Section A (multiple choice)

Question Number	Correct Answer	Mark
1	A	**1**

Question Number	Correct Answer	Mark
2	D	**1**

Question Number	Correct Answer	Mark
3	A	**1**

Question Number	Correct Answer	Mark
4	B	**1**

Question Number	Correct Answer	Mark
5	D	**1**

Question 6: N/A

Question Number	Correct Answer	Mark
7	C	**1**

Question Number	Correct Answer	Mark
8	D	**1**

Question Number	Correct Answer	Mark
9	B	**1**

Question 10: N/A

Question 11: N/A

Question 12: N/A

Question 13: N/A

Question 14: N/A

Question Number	Correct Answer	Mark
15	C	**1**

Question 16: N/A

Question 17: N/A

Question 18: N/A

Question 19: N/A

Question Number	Correct Answer	Mark
20	A	**1**

Section B

Question Number	Acceptable Answers	Reject	Mark
21(a)	$3d^3 4s^2$ OR $4s^2 3d^3$ $3d^5 4s^1$ OR $4s^1 3d^5$ both must be correct. ALLOW Electron numbers could be on the line or as subscripts IGNORE case of letters		**1**

Question Number	Acceptable Answers	Reject	Mark
21(b)(i)	Variable/varying/different/several/ more than one **oxidation state /number** **(1)** Complex (ion formation) **(1)** Treat Physical properties (if correct) including catalytic activity as neutral	Each metal has a different oxidation number Ligand exchange	**2**

Question Number	Acceptable Answers	Reject	Mark
21(b)(ii)	The following metals scores (2) marks with correct E value: Mg 1.96, Ce 1.92, U 1.39, Al 1.25, Mn 0.78, V 0.77, Zn 0.35 **NOTE:** Positive sign/unit not needed, but penalise negative value The following metals score (1) mark with correct E value: Li 2.62, Rb 2.52, K 2.51, Ca 2.46, Na 2.30, Cr 0.33, Fe 0.03 **NOTE:** Positive sign/unit not needed, but penalise negative value	All other metals 0/2	**2**

Question Number	Acceptable Answers	Reject	Mark
21(b)(iii)	Not a redox process Chromate and dichromate **both** the same/no change in oxidation number **(1)** contain Cr(VI) 6/6+ **(1)** Mark independently OR Not redox and **both** contain Cr(VI) 6/6+ **(2)**		**2**

Question Number	Acceptable Answers	Reject	Mark
21(b)(iv)	Forms two (dative/covalent) bonds/has two lone pairs (to the Transition Metal/ion) OR donates two pairs of electrons (to the Transition Metal/ion) **Check answer to (v) if mark not awarded here**	'…to the molecule'	**1**

Question Number	Acceptable Answers	Reject	Mark
21(b)(v)	**Any two from** Both have two nitrogen atoms with lone pairs or implied **(1)** or Far enough apart/longer chain in between in en (but not in hydrazine)/too close in hydrazine/hydrazine is too short/not as long **(1)** or Dative bonds/lone pairs too close/repel in hydrazine **(1)** OR for two marks Forms 5-membered ring (with en with no angle strain/stable) **(2)** or Bond angles too acute/too much ring strain in hydrazine **(2)** **Mark for iv can be awarded here.**	N=N, or triple bond in hydrazine max 1 or if implies **only** en has lone pairs max 1	**2**

Question Number	Acceptable Answers	Reject	Mark
21(c)(i)	- 0.41 (V) +1.33 (V) **Both** answers needed, with number and sign, for 1 mark IGNORE additional words		**1**

Question Number	Acceptable Answers	Reject	Mark
***21(c)(ii) QWC**	Combines the equations to obtain $8Cr^{3+} + 7H_2O \rightarrow 6Cr^{2+} + Cr_2O_7^{2-} + 14H^+$ ALLOW $6Cr^{3+} + 2Cr^{3+}$ instead of $8Cr^{3+}$ IGNORE state symbols even if wrong species **(1)**, balance **(1)** $E^{\ominus}_{reaction}$ = — 1.74V **(1)** So not feasible on condition of negative value **(1)** OR $6Cr^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 8Cr^{3+} + 7H_2O$ If fully correct **(1)** $E^{\ominus}_{reaction}$ = + 1.74V **(1)** **Disproportionation** not feasible on condition of positive value but reject 'reaction is spontaneous' **(1)** **Other wrong equations** **IF** $Cr_2O_7^{2-}$ or Cr^{2+} on left Then + 1.74 V **(1)** **If** Cr^{3+} alone on the left Then -1.74 V **(1)** and reaction not feasible **(1)**	1 max for the equation if electrons are shown balanced or unbalanced	**4**

