

1. 9701/41/O/N/16 Q4c,d,e,f

4(c)	(emf / potential / E) of an electrode OR a half-cell compared to / connected to (S)HE which can be called a "hydrogen half-cell" at concentration of 1 mol dm^{-3} and pressure of 1 atm (or in Pa) OR 298 K	1 1 2						
4(d)(i)	<table border="1"> <tr> <td>half-cell</td> <td>electrode</td> </tr> <tr> <td>$\text{Co}^{2+} / \text{Co}$</td> <td>Co / cobalt</td> </tr> <tr> <td>$\text{Fe}^{3+} / \text{Fe}^{2+}$</td> <td>Pt / carbon / graphite</td> </tr> </table>	half-cell	electrode	$\text{Co}^{2+} / \text{Co}$	Co / cobalt	$\text{Fe}^{3+} / \text{Fe}^{2+}$	Pt / carbon / graphite	1 1
half-cell	electrode							
$\text{Co}^{2+} / \text{Co}$	Co / cobalt							
$\text{Fe}^{3+} / \text{Fe}^{2+}$	Pt / carbon / graphite							
4(d)(ii)	$\text{Co} + 2\text{Fe}^{3+} \rightarrow \text{Co}^{2+} + 2\text{Fe}^{2+}$	1 1						
4(d)(iii)	$E_{\text{cell}}^{\circ} = 0.77 - (-0.28) = (+ \text{ or } -) 1.05 \text{ (V)}$	1 1						
4(e)(i)	$E_{\text{electrode}} = -0.28 + (0.059 / 2) \log [0.05] = \mathbf{-0.32 / -0.318 \text{ (V)}}$	1 1						
4(e)(ii)	more positive	1 1						
4(f)	$4\text{Fe}^{3+} + \text{V} + \text{H}_2\text{O} \rightarrow \text{VO}^{2+} + 4\text{Fe}^{2+} + 2\text{H}^+$ VO^{2+} correct equation	1 1						

2. 9701/41/M/J/16 Q4

4 (a) (i)	SCP is the EMF / potential of a cell composed of two electrodes (OR half cells) under standard conditions (OR at 289 K OR 1 mol dm^{-3})	[1]
(ii)	voltmeter and salt bridge	[1]
(iii)	A is Ag B is $\text{Ag}^+(\text{aq})$ or $\text{AgNO}_3(\text{aq})$ C is Pt D is $\text{Fe}^{2+}(\text{aq})$ and $\text{Fe}^{3+}(\text{aq})$ (combination of A and B can be reversed with combination of C and D)	[3]
(b) (i)	$\text{Ag}^+ + \text{Fe}^{2+} \longrightarrow \text{Ag} + \text{Fe}^{3+}$	[1]
(ii)	$E = E^{\circ} + 0.059 \log [\text{Ag}^+] = 0.80 - 0.03 = 0.77 \text{ V}$ so $E_{\text{cell}} = 0.77 - 0.77 = 0.0 \text{ V}$	[1] [1]

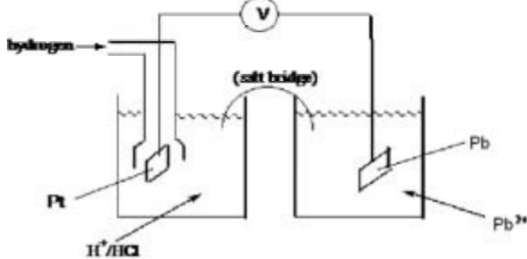
3. 9701/42/M/J/16 Q2c

<p>(c) (i)</p>	<p>M1: voltmeter / V and salt bridge labelled</p> <p>M2: Cu and Cu²⁺ / CuSO₄ (any soluble Cu(II) salt)</p> <p>M3: H₂ (arrow in) and H⁺ / HC / H₂SO₄ / any mineral acid</p> <p>M4 Pt and one solution at 1 M / 1 mol dm⁻³ OR H₂ at 1 atm</p>	<p>4</p>
<p>(ii)</p>	<p>$E^{\ominus}_{\text{cell}} = 0.34 \text{ (V)}$ and (Cu²⁺) / Cu is the positive electrode</p>	<p>1</p>
<p>d (i)</p>	<p>$K_a = 1.23 \times 10^{-5}$ $[\text{H}^+] = \sqrt{K_{a,c}} = \sqrt{(1.23 \times 10^{-5} \times 0.1)} = 1.11 \times 10^{-3} \text{ mol dm}^{-3}$ <ph <b="" =="">3.0 (2.96) ecf from [H⁺]</ph></p>	<p>2</p>

