PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



MARK SCHEME

TOPIC 14: REDOX II

SCORE	PERCENTAGE
/369	%

STEMUP

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Suggest what happens to destroy vitamin C on prolonged cooking.

(1)

.....

.....

(Total for question = 14 marks)

Q59. Which of the following is always proportional to $E^{\ominus}_{cell}$ for a chemical reaction?

- **A** $\Delta H_{reaction}$
- **B** ΔS_{system}
- **C** $\Delta S_{surroundings}$
- **D** ΔS_{total}

(Total for Question = 1 mark)

Mark Scheme

Q1.

Question Number	Acceptable Answers	Reject	Mark
(a) (i)	**In (a) any units given must be correct. Penalise once only** **IGNORE SF except 1SF. Penalise once only** **If rounding is done then must be correct, penalise once only** **TE throughout** n = (0.100 x 0.0141) = 1.41×10^{-3} / 0.00141 (mol)	1×10^{-3}	**1**

Question Number	Acceptable Answers	Reject	Mark
(a) (ii)	7.05×10^{-4} / 0.000705 (mol) ALLOW TE = ans to (i) ÷ 2 1.4×10^{-3} gives 7.0×10^{-4} 0.0014 gives 0.00070	7.10×10^{-4} / 0.000710	**1**

Question Number	Acceptable Answers	Reject	Mark
(a) (iii)	c = ($7.05 \times 10^{-4} \div 0.05$) = 1.41×10^{-2} / 0.0141 (mol dm^{-3}) ALLOW TE = ans to (ii) ÷ 0.05 OR ALLOW TE = ans to (ii) x 20		**1**

Question Number	Acceptable Answers	Reject	Mark
(a) (iv)	$Ca(OH)_2$ M_r = 74.1 **(1)** ALLOW 74 m = (1.41 x 10^{-2} x 74.1) = 1.04481 = 1.045 = 1.04 (g dm^{-3}) **(1)** If M_r = 74 then m= 1.0434 = 1.04 (g dm^{-3}) ALLOW TE = ans to (iii) x 74.1 ALLOW TE for second mark if ans to (iii) x incorrect Mr value OR 7.05 x 10^{-4} x 74.1 = 0.0522405 = 0.0522 (g) **(1)** (0.0522 ÷ 0.05) = 1.044 (g dm^{-3}) **(1)**	1.05	**2**

Question Number	Acceptable Answers	Reject	Mark
(a)(v)	It's only a rangefinder / It's a rough OR approximate titration / It's an estimation / More than 0.2 cm^3 from other titres / Overshot on first titration / Not concordant ALLOW It is anomalous / It is out of range It differs / is not consistent with titrations 1 and 2 Titrations 1 and 2 are more consistent If a list of suggestions is given, a wrong cancels a right	Not titrated accurately It is not precise Control Just 'it's a trial'	**1**

Question Number	Acceptable Answers	Reject	Mark
(a) (vi)	**Pipette** 50.0 cm^3 (of distilled water) into weighed beaker and find the mass ALLOW "fill the **pipette**" (with water) and transfer into weighed beaker and find the mass / measure the mass of the **pipetted** distilled water **(1)** ALLOW alternative containers to beaker. Use the density of water to determine the exact volume / density of water is 1(.00)g cm^{-3} /check it weighs 50(.0) g **(1)** Stand-alone marks	"Transfer 50cm^3 water into a beaker" without reference to pipette. Approx. 50g Use of lime water Use of solution	2

Question Number	Acceptable Answers	Reject	Mark
(b)	A – (Strong) heat / high temperature **(1)** B – $CaCl_2 + H_2O$ (Both needed) **(1)** C – $Ca(OH)_2$ **(1)** D – Ca **(1)** IGNORE state symbols even if wrong IGNORE any number in front of species, e.g.$½O_2$ or 2Ca given in D	Warm / Gentle heat Reflux Combustion / burnt Answers suggesting reaction with air or oxygen CaCl CaOH Ca_2	**4**

Question Number	Acceptable Answers	Reject	Mark
(c)	Bubble(s) / Fizz(ing) / Effervescence IGNORE references to colourless solution, solid disappearing and energy / temperature changes and further tests eg effect on limewater	Coloured or colourless fumes Cloudy solution Just 'CO_2 forming' Just '(colourless) gas forming' Bubbles of any gas except CO_2	**1**