Section A

Question Number	Correct Answer	Mark
22	C	**1**

Question Number	Correct Answer	Mark
23	D	**1**

Question Number	Correct Answer	Mark
24	A	**1**

Question Number	Correct Answer	Mark
25	C	**1**

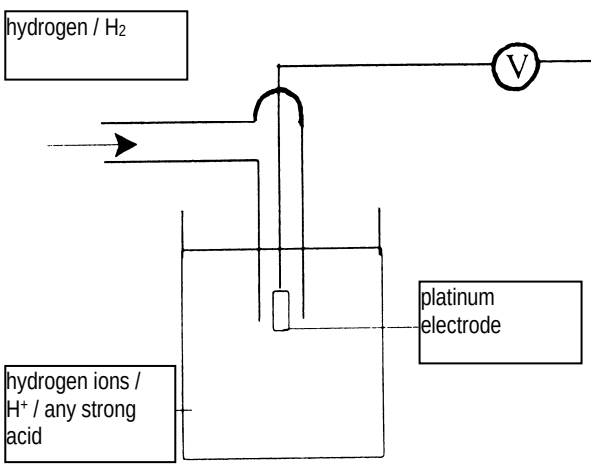
Question Number	Correct Answer	Mark
26	A	**1**

Question Number	Correct Answer	Mark
27	D	**1**

Question Number	Correct Answer	Mark
28	C	**1**

Section B

Question Number	Acceptable Answers	Reject	Mark
29 **(a)**	<table><tr><th>Half-equation</th><th>$E^{\ominus}$ / V</th></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td>+0.4(0)</td></tr><tr><td></td><td>+1.23</td></tr></table> **(1)** for each correct value Penalise omission of + once only	**+2.46**	**2**

Question Number	Acceptable Answers	Reject	Mark
29 **(b)(i)**	 **First mark**: Hydrogen / $H_2(g)$ / H_2 **(1)** IGNORE Any pressure value quoted **Second mark:** Name or formula of any strong acid (e.g. HCl / H_2SO_4) ALLOW hydrogen ions / $H^+(aq)$ / H^+ **(1)** IGNORE Any acid concentration value quoted IGNORE State symbols for ANY formula of hydrogen and / or acid, even if incorrect IGNORE any references to platinum	H(g) / H for hydrogen gas 'HCL' / HSO_4 Just 'acidic'	**2**

Question Number	Acceptable Answers	Reject	Mark
29 **(b)(ii)**	• 1 atm / 100 kPa / 101 kPa /1 bar • 1 mol dm^{-3} ($[H^+]$ / [HCl]) ALLOW '1 molar' / '1M' • 298 K / 25 ^oC ALLOW "^oK" All **THREE** conditions correct = **2** marks Any **TWO** conditions correct = **1** mark IGNORE References to 'standard conditions' References to Pt/catalyst ALLOW 0.5 mol dm^{-3} H_2SO_4 INSTEAD of the 1 mol dm^{-3} ($[H^+]$ / [HCl])	Wrong pressure units Incorrect concentration units (eg '1 mol' / 1 mol^{-1} dm^3 for $[H^+]$) 273 K / 0^oC / 'room temperature'	**2**

Question Number	Acceptable Answers	Reject	Mark
29 **(c)**	**First mark:** Mentions / some evidence for of BOTH equations 1 AND 3 fr table in any way, even if reversed or left unbalanced eg $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ AND $4OH^-(aq) + 2H_2(g) \rightarrow 4H_2O(l) + 4e^-$ **(1)** ALLOW $\rightleftharpoons$ for $\rightarrow$ **Second mark:** (Adds the above half-equations cancelling $4e^-$ to get) $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ OR $H_2(g) + ½O_2(g) \rightarrow H_2O(l)$ **(1)** ALLOW $\rightleftharpoons$ for $\rightarrow$ but must have H_2 and O_2 on left Mark the second scoring point independently Award this mark if the correct equation is seen, no matter how it is derived ALLOW MULTIPLES OF EQUATIONS IN ALL CASES IGNORE any state symbols, even if incorrect ALLOW equilibrium sign $\rightleftharpoons$ used in **ANY** of the above equations instead of the full arrows	Equations involving H^+ **If** e^- / OH^- / H^+ / two surplus H_2O molecules remain in this final equation **(0)** for 2nd mark	**2**

Question Number	Acceptable Answers	Reject	Mark
29 **(d)**	$E^{\ominus}_{cell}$ = +0.40 — (—0.83) (V) = (+)1.23 (V) + sign NOT required in final answer Correct answer with or without working scores (1) No ECF from any incorrect $E^{\ominus}$ values used	−1.23 (V)	**1**