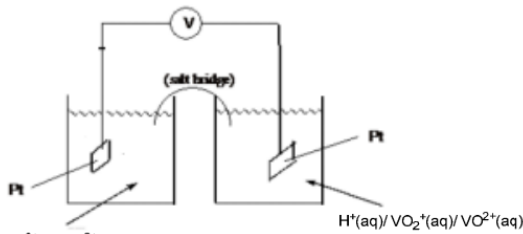
4. 9701/42/F/M/16 Q5

5 (a) (i)	any metal with an E° value more negative than -0.41 V , e.g. Fe, Mn, Zn, Mg, Cr, Al R: Li/Na/K/Ca/Ba	1
(ii)	M1: value of E_{cell} correctly calculated (with correct sign) for metal named in (i) M2: E°_{cell} is positive and so reaction is feasible	1 1
(b)	M1: ($\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightleftharpoons 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$) $E^\circ = +1.33\text{ V}$ ($\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$) $E^\circ = +1.77\text{ V}$ $E^\circ_{\text{cell}} = 0.44\text{ (V)}$ M2: E°_{cell} (0.44 V) is positive (so the reaction is feasible)/ $E^\circ(\text{Cr}_2\text{O}_7^{2-}/\text{Cr}^{3+})$ is less positive than $E^\circ(\text{H}_2\text{O}_2/\text{H}_2\text{O})$	1 1
(c)	M1: $\text{Cr}_2\text{O}_7^{2-}$: ox.no Cr = +6 because $-2 = 2 \times \text{ox.no}(\text{Cr}) + (7 \times -2)$ CrO_4^{2-} : ox.no Cr = +6 because $-2 = \text{ox.no}(\text{Cr}) + (4 \times -2)$ M2: no change in oxidation number, so reaction is not redox	1 1
(d)	M1: no. moles Cr deposited = $0.0312/52 = 6.0 \times 10^{-4}$ moles M2: deduction that 6 moles of e^- needed per mole of Cr/ reaction is $\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 12\text{e}^- \rightarrow 2\text{Cr} + 7\text{H}_2\text{O}$ M3: no. moles of $\text{e}^- = 6 \times 6.0 \times 10^{-4} = (0.125 \times t)/96\,500$ so $t = (6 \times 6.0 \times 10^{-4} \times 96\,500)/(0.125 \times 60) = 46.3\text{ min}/0.772\text{ h}/2780\text{ s}$	1 1 1

5. 9701/41/O/N/17 Q3

3(a)	the potential difference between two half-cells / two electrodes (in a cell)	1
	under standard conditions of 1 atm., 298 K, (all) solutions being 1 mol dm ⁻³	1
3(b)(i)	 <p>8 marking points, any 2 points for each mark</p> <p>H₂ / hydrogen correct delivery system for H₂ Pb²⁺ (aq) Pb electrode Pt electrode H⁺(aq) solution salt bridge voltmeter / V labelled</p>	4
3(b)(ii)	more negative	1
	shifts Pb ²⁺ (+ 2e ⁻) ⇌ Pb equilibrium / reaction to the left	1
3(c)(i)	<p>Q = 0.4 × 80 × 60 = 1920 C and use of 96500 / 193000 Moles of Pb = 1920 / 193000 = 9.95 × 10⁻³ Mass of Pb = 207.2 × 9.95 × 10⁻³ = 2.1 g</p> <p>OR Q = 0.4 × 80 × 60 = 1920 C and use of 1.6 × 10⁻¹⁹ / 1.2 × 10²² atoms Pb = 6 × 10²¹; moles of Pb = 6 × 10²¹ / 6 × 10²³ = 0.01 Mass of Pb = 207.2 × 0.01 = 2.1 g</p>	2
3(c)(ii)	PbO ₂ (s) + SO ₄ ²⁻ (aq) + 4H ⁺ + 2e ⁻ → PbSO ₄ (s) + 2H ₂ O	1
3(d)	reagents / PbO ₂ / H ₂ SO ₄ and used up / concentration decreases	1
	as fuel / hydrogen is being continuously supplied / fuel has not run out	1

6. 9701/42/O/N/17 Q4

4(a)(i)	$E^{\ominus}_{\text{cell}} = 1.00 - (-0.26) = (+)1.26 \text{ V}$	1
4(a)(ii)	$\text{VO}_2^+ + \text{V}^{2+} + 2\text{H}^+ \rightarrow \text{VO}^{2+} + \text{V}^{3+} + \text{H}_2\text{O}$	1
4(a)(iii)	 <p>solutions labelled correctly in one half-cell [1] solutions labelled correctly in both half-cells [1] two graphite or platinum electrodes [1] salt bridge and voltmeter [1]</p>	4
4(b)	<ul style="list-style-type: none"> V²⁺(aq) and Sn⁴⁺(aq): yes and $E^{\ominus}_{\text{cell}} = +0.15 - (-0.26) = +0.41 \text{ V}$ [1] $2\text{V}^{2+} + \text{Sn}^{4+} \rightarrow 2\text{V}^{3+} + \text{Sn}^{2+}$ [1] VO²⁺(aq) and Fe³⁺(aq) no reaction [1] 	3

7. 9701/42/F/M/17 Q3

3(a)(i)	A – H ₂ , 1 atm B – platinum C – 1 mol dm ⁻³ H ⁺ / HCl etc. D – salt bridge / KNO ₃ etc. E – platinum F – 1 mol dm ⁻³ Fe ²⁺ AND 1 mol dm ⁻³ Fe ³⁺	3
3(a)(ii)	positive electrode is (Pt) on RHS AND electrons flow clockwise	1
3(b)	cell potential is 0.77 – 0.34 = (+) 0.43 (V)	1
3(c)(i)	electrode potential would become more negative as equilibrium shifts to left / explanation in terms of the Nernst equation	1
3(c)(ii)	$E = -0.41 + (0.059/1)\log[\text{Cr}^{3+}]/[\text{Cr}^{2+}]$ $= -0.41 + 0.059 \log 4.0$	1
	$= -0.37$ (V)	1

8. 9701/41/O/N/18 Q8e

8(e)(i)	2CH ₃ OH + 3O ₂ ⇌ 2CO ₂ + 4H ₂ O OR 2CH ₃ OH + 3O ₂ ⇌ 2CO ₂ + 4H ⁺ + 4OH ⁻	1
8(e)(ii)	$E_{\text{cell}}^{\circ} = 1.23 - 0.02 = \mathbf{1.21}$ V	1

9. 9701/42/O/N/18 Q5c

5(c)(i)	5NO ₂ ⁻ + 2MnO ₄ ⁻ + 6H ⁺ → 2Mn ²⁺ + 5NO ₃ ⁻ + 3H ₂ O OR 5HNO ₂ + 2MnO ₄ ⁻ + H ⁺ → 2Mn ²⁺ + 5NO ₃ ⁻ + 3H ₂ O all species correct [1] balanced [1]	2
5(c)(ii)	$E_{\text{cell}}^{\circ} = 1.52 - 0.94 = \mathbf{0.58}$ (V)	1