Question Number	Acceptable Answers	Reject	Mark
(d)	**Method 1:** Calcium is larger **ion** / calcium has a bigger **ionic** radius / or reverse argument for magnesium **ion** Use of the reverse argument applies throughout **(1)** (Distance between centres of ions increases so) weaker attraction/weaker bond between (calcium and carbonate) ions OR Shielding is greater in the calcium ion so weaker attraction (of calcium nucleus for carbonate ion) **(1)** **Method 2:** Calcium **ion** has a lower charge density **(1)** weaker attraction (between ions) **(1)** IGNORE references to polarization and the breaking of the covalent bonds in the carbonate ion	Calcium is bigger Any reference to atoms/molecules scores 0 Reference to ionization energy/weaker attraction for own electrons	2

Question Number	Acceptable Answers	Reject	Mark
(e)	Calcium's flame is yellow-red /orange-red / red / brick red Magnesium has no colour (Both needed for first mark) **(1)** Electrons excited / promoted (by heat energy) **(1)** (Colour produced from) energy / light emitted as electron returns (to ground state) **(1)**	Crimson Magnesium is white / bright Just "Mg / Ca decomposes" Electrons escape the orbitals	**3**

Q2.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• 23.15 **and** 23.55 **and** 23.20 completed in table **(1)** • ✓ beneath titres **1 and 3 and** mean titre = 23.18 (cm^3) **(1)**	All three titres must be shown to 2 D.P. Allow 23.2 or 23.175 (cm^3)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	(From)(pale) pink/purple (to) colourless	**Both** colours needed for the mark Do not award mauve or magenta or violet for pink/purple Ignore references to 'clear'	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)		Example of calculation	**(5)**
	• calculation of moles of MnO_4^- in 25.0 cm^3 **(1)**	Moles MnO_4^- = $\frac{0.02(00) \times 25.0}{1000}$ = 5(.00) x 10^{-4} / 0.0005(00) (mol)
	• calculation of moles of NO_2^- in mean titre **(1)**	Moles NO_2^- in mean titre = 2.5 x moles MnO_4^- = 1.25 x 10^{-3} / 0.00125 (mol)
	• calculation of moles of NO_2^- in 250 cm^3 **(1)**	Moles NO_2^- in 250 cm^3 = moles NO_2^- in mean titre x $\frac{250}{\text{mean titre from (a)}}$ = 1.25 x 10^{-3} x $\frac{250}{23.18}$ = 0.013481449 = 0.0135 (mol) Allow TE on mean titre from (a) Ignore SF except 1 SF
	• calculation of molar mass **(1)**	• Molar mass = 2 x $\frac{1.15}{0.0135}$ = 170.3703704 (g mol^{-1}) = 170.4 (g mol^{-1}) Allow TE
	• calculation of ***x*** correctly to the nearest whole number: **(1)**	• ***x*** = $\frac{170.4 - 116.3}{18(.0)}$ ***x*** = 3.005555556 ***x*** = 3 (**must** be to nearest whole number) Allow TE from molar mass calculated Allow alternative correct methods for MP4 and MP5 Correct value of ***x*** with no working scores (1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)	$2MnO_4^- + 5NO_2^- + 6H^+ \rightarrow 2Mn^{2+} + 5NO_3^- + 3H_2O$ • evidence of multiplying 1st equation by 2 **and** 2nd equation by 5 **(1)** • overall equation correct with H^+ and H_2O and $e^{(-)}$ cancelled as appropriate **(1)**	Each of the following equations score **(1)** mark overall: $2MnO_4^- + 5NO_2^- + 16H^+ + 5H_2O \rightarrow 2Mn^{2+} + 5NO_3^- + 8H_2O + 10H^+$ OR $2MnO_4^- + 5NO_2^- + 6H^+ + 5H_2O \rightarrow 2Mn^{2+} + 5NO_3^- + 8H_2O$ OR $2MnO_4^- + 5NO_2^- + 16H^+ \rightarrow 2Mn^{2+} + 5NO_3^- + 10H^+ + 3H_2O$ Ignore state symbols, even if incorrect Allow multiples	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	An explanation that makes reference to the following: **Either** • the (calculated) value of ***x*** would be too high **(1)** • The moles of $MgCO_3$ would be too low / the moles of $Mg(NO_2)_2 \cdot xH_2O$ would be too low / the M_r of $Mg(NO_2)_2 \cdot xH_2O$ would be too high **(1)** **Or** • (So) the (calculated) value of ***x*** would be unchanged (so this does not explain the discrepancy) **(1)** • Only a small amount/mass of $MgCO_3$ would dissolve because it is very slightly soluble **(1)**	Allow 'amount' or 'mass' for 'moles' MP2 depends on MP1 MP2 depends on MP1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	An answer that makes reference to the following points: • the $MgCO_3$ would decompose / the residue would contain $NaNO_2$ / the residue would contain (the excess) Na_2CO_3 **(1)** • (so) the (proposed) method is not valid / appropriate / suitable **(1)**	 Ignore references to just 'impurities' M2 dependent on M1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(g)	An answer that makes reference to the following point: • heat (the sample) to constant mass	 Allow repetition of heating and weighing until there is no change in mass (of the sample) Ignore references to 'brown gas' etc	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(h)	An answer that makes reference to the following points: • use a larger mass (of the hydrated salt) **(1)** • Use a balance that weighs to 3 D.P. (rather than 2 D.P.) **(1)**	 Ignore references to repeat measurements Allow statements such as 'use a balance that weighs to more decimal places' /'greater resolution' / ' a more precise/sensitive balance' Do not allow 'more accurate'	**(2)**