Question Number	Acceptable Answers	Reject	Mark
29 **(e)**	Reaction / equation is the same OR Reaction / equation for both is $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ ALLOW ⇌ for → IGNORE state symbols even if incorrect ALLOW statements such as 'they both produce water from hydrogen and oxygen' / 'reactants and products are the same' ALLOW multiples of the **equation**	'Electrode potentials don't change' **Just** same product / water is produced **Just** same reactants are oxidized and reduced Same reaction but in **reverse** scores **(0)**	**1**

Question Number	Acceptable Answers	Reject	Mark
29 **(f)**	To **increase** the **surface area** /to increase the number of active sites		**1**

Question Number	Acceptable Answers	Reject	Mark
29 **(g)**	Storage (problems) OR hydrogen / oxygen / the gases have to be stored under pressure OR Leakage (of hydrogen / of oxygen /of gas) OR Transport(ation) problems OR Hard to carry / lack of portability OR Hydrogen flammable / inflammable OR Hydrogen explosive OR (Fuel cell) costly / expensive OR Needs (regular) re-filling OR Needs continual replenishment of H_2 and O_2 OR Lack of availability (of hydrogen / fuel) OR Hydrogen is made from fossil fuels / hydrogen is made by electrolysis / hydrogen is made from Natural Gas / hydrogen is made from non-renewable resources ALLOW water is a Greenhouse gas / Fuel cell(s) have short(er) life-span / Fuel cells have to be (regularly) replaced IGNORE references to just 'danger' or just 'safety' or just 'hazardous' Any arguments in terms of **voltage** output References to cannot be recharged	'Fuel cell can only be used once' scores (**0)**	**1**

Total for Question 29 **= 12 Marks**

Question Number	Acceptable Answers	Reject	Mark
30 (a)(i)	$TiCl_4 + 4Na \rightarrow 4NaCl + Ti$ IGNORE State symbols, even if incorrect ALLOW Multiples Reversible arrows		**1**

Question Number	Acceptable Answers	Reject	Mark
30 (a)(ii)	Ti **reduced** as oxidation number decreases from **+4 to 0**/ changes from **+4 to 0** **(1)** Na **oxidized** as oxidation number increases from **0 to +1** /changes from **0 to +1** **(1)** ALLOW Correct oxidation numbers only for one mark **NOTE** Max (1) if no + sign included ALLOW **'4+'** and/or **'1+'** given instead of **+4** and **+1** **NOTE** If any of the oxidation numbers are wrong, award max (1) for the idea that during oxidation the oxidation number increases **AND** during reduction the oxidation number decreases IGNORE References to loss and /or gain of electrons		**2**

Question Number	Acceptable Answers	Reject	Mark
30 **(b)**	(Ti [Ar]) $3d^2\ 4s^2$ / $4s^2\ 3d^2$ **(1)** (Ti^{3+} [Ar]) $3d^1$ / $3d^1\ 4s^0$ (Ti^{4+} [Ar]) 'nil' / $3d^0\ 4s^0$ /$3d^0$ space left blank by candidate BOTH Ti^{3+} and Ti^{4+} correct for second mark **(1)** Mark CQ on Ti electron configuration for the second mark ALLOW Upper case (e.g. 'D' for 'd' in electronic configurations) Subscripts for numbers of electrons Full correct electronic configurations $1s^2$, $2s^2$.....		**2**

Question Number	Acceptable Answers	Reject	Mark
30 **(c)(i)**	**(d-block element)** **EITHER** Ti has (two) electrons in the 3d subshell / Ti has a partially filled d-subshell / Ti has a partially filled d-orbital / Ti has electrons in d-orbital(s) / Ti has electrons in d-subshell (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital **OR** (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital	**Outer / highest energy** electrons are in a d-orbital / **Outer / highest energy** electrons are in a d-subshell Electrons in the 'd-block'/ 'electrons in the d-shell'	**1**

Question Number	Acceptable Answers	Reject	Mark
30 **(c)(ii)**	(transition element) Forms one (or more stable) **ions** / forms **Ti^{3+}** (ions) which have incomplete d-orbital(s) / an incomplete d-subshell / a partially filled d-subshell / an unpaired d electron IGNORE References to variable oxidation states		**1**

Question Number	Acceptable Answers	Reject	Mark
30 **(d)(i)**	**First mark:** d-subshell splits /d-orbital**s** split (in energy by ligands) /d energy level(s) split(s) **(1)** **Second mark:** **absorbs light** (in visible region) **(1)** **Third mark:** Electron transitions from lower to higher energy / electron(s) jump from lower to higher energy OR Electron(s) promoted (within d) **(1)** Mark independently **NOTE** Maximum of (1) mark (i.e. the first mark only) if refers to electrons falling back down again	d-**orbital /** d-**shell** splits absorbs **purple** light	**3**