11. 9701/41/M/J/18 Q3

3(a)		anode	cathode	3
	AgNO ₃ (aq)	oxygen / O ₂	silver / Ag	
	saturated NaCl (aq)	chlorine / Cl ₂	hydrogen / H ₂	
	CuSO ₄ (aq)	oxygen / O ₂	copper / Cu	
3(b)(i)	2I ⁻ → I ₂ + 2e ⁻			1
	Ca ²⁺ + 2e ⁻ → Ca			1
3(b)(ii)	<ul style="list-style-type: none"> Ca / Calcium reduced and I / iodine oxidised Oxidation number of calcium decreases from 2 to 0 Oxidation number of iodine increases from -1 to 0 2 points = 1 mark 3 points = 2 marks			2
3(b)(iii)	<ul style="list-style-type: none"> metal / grey / silvery purple AND vapour / gas / fumes amount of melt decreases any 2 points for 1 mark			1
3(c)	2 × 60 × 60 × 0.8 = 5760 C AND 5760 / 96500 = 0.060 (0.0597) F			1
	1.11 / 55.8 = 0.020 (0.0199) mol of Fe			1
	0.06 / 0.02 = 3 ∴ Fe ³⁺ or +3 or 3			1

12. 9701/42/M/J/18 Q3

3(a)		anode	cathode	3
	NaOH (aq)	oxygen / O ₂	hydrogen / H ₂	
	dilute CuCl ₂ (aq)	oxygen / O ₂	copper / Cu	
	conc MgCl ₂ (aq)	chlorine / Cl ₂	hydrogen / H ₂	
3(b)(i)	2Br ⁻ → Br ₂ + 2e ⁻ or 2Br ⁻ - 2e ⁻ → Br ₂			1
	Zn ²⁺ + 2e ⁻ → Zn			1
	Zinc / Zn ²⁺ reduced and Br ⁻ / bromide oxidised			1
3(b)(ii)	liquid / molten metal or orange- brown / reddish brown vapour / gas (at anode) or amount of melt / electrolyte decreases			1
3(c)	<ul style="list-style-type: none"> 50 × 60 × 1.2 or 3600 C (calculation of number of Coulombs) 3600 / 96 500 or 0.0373 F (calculation of number of Faradays) 0.0373 F / 2 or 0.01865 / 0.0187 mol H₂ (use of stoichiometry) 0.01865 × 24 000 = 448-449 (Use of 24 000 & answer to 3sf) 2 points = 1 mark 3 points = 2 marks 4 points = 3 marks			3

13. 9701/42/M/J/18 Q5d

5(d)(i)	F ₂ or S ₂ O ₈ ²⁻	1
5(d)(ii)	+1.05 or +0.19	1
5(d)(iii)	2Co ²⁺ + F ₂ → 2Co ³⁺ + 2F ⁻ or 2Co ²⁺ + S ₂ O ₈ ²⁻ → 2Co ³⁺ + 2SO ₄ ²⁻	1

14. 9701/42/F/M/18 Q2

2(a)	the E° for X ₂ / X ⁻ becomes less positive / decrease down the group so the halogens are less reactive (as oxidants) down the group	2
2(b)(i)	Cl ₂ + H ₂ O → HCl + HClO	1
2(b)(ii)	Cl ₂ /Cl ⁻ = +1.36 V and ClO ⁻ / (Cl ⁻ + OH ⁻) = +0.89 V so E° _{cell} = 1.36 - 0.89 = (+) 0.47 V	2
2(b)(iii)	box three ticked Le Chatelier argument, more OH ⁻ / increase reactant concentration so equilibrium shifts right or an argument based on the half cell with OH ⁻	2
2(c)(i)	Br ⁻ + 3ClO ⁻ → BrO ₃ ⁻ + 3Cl ⁻	1
2(c)(ii)	E° _{cell} = 0.89 - 0.58 = +0.31 V	1
2(c)(iii)	4HBrO ₃ → 2Br ₂ + 5O ₂ + 2H ₂ O	1

15. 9701/42/F/M/18 Q6

6(a)(i)	X is an ammeter	1
6(a)(ii)	Y is AgNO ₃ or AgF or AgClO ₄	1
6(b)	n(Ag) = 0.500 / 107.9 = 4.6(34) × 10 ⁻³ n(C) = 0.200 × 40 × 60 = 480 C n(e ⁻) = 480 / 1.60 × 10 ⁻¹⁹ = 3.00 × 10 ²¹ n(e ⁻) / n(Ag) = 3.00 × 10 ²¹ / 4.634 × 10 ⁻³ = 6.474 × 10 ²³ (6.5 × 10²³)	3

16. 9701/41/O/N/19 Q1

1(a)	Platinum / Pt Aluminium / Al BOTH	1
1(b)(i)	M1: use of or quoting a valid Nernst equation $E = E^\ominus + 0.0590 / z \log [\text{ox}] / [\text{red}]$ OR $E = 0.15 + (0.0590 / 2) \log 2$ M2: $E = (+)0.16$ (0.159) V minimum 2 sig. fig. correct answer scores 2 marks	2
1(b)(ii)	$E_{\text{cell}} = 0.16 - (-1.66) = +1.82 \text{ V}$ minimum 3 sig. fig.	1
1(b)(iii)	$2\text{Al} + 3\text{Sn}^{4+} \rightarrow 2\text{Al}^{3+} + 3\text{Sn}^{2+}$ M1: species M2: balancing	2
1(c)	M1: number of C (= $300\,000 \times 60 \times 60 \times 24$) = 2.59×10^{10} (C) M2: number of F (= $2.592 \times 10^{10} / 9.65 \times 10^4$) = 2.69×10^5 (moles of electrons) M3: moles of Al (= $2.69 \times 10^5 / 3$) = 8.95×10^4 M4: mass of Al (= $8.95 \times 10^4 \times 27$) = 2420 kg correct answer scores 4 marks	4
1(d)	M1: ($\text{Cr}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cr}$) $E^\ominus = -0.91$ and ($2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2$) $E^\ominus = 0.00$ seen M2: hydrogen formed instead / hydrogen (ions) easier to reduce / hydrogen has more positive E^\ominus	2

