OCR
Oxford Cambridge and RSA

GCE

Chemistry A

H432/01: Periodic table, elements and physical chemistry

Advanced GCE

Mark Scheme for November 2020

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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.

Annotations

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
	Blank page

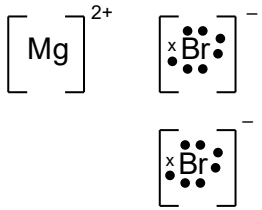
Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

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

SECTION A

Question	Answer	Marks	AO element	Guidance
1	D	1	2.7	
2	B	1	1.2	
3	B	1	2.2	
4	C	1	2.2	
5	A	1	1.1	
6	A	1	2.2	
7	D	1	1.1	
8	D	1	2.6	
9	B	1	2.6	
10	C	1	1.2	**ALLOW** 2 in the answer box
11	D	1	2.2	
12	C	1	2.6	
13	B	1	1.1	
14	D	1	1.2	**ALLOW** 1 in the answer box
15	C	1	1.1	
	Total	**15**		

SECTION B

Question			Answer	Marks	AO element	Guidance
16	(a)		(The mean/average mass) taking into account the relative abundancies of the isotopes ✓	1	1.1	**ALLOW** sum of (isotopic mass × %abundance) sum of (isotopic mass × abundance) / total abundance **DO NOT ALLOW** average mass of the isotopes
		(i)	 Mg with no (or 8) outer electrons **AND** 2 × Br with '*dot-and-cross*' outer octet ✓ Correct charges ✓	2	1.2 2.5	**ALLOW** 8 electrons in Mg^{2+} **BUT** 'extra' electron in Br^- must match symbol for electrons in Mg^{2+} **IGNORE** inner shells and circles **ALLOW** 1 mark if both electron arrangements and charges are correct but only one Br is drawn. **ALLOW** $2[Br^-]$, $2[Br]^-$ (brackets not required)
		(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 1.71 × 10^{22} award 3 marks** --- $n(MgBr_2) = \frac{1.74}{184.1}$ = 0.00945….. mol ✓ Moles of ions = 0.00945…. × 3 = 0.0283…. mol ✓ Number of ions = 0.0283... × 6.02 × 10^{23} = 1.71 × 10^{22} ✓ **3SF** required	3	2.2×3	**ALLOW ECF** Calculator answer = 9.451385117 × 10^{-3} **ALLOW ECF** from incorrect moles of ions. e.g. 0.00945 Common error 5.69 × 10^{21} no × 3 2 marks

Question	Answer	Marks	AO element	Guidance
(c)*	*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5–6 marks)** Explains all three melting point values and conductivities in terms of structure, bonding, particles and relative strengths of the forces. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Attempts to explain all three melting point values and conductivities in terms of the structure, bonding, particles of all three substances, but explanations may be incomplete or may contain only some correct statements or comparisons. **OR** Correctly explains two of the melting point values and conductivities in terms of the structure, bonding, particles. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Identifies only some of the structures, forces and particles **AND** Attempts to explain the melting point values **OR** conductivities in terms of the structure, bonding, particles *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**6**	1.1×3 2.1×3	**Indicative scientific points may include:** **<u>Structure and bonding</u>** **Magnesium** • Structure: giant lattice • Metallic bonding • **Delocalised** electrons **Bromine** • Structure: simple molecular • induced dipole dipole forces **(**London forces) • (Between) molecules **DO NOT ALLOW** (between) atoms **Magnesium bromide** • Structure: giant lattice • Ionic bonding • (Between) oppositely charged ions **<u>Comparison of bond strengths</u>** • Metallic and ionic bonds are stronger than London forces **OR** Metallic and Ionic bonds need more energy to break than London forces **<u>Conductivity</u>** • Magnesium: conducts due to delocalised electrons can move/mobile. **IGNORE** 'Carry' charge for movement • Magnesium bromide: In solid IONS cannot move; in solution IONS can move. **DO NOT ALLOW** electrons. • Bromine: Does not conduct as no mobile charge carriers.

