - (-133)$ $= 22.9 + 133$ $= (+)156$ (J K⁻¹ mol⁻¹) 3 SF required</p> <p>ALLOW ECF from incorrect $\Delta_r S$ (Part 1)</p>

Question		Answer	Marks	AO element	Guidance
(c)	(i)	109.5(°) AND tetrahedral ✓	1	AO1.2	ALLOW 109–110(°)
	(ii)	<p>OR</p> <p>OR</p> <p>✓</p> <p>IGNORE absence of charges OR incorrect charges</p>	1	AO3.1	<p>IGNORE charges</p> <p>ALLOW cyclic structures. Three 6-ring structures possible, e.g.</p> <p>NOTE: There MUST be 2 atoms in centre between 6-bonded S atoms. e.g. DO NOT ALLOW</p> <p>For other structures, contact TL</p>
Total			13		

Question			Answer	Marks	AO element	Guidance
6	(a)	(i)	A: $\text{Fe}(\text{OH})_3(\text{s})$ ✓ B: $\text{Ag}_2\text{S}(\text{s})$ ✓	2	AO3.1 ×2	ALLOW $\text{Fe}(\text{OH})_3(\text{H}_2\text{O})_3$ IGNORE state symbols
		(ii)	Student is incorrect AND No oxidation numbers change OR example, e.g, Fe stays as +2 ✓	1	AO3.2	ALLOW no electron transfer
		(iii)	$2[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + \text{Cl}_2 \rightarrow 2[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 2\text{Cl}^-$ ✓	1	AO3.1	ALLOW multiples e.g. $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + \frac{1}{2}\text{Cl}_2 \rightarrow [\text{Fe}(\text{H}_2\text{O})_6]^{3+} + \text{Cl}^-$ ALLOW $2[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + \text{Cl}_2 \rightarrow 2[\text{Fe}(\text{H}_2\text{O})_5\text{OH}]^{2+} + 2\text{HCl}$ OR $2[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + \text{Cl}_2 \rightarrow 2[\text{Fe}(\text{H}_2\text{O})_5\text{Cl}]^{2+} + 2\text{H}_2\text{O}$ NOTE: equation MUST be balanced by charge and oxidation number IGNORE state symbols
		(iv)	$5\text{H}_2\text{S} + 2\text{MnO}_4^- + 6\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 5\text{S} + 8\text{H}_2\text{O}$ ✓✓ 1st mark ALL Correct species (SIX) OR Equation containing Mn and S species correctly balanced i.e. $5\text{H}_2\text{S} + 2\text{MnO}_4^- \dots \rightarrow 2\text{Mn}^{2+} + 5\text{S} \dots$ 2nd mark Complete correct balanced equation	2	AO3.1 ×2	ALLOW multiples, e.g. $2\frac{1}{2}\text{H}_2\text{S} + \text{MnO}_4^- + 3\text{H}^+ \rightarrow \text{Mn}^{2+} + 2\frac{1}{2}\text{S} + 4\text{H}_2\text{O}$ ALLOW equation with S^{2-} , e.g. $5\text{S}^{2-} + 2\text{MnO}_4^- + 16\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 5\text{S} + 8\text{H}_2\text{O}$ IGNORE extra electrons for 1st mark

Question	Answer	Marks	AO element	Guidance
(b)*	<p><i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) Reaches a comprehensive conclusion to determine the correct formulae of almost all of C, D, E, F, G AND 9H₂O</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Reaches a sound conclusion to determine the correct formulae of at least half of C, D, E, F, G AND 9H₂O.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Reaches a simple conclusion to determine the correct formulae of some of C, D, E, F, G AND 9H₂O.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p>0 marks No response or no response worthy of credit.</p>	6	AO1.2 ×2 AO3.1 ×2 AO3.2 ×2	<p>Indicative scientific points may include:</p> <p>Formula of C, D, E, F and G</p> <ul style="list-style-type: none"> • C: Fe(NO₃)₃•9H₂O OR FeN₃O₉•9H₂O • D: FeN₃O₉ OR Fe(NO₃)₃ • E: Fe₂O₃ • F: NO₂ • G: O₂ • 9H₂O <p><i>Examples of evidence</i></p> $n(\text{H}_2\text{O}) = \frac{0.486}{18.0} = 0.027 \text{ (mol)}$ $0.027 : 0.003 = 1 : 9 \rightarrow \mathbf{9H_2O}$ $n(\text{F}) = \frac{270 - 54}{24000} = \frac{216}{24000} = 0.009(00) \text{ (mol)}$ $M(\text{E}) = 55.8 \times 2 + 16.0 \times 3 = 159.6$ $M(\text{F}) = \frac{0.414}{0.009(00)} = 46 \text{ (g mol}^{-1}\text{)}$ <p>G: oxygen linked to relighting glowing split</p> <p>NOTE: Equations could include evidence e.g</p> $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O} \rightarrow \text{Fe}(\text{NO}_3)_3 + 9\text{H}_2\text{O}$ $\text{FeN}_3\text{O}_9 \cdot 9\text{H}_2\text{O} \rightarrow \text{FeN}_3\text{O}_9 + 9\text{H}_2\text{O}$ $2\text{Fe}(\text{NO}_3)_3 \rightarrow \text{Fe}_2\text{O}_3 + 6\text{NO}_2 + 1\frac{1}{2}\text{O}_2$
	Total	12		

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