17. 9701/42/O/N/19 Q1

1(a)	Platinum and platinum	1
1(b)(i)	M1: Nernst quoted correctly $E = E^\ominus + 0.0590 / z \log [\text{ox}] / [\text{red}]$ or $E = 1.49 + 0.0590 \log 5$ M2: (+)1.53 V minimum 2 sig. fig. Correct answer scores 2 marks	2
1(b)(ii)	+ / - 0.46 minimum 2 sig. fig.	1
1(b)(iii)	M1: $\text{Mn}^{3+} + 2\text{Br}^- \rightarrow \text{Mn}^{2+} + \text{Br}_2$ M2: $2\text{Mn}^{3+} + 2\text{Br}^- \rightarrow \text{Mn}^{2+} + \text{Br}_2$	2
1(c)	M1: 16200 C M2: 1.0125×10^{23} electrons (use of 1.60×10^{-19}) M3: 0.0802 moles of copper (use of 5.09 and 63.5) M4: 0.1603 moles electrons M5: $L = 6.32 \times 10^{23}$ (correct answer [5]) other approaches acceptable including: M1: 16200 C M2: 1.0125×10^{23} electrons (use of 1.60×10^{-19}) M3: 5.0625×10^{22} copper atoms M4: 0.0802 moles of copper (use of 5.09 and 63.5) M5: $L = 6.32 \times 10^{23}$ (correct answer [5])	5
1(d)	M1: $\text{Mg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mg}$ $E^\ominus = -2.38$ and $2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2$ $E^\ominus = 0.00$ M2: hydrogen produced instead / hydrogen easier to reduce / hydrogen preferentially reduced / hydrogen has more positive E^\ominus	2

18. 9701/41/M/J/19 Q3c

3(c)(i)	M1 $\text{Li} \rightarrow \text{Li}^+ + \text{e}^-$ and $\text{I}_2 + 2\text{e}^- \rightarrow 2\text{I}^-$ M2 $2\text{Li} + \text{I}_2 \rightarrow 2\text{Li}^+ + 2\text{I}^-$	2
3(c)(ii)	$E^\circ_{\text{cell}} = 0.54 - (-3.04) = +3.58 \text{ V}$ [1]	1
3(c)(iii)	M1 amount of Li = $0.10 / 6.9 = 1.45 \times 10^{-2} \text{ mol}$ [1] M2 Q needed = $96500 \times 1.45 \times 10^{-2} = 1399$ (1398.55) C [1] ecf M3 $t = 1399 / (2.5 \times 10^{-5}) = 5.6 \times 10^7 \text{ s}$ [1] ecf 2sf min	3

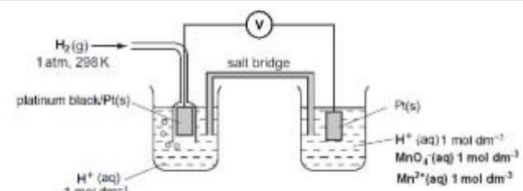
19. 9701/42/M/J/19 Q1d

1(d)	The potential difference when a half-cell is connected to a (standard) hydrogen electrode under standard conditions [1] OR the potential difference / voltage / EMF between a hydrogen electrode and another half-cell under standard conditions [1]	1
1(e)(i)	salt bridge • voltmeter / V • Ag • Ag^+ (or soluble silver salt) • Pt • H_2 (and delivery correct) + H^+ (or named strong acid) • 1 atm. (pressure) • 1 mol dm^{-3} (and 298 K) • mark as • ✓ • ✓ • ✓ • ✓ • ✓ [4]	4
1(e)(ii)	Ag electrode labelled and arrow (in the external circuit moving towards this electrode) [1]	1

20. 9701/42/F/M/19 Q4c

4(c)(i)	$E^\circ_{\text{cell}} = 0.15 - 0.54 = -0.39 \text{ (V)}$	1
4(c)(ii)	since E°_{cell} is negative (reaction is not likely to occur) OR since $E^\circ_{\text{cell}} < 0$ (reaction is not feasible / not spontaneous)	1
4(c)(iii)	$E = E^\circ + (0.059 / 1) \log(1.0 / 1.3 \times 10^{-6})$ $= +0.15 + 0.059 \times 5.89$ $= +0.50 / 0.497 \text{ V}$	2
4(c)(iv)	E°_{cell} is very negative OR calculation ($E^\circ_{\text{cell}} = 0.15 - 1.36 = -1.21 \text{ V}$)	1