Question			Answer	Marks	AO element	Guidance
	(d)	(i)	$Mg^{2+}(g) + 2Br(g) + 2e^-$ ✓ $Mg(s) + Br_2(l)$ ✓	2	1.2× 2	State symbols required. **CARE:** Liquid state symbol for Br_2
		(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = –346.5 award 2 marks** --- $2\Delta H$ hyd = – 525 – 186 – (2 x 112) – 148 – 736 – 1450 + (2 x -325) + 1926 **OR** – 525 – 186 – 224 – 148 – 736 – 1450 + 650 + 1926 **OR** = – 693 ✓ ΔH hyd = –346.5 (kJ mol^{-1}) ✓	2	2.2×2	**ALLOW -347** (kJ mol^{-1}) for 2 marks. **ALLOW** for 1 mark **ONE** error with sign **OR** use of 2: –693 (not divided by 2 at the end) 346.5 (wrong sign on answer) **Common errors for 1 mark** –2272.5 (–1926 instead of 1926) -1386 (**2** x -693 instead of -693) –996.5 (–650 instead of 650) –509 (**2** × 325 not used) –290.5 (**2** × 112 not used) –198.5 (148 instead of –148) –160.5 (186 instead of –186) –122.5 (224 instead of –224) 178.5 (525 instead of –525) 389.5 (736 instead of –736) 1103.5 (1450 instead of –1450) **For other answers**, check for a **single** transcription error or calculation error which could merit 1 mark **DO NOT ALLOW** any answer which involves two errors e.g. –453 (**2** × 325 not used **AND 2 x** 112 not used)

Question			Answer	Marks	AO element	Guidance
		(iii)	**Equation:** $Mg^{2+}(g) + 2Br^{-}(g) \rightarrow MgBr_2(s)$ ✓ **CHECK THE ANSWER ON ANSWER LINE** **If answer = –2433 award 2 marks** --- Lattice enthalpy = $\Delta_{hy}H(Mg^{2+}) + 2 \times \Delta_{hy}H(Br^{-}) - \Delta_{sol}H(MgBr_2)$ **OR** -1926 + (2 x -346.5) – (-186) **OR** $\Delta_fH(MgBr_2) - 2\Delta_{at}H(Br) - \Delta_{at}H(Mg)$ – 1st IE(Mg) – 2nd IE(Mg) – $2\Delta_{ea}H(Br)$ **OR** -525 – (2 x 112) – 148 – 736 – 1450 – (2 x -325) ✓ **Lattice enthalpy** = –2433 kJ mol^{-1} ✓	**3**	1.2 2.2 x 2	State symbols required **For other answers**, check for a **single** transcription error or calculation error which could merit 1 mark **DO NOT ALLOW** any answer which involves two errors **ALLOW ECF** from incorrect answer to d(ii)
			Total	**18**		

Question			Answer	Marks	AO element	Guidance
17	(a)		High pressure **AND** low temperature ✓ Right-hand side has fewer (gaseous) moles/molecules **OR** left-hand side has more (gaseous) moles/molecules ✓ (Forward) reaction is exothermic/gives out heat **OR** reverse reaction is endothermic/takes in heat ✓	**3**	1.2×1 1.1×2	Marks are independent **ORA** throughout **ALLOW** RHS **ALLOW** suitable alternatives for RHS e.g. product side
	(b)		(Reaction can be carried out at) lower temperatures / lower energy demand ✓ Less (fossil) fuels burnt / less CO_2 emissions ✓	**2**	1.1×2	**ALLOW** lower pressures as alternative to lower temperature **ALLOW** reduced carbon footprint as alternative to less fuels burnt **ALLOW** different reactions can be used with greater atom economy / less waste **ALLOW** can reduce use of toxic substances

Question	Answer	Marks	AO element	Guidance
(c)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 25.55 kJ mol^{-1} **OR** 25550 J mol^{-1} **award first 4 marks** --- $\Delta S = 238 - (198 + 2 \times 131)$ ✓ = –222 (J K^{-1} mol^{-1}) **OR** –0.222 (kJ K^{-1} mol^{-1}) ✓ $\Delta G = \Delta H - T\Delta S$ **OR** $\Delta G = -91 - (525 \times -0.222)$ **OR** $\Delta G = -91000 - (525 \times -222)$ ✓ = 25.55 kJ mol^{-1} **OR** 25550 J mol^{-1} ✓ (Reaction is) not feasible **AND** $\Delta G > 0$ ✓	**5**	2.2×4 3.2×1	**ALLOW ECF** **IGNORE** units at this stage Units for ΔG required **ALLOW** 26 kJ mol^{-1} **OR** 26000 J mol^{-1} up to calculator value.