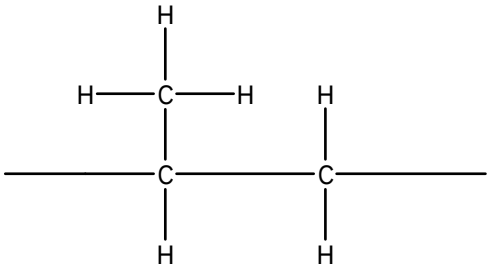
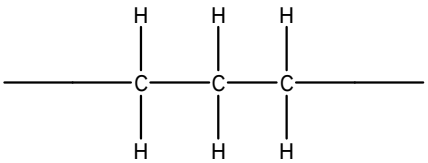
Question Number	Acceptable Answers	Reject	Mark
30 **(d)(ii)**	No d-electrons / empty d-subshell		**1**

Question Number	Acceptable Answers	Reject	Mark
30 **(e)(i)**	**TiO_2** **'Structure' mark** **EITHER** Giant (structure) **OR** Lattice (structure) IGNORE Whether stated as ionic or covalent for this mark **(1)** **TiO_2** **'Bonding' mark** EITHER **Strong** (electrostatic) attraction between ions ALLOW **Strong** ionic bonds / ionic bonds require a lot of energy to break **OR** **Strong** covalent bonds/covalent bonds require a lot of energy to break **(1)** **$TiCl_4$** **'Structure' mark** (Simple) molecules / (small) molecules **/**molecular **(1)** **$TiCl_4$** **'Bonding' mark** **Weak** London / dispersion / van der Waals' forces (between molecules) / London /dispersion / van der Waals' forces (between molecules) require little energy to break	TiO_2 (small) molecule**s** / simple molecular For TiO_2 mention of any type of intermolecular forces between molecules of TiO_2 $TiCl_4$ giant structure Covalent bonds broken (on melting) in $TiCl_4$ Ionic bonding in $TiCl_4$ Hydrogen bonding **(0)** for this mark	**4**

	NOTE If candidates assumes TiO_2 and $TiCl_4$ are both simple molecular, can score last mark for saying that the **named** intermolecular forces in TiO_2 are stronger that those in $TiCl_4$ IGNORE (Permanent) dipole-dipole forces **(1)** Mark the four scoring points independently		

Question Number	Acceptable Answers	Reject	Mark
30 **(e)(ii)**	Amphoteric ALLOW Recognisable spellings		**1**

Question Number	Acceptable Answers	Reject	Mark
30 **(e)(iii)**	$TiO_2 + 2H_2O + 2KOH \rightarrow K_2Ti(OH)_6$ OR $TiO_2 + 2H_2O + 2OH^- \rightarrow Ti(OH)_6^{2-}$ IGNORE state symbols even if incorrect		**1**

Question Number	Acceptable Answers	Reject	Mark
30 **(e)(iv)**	 **MUST** have continuation bonds at each end ALLOW CH_3 IGNORE n and any brackets	 **Two** (or more) repeat units shown	**1**

Question Number	Acceptable Answers	Reject	Mark
30 **(f)(i)**	(H_2O_2 + $2H^+$ +) **$2e^{(-)}$ → $2H_2O$** **BOTH** $2e^{(-)}$ **and 2**H_2O needed for the mark		**1**

Question Number	Acceptable Answers	Reject	Mark
30 **(f)(ii)**	(Moles H_2O_2 = $\frac{0.0200 \times 22.50}{1000}$ =) 4.5×10^{-4} mol H_2O_2 **(1)** (Moles Ti^{3+} reacting in 25.0 cm^3) = 9.0×10^{-4} mol Ti^{3+} (Moles Ti^{3+} in 250 cm^3) = 9.0×10^{-3} mol Ti^{3+} **(1)** (Original concentration of Ti^{3+} = $\frac{9.0 \times 10^{-3}}{0.00500}$ =) 1.8 (mol dm^{-3}) **(1)** 1.8 (mol dm^{-3}) with or without working scores **(3)** **NOTES:** If mole ratio H_2O_2 : Ti^{3+} is 1:1 final answer for concentration of Ti^{3+} is 0.9 (mol dm^{-3}) scores **(2)** overall If mole ratio H_2O_2 : Ti^{3+} is 2:1 final answer for concentration of Ti^{3+} is 0.45 (mol dm^{-3}) scores **(2)** overall If candidate forgets to multiply no. of moles of Ti^{3+} by 10 then answer is 0.18 (moldm-3) this scores **(2)** If volume of H_2O_2 used is 25.0 no first mark, but can score **(2**) if final answer CQ is 2(.0) (mol dm^{-3})		**3**

Question Number	Acceptable Answers	Reject	Mark
30 **(f)(iii)**	(It/titanium(III)/Ti^{3+}) **oxidized** (by oxygen in the air) ALLOW 'It is a **strong** reducing agent'	Hydrolysis	**1**

Total for Question 30 = 23 Marks