21. 9701/41/O/N/20 Q3

3(a)	(anode =) oxygen / O_2 AND (cathode =) hydrogen/ H_2 BOTH [1]	1
3(b)	M1: $Q = 1.5 \times 60 \times 60 \times 4.5 = 24300 \text{ (C)}$ [1] M2: no. of F / moles of $\text{e}^- = 24300 / 96500 = 0.25(1813)$ [1] ecf M3: volume of $\text{Cl}_2 = 24 \times 0.252 / 2 = 3.02 \text{ dm}^3$ [1] ecf min 2sf M4: mass of Na = $0.252 \times 23 = 5.79$ (5.7917) g Na [1] ecf min 2sf	4
3(c)(i)	 <ul style="list-style-type: none"> MnO_4^-, H^+, Mn^{2+} in same beaker AND H^+ in other beaker both electrodes Pt(s) (ALLOW graphite) one solute clearly identified as 1M / 1 mol dm^{-3} 298 K OR 1 atm voltmeter / potentiometer labelled (or circled V) salt bridge labelled (must touch the solution) a good delivery system for $\text{H}_2(\text{g})$ $\text{H}_2(\text{g})$ mark as two correct points = 1 mark [4]	4
3(c)(ii)	F₂ OR S₂O₈²⁻ OR H₂O₂ OR HOCl OR Co³⁺ OR Pb⁴⁺ [1] $2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 5\text{F}_2 \rightarrow 2\text{MnO}_4^- + 16\text{H}^+ + 10\text{F}^-$ [1] OR $2\text{Mn}^{2+} + 5\text{S}_2\text{O}_8^{2-} + 8\text{H}_2\text{O} \rightarrow 2\text{MnO}_4^- + 16\text{H}^+ + 10\text{SO}_4^{2-}$ OR $\text{Mn}^{2+} + 4\text{H}_2\text{O} + 5\text{Co}^{3+} \rightarrow \text{MnO}_4^- + 8\text{H}^+ + 5\text{Co}^{2+}$ OR $2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 5\text{Pb}^{4+} \rightarrow 2\text{MnO}_4^- + 16\text{H}^+ + 5\text{Pb}^{2+}$ OR $2\text{Mn}^{2+} + 5\text{H}_2\text{O}_2 \rightarrow 2\text{MnO}_4^- + 6\text{H}^+ + 2\text{H}_2\text{O}$ OR $2\text{Mn}^{2+} + 10\text{HOCl} \rightarrow 2\text{MnO}_4^- + 6\text{H}^+ + 5\text{Cl}_2 + 2\text{H}_2\text{O}$	2

22. 9701/42/O/N/20 Q4

4(a)	chlorine AND hydrogen [1]	1
4(b)	$15 \times 60 \times 0.75 = 675 \text{ C}$ [1] $675 / 96500 = 7.0 \times 10^{-3} \text{ moles e}^-$ [1] $7.0 \times 10^{-3} \times 0.25$ gives $1.75 \times 10^{-3} \text{ moles O}_2$ $1.75 \times 10^{-3} \times 24000 = 42 (41.969) \text{ cm}^3 \text{ O}_2$ [1] OR $15 \times 60 \times 0.75 = 675 \text{ C}$ [1] $675 / 1.60 \times 10^{-19} = 4.22 \times 10^{21} \text{ e}^- = 7.01 \times 10^{-3} \text{ moles e}^-$ [1] gives $1.75 \times 10^{-3} \text{ moles O}_2 = 42 (42.047) \text{ cm}^3$ [1]	3
4(c)(i)	1.36 1.07 0.54 [1]	1
4(c)(ii)	all of them [1] (all E^\ominus values greater than 0.15 / E^\ominus_{cell} greater than zero [1] e.g. $\text{Sn}^{2+} + \text{X}_2 \rightarrow \text{Sn}^{4+} + 2\text{X}$ [1]	3
4(c)(iii)	MnO_2 [1]	1
4(d)(i)	1.24 V [1]	1
4(d)(ii)	platinum, platinum [1]	1
4(d)(iii)	increase $[\text{Fe}^{2+}]$ or decrease $[\text{Fe}^{3+}]$ increase $[\text{S}_2\text{O}_8^{2-}]$ or decrease $[\text{SO}_4^{2-}]$ [1]	1

23. 9701/41/M/J/20 Q3

3(a)(i)	$6\text{CO}_2 + 24\text{H}^+ + 24\text{e}^- \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O}$ ALLOW $6\text{CO}_2 + 12\text{H}^+ + 12\text{e}^- \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 3\text{O}_2$ for both marks ALLOW one mark for an unbalanced equation showing the correct species of either equation	2
3(a)(ii)	salt bridge (indicated) voltmeter / V labelled O_2 good delivery system H_2 good delivery system Pt electrode $\text{H}^+ / \text{HCl} / \text{H}_2\text{SO}_4$ solution labelled (at least once) 1 atm 1 mol dm ⁻³ quoted Every two correct responses = 1 mark	4
3(a)(iii)	$E^\ominus_{\text{cell}} = (+) 1.23 \text{ V}$ AND positive electrode = O_2 half-cell identified	1

24. 9701/41/M/J/20 Q7a

7(a)(iv)	M1 $E = E^\ominus + 0.059 \log[\text{Ag}^+]$ M2 $E = 0.80 + 0.059 \log(1.2 \times 10^{-4}) = 0.57 \text{ V}$ ecf from (a)(ii) min 2sf	2
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25. 9701/42/M/J/20 Q2f

2(f)	It is feasible as the E_{cell} will be positive/+0.12 V	1
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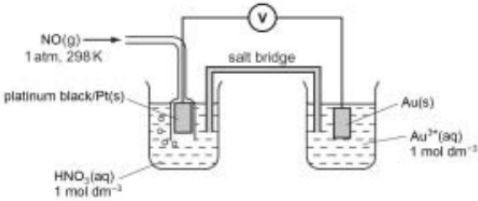
26. 9701/42/M/J/20 Q6

8(a)(i)	M1 potential difference between two half-cells/two electrodes in a cell M2 under conditions of 1 atm., 298 K, (all) solutions being 1 mol dm ⁻³	2
8(a)(ii)	both platinum	1
8(a)(iii)	$E^{\circ}_{\text{cell}} = 1.82 - 1.36 = (+)0.46 \text{ V}$	1
8(a)(iv)	$2\text{Co}^{3+} + 2\text{Cl}^{-} \rightarrow \text{Cl}_2 + 2\text{Co}^{2+}$	1
8(b)	M1 $Q = 2.5 \times 30 \times 60 \text{ C} = 4500 \text{ C}$ AND 96500 OR 579000 seen moles of $\text{CO}_2 = 4500/579000 = 7.8 \times 10^{-3}$ or 7.77×10^{-3} M2 volume of $\text{CO}_2 = 7.77 \times 10^{-3} \times 24000 = 187 \text{ cm}^3$	2