Question			Answer	Marks	AO element	Guidance
	(d)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 2.22 $\times$ 10^4 **award first 2 marks** --- ln $K_p = -\Delta G/RT = \frac{2.48 \times 10^4}{8.314 \times 298}$ = 10.01 ✓ K_p = 2.22 $\times$ 10^4 (**3SF required**) ✓ Units = atm^{-2} ✓	**3**	3.1×2 1.2×1	**ALLOW ECF** for transcription errors in first sum **ALLOW** 10 up to calculator value of 10.00979992 **ALLOW** 22200 **ALLOW** 2.20 $\times$ 10^4 **OR** 22000 (use of 10) **ALLOW** alternatives (k)Pa^{-2} **OR** N^{-2} m^4 **OR** $mmHg^{-2}$ **OR** PSI^{-2} **OR** bar^{-2} **Common errors for 1 mark:** 22400 (use of 8.31) 4.50 x 10^{-5} (use of -10.01)
			Total	**14**		

Question			Answer	Marks	AO element	Guidance
18	(a)		**Equation**: $Mg + 2CH_3COOH \rightarrow (CH_3COO)_2Mg + H_2$ ✓	3	2.6	**ALLOW** $Mg(CH_3COO)_2$ **ALLOW** multiples **IGNORE** Oxidation numbers in formulae **IGNORE** state symbols
			Oxidation: Mg from 0 to +2 ✓		1.2	Mark independently from equation
			Reduction: H from +1 to 0 ✓		1.2	**ALLOW** 1 mark for correct oxidation numbers but incorrectly linked to redox.
	(b)		$HCOOH + CH_3COOH \rightleftharpoons HCOO^- + CH_3COOH_2^+$ ✓ **A1 B2 B1 A2** **OR** **A2 B1 B2 A1** ✓ **CARE:** Both + and – charges required for products in equilibrium **DO NOT AWARD** the 2nd mark from an equilibrium expression that omits either charge	2	1.2×2	**IGNORE** state symbols (even if wrong) **IF** proton transfer is wrong way around **ALLOW** 2nd mark for idea of acid–base pairs, ***i.e.*** $HCOOH + CH_3COOH \rightleftharpoons HCOOH_2^+ + CH_3COO^-$ **B2 A1 A2 B1** **NOTE** For the 2nd marking point (acid–base pairs), this is the **ONLY** acceptable **ECF** ***i.e. NO ECF** from impossible chemistry*
	(c)	(i)	$[H^+] = 10^{-2.72}$ **OR** 1.905×10^{-3} (mol dm^{-3}) ✓ $[CH_3COOH] = \frac{(1.905 \times 10^{-3})^2}{1.78 \times 10^{-5}}$ ✓ (= 0.204 mol dm^{-3})	2	2.4×2	**ALLOW** 2SF up to calculator value of $1.905460718 \times 10^{-3}$ **ALLOW** use of [HA] Mark is for working.

Question	Answer	Marks	AO element	Guidance
(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 2.4×10^{-2} (mol dm^{-3}) **award 4 marks** --- **Calculation of H^+ in buffer** $[H^+]_{buffer} = 10^{-4.00}$ **OR** 1×10^{-4} (mol dm^{-3}) ✓ **Calculation of CH_3COOH in buffer** $n(CH_3COOH)$ **OR** $[CH_3COOH]_{buffer}$ $= \frac{0.204}{1000} \times 400$ **OR** 8.16×10^{-2} ✓ **Calculation of $[CH_3COO^-]$ in buffer (in 1 dm^3)** $[CH_3COO^-]_{buffer} = 1.78 \times 10^{-5} \times \frac{8.16 \times 10^{-2}}{1 \times 10^{-4}}$ **OR** 1.5×10^{-2} (mol dm^{-3}) ✓ **Calculation of original $[CH_3COO^-]$ (in 600 cm^3)** $[CH_3COO^-]_{initial} = (\frac{1.45248 \times 10^{-2} \times 1000}{600})$ $= 2.4 \times 10^{-2}$ (mol dm^{-3}) ✓ ----	**4**	3.3×3 3.4×1	**ALLOW ECF** **ALLOW** [HA] and [A^-] in working **ALLOW** 1.5×10^{-2} up to calculator value 1.45248×10^{-2} (mol dm^{-3}) **ALLOW** 2.4×10^{-2} up to calculator value 2.4208×10^{-2} (mol dm^{-3}) **COMMON ERRORS BUT CHECK WORKING** $[CH_3COO^-]_{initial} = 8.7 \times 10^{-3}$ 3 marks *600 and 1000 inverted* $[CH_3COO^-]_{initial} = 3.6 \times 10^{-6}$ 3 marks *$[CH_3COOH] : [H^+]$ inverted* $[CH_3COO^-]_{initial} = 1.3 \times 10^{-6}$ 2 marks *$[CH_3COOH] : [H^+]$ inverted AND 600 and 1000 inverted* No volumes used = 3.6×10^{-2} 2 marks