27. 9701/42/F/M/20 Q2b

2(b)(i)	$2\text{Al}^{3+} + 3\text{O}^{2-} + 3\text{C} \rightarrow 2\text{Al} + 3\text{CO}$	1
2(b)(ii)	M1 $Q = It = 3.5 \times 10^5 \times 3 \times 60^2 = 3.78 \times 10^9 \text{ C}$ M2 no. of mol $e^{-} = 3.78 \times 10^9 / 96500 = 3.92 \times 10^4$ M3 mass $\text{Al} = 27 \times 3.92 \times 10^4 / 3 = 3.5(3) \times 10^5 \text{ g}$	3
2(b)(iii)	$3\text{SiF}_4 + 2\text{H}_2\text{O} \rightarrow 2\text{H}_2\text{SiF}_6 + \text{SiO}_2$	1

28. 9701/42/F/M/20 Q3

3(a)(i)	Mark as • ✓ ✓ <ul style="list-style-type: none"> voltage of an electrode / half-cell compared / connected to (S)HE / hydrogen half-cell / electrode under standard conditions / 1 mol dm⁻³, 1 atm, 298 K 	2
3(a)(ii)	 <p>Mark as • ✓ • ✓ • ✓ • ✓</p> <ul style="list-style-type: none"> $\text{HNO}_3(\text{aq})$ and $\text{Au}^{3+}(\text{aq})$ $\text{Au}(\text{s})$ and $\text{Pt}(\text{s})$ electrode voltmeter (or circled V) salt bridge labelled $\text{NO}(\text{g})$ a good delivery system for NO 1M / 1 mol dm⁻³ 298 K AND 1 atm 	4
3(a)(iii)	$\text{Au}^{3+} + \text{NO} + 2\text{H}_2\text{O} \rightarrow \text{Au} + \text{NO}_3^{-} + 4\text{H}^{+}$	1
3(a)(iv)	$+1.50 - 0.96 = +0.54 \text{ (V)}$	1
3(a)(v)	M1 M2 any two [1] all four [2] <ul style="list-style-type: none"> adding conc HNO_3 shifts equilibrium 3 to the right E for (half-equation 3) increases / more positive adding conc HCl shift equilibrium 2 to the left E for (half-equation 2) decreases / less positive M3 $E(3)$ becomes greater than $E(2)$	3

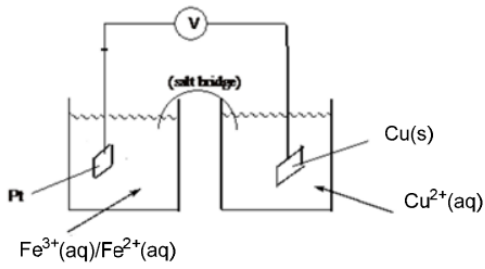
29. 9701/41/O/N/21 Q1

1(a)	moles of H ₂ = 462 / 24 000 = 0.01925[1] molecules of H ₂ = 0.019 × 6.02 × 10 ²³ = 1.16 × 10²² (1.1×10 ²² / 1.2 × 10 ²²) [1] min 2sf ecf M1	2
1(b)	number of electrons = 1.16 × 10 ²² × 2 = 2.32 × 10²² [1] min 2sf ecf 1a	1
1(c)	Q = 2.32 × 10 ²² × 1.6 × 10 ⁻¹⁹ = 3.71 × 10³ [1] min 2sf ecf 1b	1
1(d)	x = 3.71 × 10 ³ / (14 × 60) = 4.4 (A) [1] min 2sf ecf 1c	1

30. 9701/42/O/N/21 Q3

3(a)	0.351 / 24 = 0.015 (mol) [1] 0.015 × 6.02 × 10 ²³ = 9.0 × 10 ²¹ / 8.8 × 10 ²¹ [1]	2
3(b)	1.76 × 10 ²² / 1.8 × 10 ²² [1]	1
3(c)	2817 / 2816 / 2820 / 2800 C [1]	1
3(d)	15 / 15.1 / 15.05 / 15.15 minutes [1]	1

31. 9701/41/M/J/21 Q3b

3(b)(i)	M1: emf / potential difference / difference in electrode potential between two half-cells / two electrodes (in a cell) M2: (all solutions being) 1 mol dm ⁻³ AND either 1 atm OR 298 K	2
3(b)(ii)	salt bridge, voltmeter, Cu(s), Cu ²⁺ (aq), Pt(s), Fe ²⁺ and Fe ³⁺ (aq) two for one mark, four for two marks, six for three marks 	3
3(c)(i)	M1: 2I ⁻ + 2Fe ³⁺ → I ₂ + 2Fe ²⁺ M2: S ₂ O ₈ ²⁻ + 2Fe ²⁺ → 2SO ₄ ²⁻ + 2Fe ³⁺	2
3(c)(ii)	M1: I ₂ / I ⁻ + 0.54 V AND Fe ³⁺ / Fe ²⁺ + 0.77 V AND [Fe(CN) ₆] ³⁻ / [Fe(CN) ₆] ⁴⁻ + 0.36 V M2: E° of I ₂ / I ⁻ is more positive / greater than E° of [Fe(CN) ₆] ³⁻ / [Fe(CN) ₆] ⁴⁻ OR E° _{cell} = -0.18 V so no reaction occurs OR E° of Fe ³⁺ / Fe ²⁺ is more positive / greater than E° of I ₂ / I ⁻ OR E° _{cell} = 0.23 V so reaction occurs [1]	2
3(d)(i)	S ₂ O ₈ ²⁻ and tartrate ions are both negatively charged / both reactants same charge AND so repel each other OR have a high E _a	1
3(d)(ii)	C ₄ H ₄ O ₆ ²⁻ + 2H ₂ O ⇌ 2CO ₂ + 2HCO ₂ ⁻ + 6H ⁺ + 6e ⁻	1

32. 9701/42/M/J/21 Q1e

1(e)(ii)	$E^{\circ}_{\text{cell}} = 1.23 - (-0.41) = (+)1.64 \text{ V}$ OR $E^{\circ}_{\text{cell}} = 0.68 - (-0.41) = (+)1.09 \text{ V}$ value linked to (e)(i)	1
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33. 9701/42/M/J/21 3a,b

3(a)(i)	M1: voltage of an electrode / a half-cell compared to / connected to (standard) hydrogen electrode / half-cell M2: (at concentration of) 1 mol / dm ³ AND (pressure of) 1 atm / 101 kPa (or in Pa) AND 298 K / 25°C	2								
3(a)(ii)	<table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>E°</th> <th>redox system</th> </tr> </thead> <tbody> <tr> <td>Most negative</td> <td>B</td> </tr> <tr> <td style="text-align: center;">↑</td> <td>C</td> </tr> <tr> <td>Least negative</td> <td>A</td> </tr> </tbody> </table>	E°	redox system	Most negative	B	↑	C	Least negative	A	1
E°	redox system									
Most negative	B									
↑	C									
Least negative	A									
3(b)(i)	$E^{\circ}_{\text{cell}} = 1.07 - 0.80 = (+)0.27 \text{ V}$ AND direction of electron flow = Ag ⁺ / Ag to Br ₂ / Br ⁻	1								
3(b)(ii)	M1: E°_{cell} 3rd box ticked M2: [Ag ⁺] decreases AND so (Ag ⁺ / Ag) equilibrium shifts to the left OR [Ag ⁺] decreases AND E for (Ag ⁺ / Ag) becomes less positive / more negative	2								

34. 9701/42/M/J/21 Q4b

4(b)(i)	anode: chlorine / Cl ₂ cathode: hydrogen / H ₂	1
4(b)(ii)	M1: Q = 0.75 × 60 × 60 = 2700 C AND 96 500 or 193 000 used M2: [a] moles of Ca = 2700 / 193 000 = 0.0140 [b] mass = 0.0140 × 40.1 = 0.56 g	2

35. 9701/42/F/M/21 Q1b

1(b)	M1/2: Any two of: <ul style="list-style-type: none"> • Co³⁺ is reduced Co²⁺ • oxygen gas/O₂ is evolved • E of Co³⁺ greater than E of O₂ M3: no change (to [Co(edta)] ⁻) / not feasible OWTTE	3
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36. 9701/42/F/M/21 Q2b

2(b)(ii)	$2\text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^-$	1
2(b)(iii)	<p>M1: coulombs and correct use of + 96500 M2: correct use of 3 and 8 M3: correct use of 55.8 and answer</p> <p>M1: $Q = It = 50 \times 6 \times 60^2$ OR 1.08×10^6 C AND no. of faraday = $1.08 \times 10^6 / 96500$ OR 11.2 / 11.19 mol e^-</p> <p>M2: $\text{Fe}^{2+} + 2\text{Fe}^{3+} + 8\text{e}^- \rightarrow 3\text{Fe}$ \therefore moles of Fe = $3 / 8 \times \text{M1} = 4.20$ mol Fe ecf</p> <p>M3: mass of Fe = $55.8 \times \text{M2} = 234.2$ g ecf 3sf min</p>	3
2(c)(i)	Any one of: small size / compact, low mass, high voltage OWTTE	1
2(c)(ii)	Li from +1 to +1 Fe from +3 to +2	1
2(c)(iii)	$\text{LiC}_6 + \text{FePO}_4 \rightarrow \text{LiFePO}_4 + 6\text{C}$	1

37. 9701/42/F/M/21 Q3c

3(c)(i)	<p>M1: $E_{\text{cell}}^{\ominus}$ for $\text{IO}_3^- / \text{H}_2\text{O}_2 = -0.68 + 1.19 = +0.51$ (\therefore feasible) M2: $E_{\text{cell}}^{\ominus}$ for $\text{H}_2\text{O}_2 / \text{I}_2 = +1.77 - 1.19 = +0.58$ (\therefore feasible) M3: $5\text{H}_2\text{O}_2 + \text{I}_2 \rightarrow 4\text{H}_2\text{O} + 2\text{IO}_3^- + 2\text{H}^+$</p>	3
3(c)(ii)	$2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$	1

38. 9701/41/O/N/22 Q3

3(a)(i)	(Ion $\text{Sn}^{2+}/\text{Sn}^{4+}$) concentration 1 mol dm^{-3} AND 298 K (25 °C)	1
3(a)(ii)	<ul style="list-style-type: none"> • both half-cells have Pt or C electrode • $\text{Sn}^{2+} / \text{Sn}^{4+}$ AND H^+ solutions • feasible gas delivery system • H_2 label • V/voltmeter AND correct circuit AND salt bridge touching solution • salt bridge labelled 	3
3(a)(iii)	no (reaction) AND both E^{\ominus} values ($\text{Sn}^{2+} / \text{Sn}$) -0.14 and ($\text{Cl}_2 / \text{Cl}^-$) $+1.36$ [1] E_{cell} is -1.5 V / E_{cell} is negative OR E^{\ominus} of $\text{Sn}^{4+} / \text{Sn}^{2+}$ is more negative/smaller than E^{\ominus} of $\text{Cl}_2 / \text{Cl}^-$ [1]	2
3(a)(iv)	$\text{Sn}^{2+} \rightarrow \text{Sn}^{4+}$ and $\text{VO}^{2+} \rightarrow \text{V}^{3+}$ [1] $\text{Sn}^{2+} + 2\text{VO}^{2+} + 4\text{H}^+ \rightarrow \text{Sn}^{4+} + 2\text{V}^{3+} + 2\text{H}_2\text{O}$ [1]	2
3(b)	moles of Sn = $2.95 / 118.7 = 0.0249$ moles moles of Al (is 2 / 3 moles of Sn) = 0.0166 moles [1] mass of Al = $0.0166 \times 27 = 0.447 / 0.448$ g to 3sf [1] ecf	2