Question			Answer	Marks	AO element	Guidance
			ALLOW alternative approach based on Henderson–Hasselbalch equation (**ALLOW** $-\log K_a$ for pK_a) e.g. $pH = pK_a + \log\frac{[CH_3COOH]}{[CH_3COO^-]}$ **OR** $pK_a - \log\frac{[CH_3COO^-]}{[CH_3COOH]}$ **OR** $4 = 4.75 + \log\frac{8.16 \times 10^{-2}}{[CH_3COO^-]}$ **OR** $4.75 - \log\frac{[CH_3COO^-]}{8.16 \times 10^{-2}}$ ✓ $\log[CH_3COO^-] = 4 - 4.75 - 1.09 = -1.84$ ✓ $[CH_3COO^-]_{buffer} = 1.5 \times 10^{-2}$ ✓ $[CH_3COO^-]_{initial} = 2.4 \times 10^{-2}$ ✓			**ALLOW** $-\log K_a$ for pK_a ----------
			Total	**12**		

Question			Answer	Marks	AO element	Guidance
19	(a)		**Circuit** Complete circuit **AND** voltmeter **AND** salt bridge linking two half-cells ✓ **Half cells** Ag **AND** Ag^+ **AND** 1 mol dm^{-3} solution ✓ Pt **AND** H^+ **AND** MnO_4^- **AND** Mn^{2+} **AND** 1 mol dm^{-3} /equimolar solution ✓	3	3.4× 1 1.2× 1 1.2×1	Voltmeter must be shown **AND** salt bridge must be labelled **ALLOW** small gaps in circuit If species in **BOTH** half cells are correct but concentration of 1 mol dm^{-3} omitted, **ALLOW** 1 mark for **BOTH** half cells. **ALLOW** acidified as an alternative for H^+ **IGNORE** stated pressure *Not relevant here as no gas*
	(b)		**Comparison of E values** *E* of redox system **4** (MnO_4^-/Mn^{2+}) is more positive/less negative than *E* of redox systems **2** (HCOOH/HCHO) **OR 1** (CO_2/HCOOH)✓ **Equilibrium shift related to *E* values** More negative/less positive/system **2** (HCOOH/HCHO) **OR** system 1 (CO_2/HCOOH) shifts left **OR** Less negative/more positive/system 4 (MnO_4^-/Mn^{2+}) shifts right ✓ • **2 and 4** $2MnO_4^- + 5HCHO + 6H^+ \rightarrow 2Mn^{2+} + 5HCOOH + 3H_2O$ ✓ • **1 and 4** $2MnO_4^- + 5HCOOH + 6H^+ \rightarrow 2Mn^{2+} + 5CO_2 + 8H_2O$ ✓	4	3.1× 2 3.2× 2	**IGNORE** higher/lower ALLOW Overall $E_{reaction}$ = (+)1.54V **OR** (+)1.62V For 'shifts left', **ALLOW** 'is oxidised' **OR** 'electrons are lost ' **OR** 'reducing agent' For 'shifts right', **ALLOW** 'is reduced' **OR** 'electrons are gained' **OR** 'oxidising agent' **IGNORE** state symbols **ALLOW** multiples **DO NOT ALLOW** un-cancelled species, e.g. H^+, on both sides **ALLOW** for 1 mark two balanced equations with uncancelled species. **ALLOW** combined equation for 2 marks: $4MnO_4^- + 5HCHO + 12H^+ \rightarrow 4Mn^{2+} + 5CO_2 + 11H_2O$

Question			Answer	Marks	AO element	Guidance
	(c)		$2H^+ + ½O_2 + 2e^- \rightarrow H_2O$ ✓ 1.34 + (–0.11) = (+)<u>1.23</u> (V) ✓	2	2.6 2.2×1	**IGNORE** state symbols **ALLOW** multiples
			Total	9		