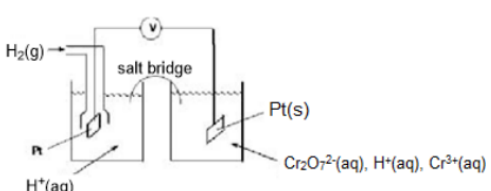
39. 9701/42/O/N/22 Q3

3(a)(i)	the voltage produced by a half-cell compared with a standard hydrogen electrode [1] 1 mol dm ⁻³ , 298 K, 1 atm [1]	2
3(a)(ii)	Mg wire and Pt wire [1] voltmeter, salt bridge, complete circuit [1] solutes Mg ²⁺ and MnO ₄ ⁻ , Mn ²⁺ , H ⁺ [1]	3
3(a)(iii)	Mg is minus, Pt is plus arrow points towards MnO ₄ ⁻ / Mn ²⁺ half-cell	1
3(a)(iv)	3.90 V	1
3(a)(v)	5Mg + 2MnO ₄ ⁻ + 16H ⁺ → 5Mg ²⁺ + 2Mn ²⁺ + 8H ₂ O	1
3(a)(vi)	no change and dilution will make Mg ²⁺ / Mg potential even more negative	1
3(b)	either: 4.75 × 10 ²² × 2 × 1.60 × 10 ⁻¹⁹ = 15 200 C OR 2 × 96 500 × (4.75 × 10 ²²) / 6.02 × 10 ²³ = 15 228 C [1] 15 200 / (15 × 60) = 16.9 A OR 15 228 / (15 × 60) = 16.9 A [1]	2

40. 9701/41/M/J/22 Q2e

2(e)(iii)	MnO ₂ AND redox	1
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41. 9701/41/M/J/22 Q3c

3(c)(i)	voltage / EMF / potential difference when a half-cell is connected to a (standard) hydrogen electrode under standard conditions	1
3(c)(ii)	ions move (from the salt bridge) to maintain charge balance / complete the circuit	1
3(c)(iii)	 <p>298K, 1 atm, 1 mol dm⁻³ Pt, H₂(g), good delivery system, 298 K, 1 atm Pt, Cr₂O₇²⁻(aq), H⁺(aq) / Cr³⁺(aq), 1 mol dm⁻³ seen once, voltmeter three for one mark, six for two marks, nine for three marks</p>	3
3(c)(iv)	SHE labelled negative AND arrow in the external circuit moving away from this electrode	1
3(d)(i)	M1 Cr ₂ O ₇ ²⁻ + 3CH ₃ CHO + 8H ⁺ ⇌ 2Cr ³⁺ + 3CH ₃ COOH + 4H ₂ O ALLOW Cr ₂ O ₇ ²⁻ + 3CH ₃ CHO + 5H ⁺ ⇌ 2Cr ³⁺ + 3CH ₃ COO ⁻ + 4H ₂ O M1 E _{cell} ^o = +2.27 (V)	2
3(d)(ii)	M1 ΔG ^o = -nFE _{cell} ^o M2 ΔG ^o = -4 × 96 500 × 2.01 = -775 860 J mol ⁻¹ ΔG ^o = -776 kJ mol ⁻¹ min 3sf	2

42. 9701/41/M/J/22 Q4c

4(c)	[Fe(CN) ₆] ³⁻ AND equilibrium lies most to the left / lowest E° value	1
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43. 9701/42/M/J/22 Q5

5(a)	electrolyte	substance liberated at the anode	substance liberated at the cathode	3
	PbBr ₂ (l)	Br ₂ / bromine	Pb / lead	
	concentrated NaCl(aq)	Cl ₂ / chlorine	H ₂ / hydrogen	
	Cu(NO ₃) ₂ (aq)	O ₂ / oxygen (+ H ₂ O)	Cu / copper	
two for one mark, four for two marks, six for three marks				
5(b)(i)	F = Le OR F is directly proportional to L			1
5(b)(ii)	number of Cu ²⁺ formed = 0.35 / 63.5 = 5.51 × 10 ⁻³ Q = I × t = 0.60 × 30 × 60 = 1080 C number of electrons = 1080 / 1.6 × 10 ⁻¹⁹ = 6.75 × 10 ²¹ ecf number of Cu ²⁺ ions = 6.75 × 10 ²¹ / 2 = 3.375 × 10 ²¹ ecf number of Cu ²⁺ ions per mole (L) = 3.375 × 10 ²¹ / 5.51 × 10 ⁻³ = 6.12 × 10 ²³ ecf min 2sf all five points for four marks ALLOW valid alternate calculations of L			4

44. 9701/42/F/M/22 Q3c

3(c)(i)	M1: $\Delta G = -nE_{\text{cell}}^{\ominus}F$ AND n = 4 M2: $\therefore E_{\text{cell}}^{\ominus} = -436100 / -4(96500) = 1.13 \text{ V ecf}$ M3: $E_{\text{cell}}^{\ominus} = E^{\ominus}(\text{O}_2, 4\text{H}^+ \text{H}_2\text{O}) - E^{\ominus}(\text{TiO}^{2+} \text{Ti}^{3+}) = 1.23 - E^{\ominus}(\text{TiO}^{2+} \text{Ti}^{3+})$ $\therefore E^{\ominus}(\text{TiO}^{2+} \text{Ti}^{3+}) = (+)0.1 \text{ (V) ecf}$	3
3(c)(ii)	Ti ³⁺ empty / vacant d orbitals can form dative bonds / accept a lone pair from a ligand OR Ti ³⁺ has vacant d-orbitals which are energetically accessible	1
3(c)(iii)	the E° of the half-cell must be greater than +1.23 V / E° of the O ₂ H ⁺ half-cell as E° _{cell} < 0 and the reaction does not occur	1