Question			Answer	Marks	AO element	Guidance
20	(a)	(i)	To keep [CH_3OH] (effectively) constant **OR** Zero order with respect to CH_3OH **OR** To ensure equilibrium is far to the right ✓	1	3.3	**ALLOW** Change in [CH_3OH] is negligible **ALLOW** rate is independent of [CH_3OH] **IGNORE** Methanol doesn't run out/is not limiting reagent.
		(ii)	One half-life $t_{½}$ between 102 and 110 (mins) Two half-lives calculated **OR** evidence on the graph of two half-lives **AND** constant half-life/values (means first order) ✓	2	3.1 3.2	 **ALLOW** any two combinations of positions, e.g. 5 and 2.5 **AND** 4 and 2 **AND** 3 and 1.5
		(iii)	**Using gradients** Evidence of tangent at $t = 0$ and intercept between 100 -140 (min) ✓ Correctly calculated gradient in the range of 2.9×10^{-5} to 4.0×10^{-5} (mol dm^{-3} min^{-1}) ✓ **OR** **Using half-life** *For* $t_{½}$ *= 106 min,* $k = \frac{\ln 2}{t_{½}} = 0.00654$ (min^{-1}) ✓ rate $= 0.00654 \times 5 \times 10^{-3}$ $= 3.27 \times 10^{-5}$ (mol dm^{-3} min^{-1}) ✓	2	3.1×1 3.2×1	 **ALLOW ECF** from value of $t_{½}$ in **(a)(ii)**

Question			Answer	Marks	AO element	Guidance
	(b)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 7.4 award 4 marks** --- **Initial moles of reactants** **1 mark** $n(CH_3OH)_{initial} = \frac{9.6}{32} = 0.3$ (mol) **AND** $n(CH_3COOH)_{initial} = \frac{12}{60} = 0.2$ (mol) ✓ **Equilibrium moles** **2 marks** $n(CH_3COOH)$ reacted $= 0.2 - 0.03 = 0.17$ (mol) **AND** $n(CH_3OH)_{equil} = 0.3 - 0.17 = 0.13$ (mol) ✓ $n(CH_3COOCH_3)_{equil} = 0.17$ (mol) **AND** $n(H_2O)_{equil} = 0.17$ (mol) ✓ **K_c calculation** **1 mark** $K_c = \frac{0.17/V \times 0.17/V}{0.13/V \times 0.03/V} = 7.4$ ✓	**4**	1.2×1 2.8×3	**ALLOW** minimum of **2SF** throughout **ALLOW ECF** from initial moles **ALLOW ECF** from equilibrium moles Use of V not required but Kc expression must be correct **ALLOW** up to calculator answer of 7.41025641
			Total	**9**		

Question			Answer	Marks	AO element	Guidance
21	(a)		**Interpretation of Results** Orange contains bromine **AND** no reaction **AND** violet contains iodine ✓	5	2.3× 1	Results can be interpreted anywhere in answer.
			Ionic equation $Br_2 + 2I^- \rightarrow 2Br^- + I_2$ ✓		2.6×1	**ALLOW** multiples, e.g. $\frac{1}{2}Br_2 + I^- \rightarrow Br^- + \frac{1}{2}I_2$ **IGNORE** other halogen/halide equations **IGNORE** state symbols
			Reactivity (down the group) Reactivity decreases **AND** oxidising power decreases **OR** gains electrons less easily **OR** forms negative ion/1– ion less easily **OR** less energy released when electron **gained** ✓ OR more negative electron affinity		1.1×3	**ALLOW** ORA **DO NOT ALLOW** idea of losing electrons/ionisation energy **IGNORE** chlorine is the most electronegative **IGNORE** explanations in terms of displacement
			Size/shells/shielding (down the group) Greater atomic radius **OR** more shells **OR** more shielding ✓			
			Attraction (down the group) Less **nuclear** attraction down the group ✓			

Question			Answer	Marks	AO element	Guidance
	(b)		*Benefit **AND** risk required for **ONE** mark* **Benefit:** kills bacteria ✓ **AND** **Risk:** toxic/poisonous **OR** forms chlorinated hydrocarbons **OR** forms carcinogens/toxic compounds ✓	**1**	1.1	**ALLOW** kills micro-organisms **OR** kills pathogens **OR** kills viruses **OR** sterilises/disinfects water **IGNORE** antiseptic, reduces risk of disease, cleans water **IGNORE** 'harmful'/'dangerous' **IGNORE** chlorine is carcinogenic/ dangerous for health/causes breathing problems
	(c)		$n(\mathbf{A}) = \frac{0.209}{29} = 0.00721$ (mol) ✓ $M_r = \frac{1.26}{0.00721} = 174.8$ ✓ Molecular formula = BrF_5 ✓ Formula is dependent on M_r	**3** 2.2×2 3.2		**ALLOW ECF** **ALLOW 2SF** 0.0072 up to calculator value 0.0072068965517 **ALLOW** 175 up to calculator value 174.8325359 **ALLOW** F_5Br **ALLOW ECF** that matches calculated M_r
			Total	**9**		

Question			Answer	Marks	AO element	Guidance
22	(a)*	(i)	*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5–6 marks)** All three tests are covered in detail, with at least **six** of **B** to **H** identified correctly and equations mostly correct. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** All three tests are covered with at least **four** of **B** to **H** identified correctly. Some attempt at writing equations, but with several omissions or incorrect formulae. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Only two tests covered with at least **two** of **B** to **H** identified correctly, and little attempt at writing equations. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**6**	3.3×3 3.4×3	**Indicative scientific points may include:** **Identification of unknowns** Can be identified within labelled equation. **B** is $FeSO_4$ **OR** Iron(II) sulfate • Test 1: Fe^{2+} present • Test 2: SO_4^{2-} present **D** is $Fe(OH)_2$ **OR** $[Fe(H_2O)_4(OH)_2]$ **OR** iron(II) hydroxide **G** is $BaSO_4$ OR barium sulfate **C** is $CrCl_3$ **OR** chromium(III) chloride • Test 1: Cr^{3+} present • Test 3: Cl^- present **E** is $Cr(OH)_3$ **OR** $[Cr(H_2O)_3(OH)_3]$ **OR** chromium(III) hydroxide **F** is $[Cr(NH_3)_6]^{3+}$ **H** is silver chloride OR $AgCl$ **Equations** **D**: $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$ **OR** $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ **OR** $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow [Fe(H_2O)_4(OH)_2] + 2H_2O$ **OR** $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Fe(H_2O)_4(OH)_2] + 2NH_4^+$ **OR** $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow Fe(OH)_2 + 4H_2O + 2NH_4^+$ **E**: $[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow Cr(OH)_3 + 6H_2O$ **OR** $Cr^{3+} + 3OH^- \rightarrow Cr(OH)_3$ **OR** $[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow [Cr(H_2O)_3(OH)_3] + 3H_2O$ **OR** $[Cr(H_2O)_6]^{3+} + 3NH_3 \rightarrow [Cr(H_2O)_3(OH)_3] + 3NH_4^+$ **OR**

Question			Answer	Marks	AO element	Guidance
						$[Cr(H_2O)_6]^{3+} + 3NH_3 \rightarrow Cr(OH)_3 + 3H_2O + 3NH_4^+$ **F**: $[Cr(H_2O)_6]^{3+} + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 6H_2O$ **OR** $Cr(OH)_3 + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 3OH^-$ **OR** $[Cr(H_2O)_3(OH)_3] + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 3H_2O + 3OH^-$ **G**: $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$ **H**: $Ag^+ + Cl^- \rightarrow AgCl$

Question			Answer	Marks	AO element	Guidance
	(b)	(i)	Ni : S : N = $\frac{16.26}{58.7} : \frac{35.36}{32.1} : \frac{31.0}{14}$ **OR** 0.277 : 1.10 : 2.21 **OR** 1 : 4 : 8 ✓ x = 4 ✓ 2 + x + y = 8 y = 2 ✓	**3**	3.1×1 3.2×2	**ALLOW** any correct method **ALLOW** NiS_4N_8 for ratio **ALLOW ECF** for y from incorrect x
		(ii)	+2 ✓	**1**	2.1	+ required **ALLOW** 2+
	(c)		$n(MnO_4^-)$ in titration $= 0.01 \times \frac{12.6}{1000} = 1.26 \times 10^{-4}$ ✓ $n(SO_3^{2-})$ in 25.0 cm^3 $= 1.26 \times 10^{-4} \times 2.5 = 3.15 \times 10^{-4}$ (mol) ✓ $n(SO_3^{2-})$ in 250 cm^3 $= 10 \times 3.15 \times 10^{-3} = 3.15 \times 10^{-3}$ (mol) ✓ mass Na_2SO_3 in 525 g meat $= 3.15 \times 10^{-3} \times 126.1 = 0.397$ (g) ✓ mass Na_2SO_3 in 1 kg of meat $= 0.397215 \times \frac{1000}{525} = 0.7566$ g **OR** 756.6 mg **AND** less than the maximum permitted level **OR** AW ✓	**5**	1.2×1 2.8×3 3.2×1	**ALLOW** 3 SF or more throughout **ALLOW ECF** throughout Calculator = 0.397215 g **ALLOW** within range: 756 to 757 mg **ALLOW** 0.397 g<0.446 g per 525 g meat.
			Total	**15**		

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