Q3.

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

Q4.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• calculation of moles of $Cr_2O_7^{2-}$ **(1)** • calculation of moles of Mn^{2+} **(1)** • deduction of whole number mole ratio of $Cr_2O_7^{2-}$: Mn^{2+} **(1)** • deduction of total number of electrons lost by 3 mol of Mn^{2+} **(1)** • deduction of final oxidation state of manganese **(1)**	Example of calculation • moles of $Cr_2O_7^{2-}$ = $\frac{0.100 \times 20.0}{1000}$ = 2(.00) x 10^{-3} (mol) • moles of Mn^{2+} = $\frac{0.200 \times 30.0}{1000}$ = 6(.00) x 10^{-3} (mol) • mole ratio $Cr_2O_7^{2-}$: Mn^{2+} = 1 : 3 • 3 mol Mn^{2+} lose a total of $6e^-$ • each Mn^{2+} loses $2e^-$, so final oxidation state of Mn is (+)4 / IV /Mn^{4+} MP3 and MP4 may be awarded via alternative methods e.g. use of oxidation numbers / moles of electrons correct final oxidation state with no working scores M5 only	**(5)**

Q5.

Question Number	Correct Answer	Reject	Mark
	D		1

Q6.

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

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: **EITHER** • the solution of manganate(VII) ions (1) • as distilled water/other solutions remaining in burette will dilute the solution of manganate(VII) ions (1) **OR** • Distilled water, followed by the solution of manganate(VII) ions (1) • So the distilled water will not dilute the solution of manganate(VII) ions (1)		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(a) (ii)	An answer that makes reference to the following points: • measure from the bottom of the meniscus (of the solution of manganate(VII) ions) (1) • with eyes / head at same level (as meniscus) **or** ensuring the burette is vertical **or** use of white background to emphasise meniscus **or** ensuring funnel is removed from top of burette **or** ensuring there is no air bubble in the tip of the burette (1)		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(a) (iii)	An explanation that makes reference to the following point: • it will not change the amount / moles (of reactants) in the flask		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	• $H_2C_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-$ / $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ <u>and</u> $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ (1) • $5H_2C_2O_4 + 2MnO_4^- + 6H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$ / $5C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$ (2)	Ignore state symbols Allow for 1 mark: $5H_2C_2O_4 + 2MnO_4^- + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O + 10H^+$	**3**

Question Number	Acceptable Answer	Additional Guidance	Mark
	• mean = 22.7 / 22.70 (cm^3) (1)		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(d)	• calculates amount of MnO_4^- (1) • calculates amount of $H_2C_2O_4$ (in 25 cm^3) (1) • calculates amount of $H_2C_2O_4$ (in 250 cm^3) (1) • calculates relative molecular mass of acid (1) • calculates **x** (1)	Example of calculation Amount of MnO_4^- = 22.7/1000 x 0.0105 = 2.3835 x 10^{-4} mol TE on mean in (c) Amount of $H_2C_2O_4$ (in 25 cm^3) = 2.3835 x 10^{-4} x 2.5 = 5.95875 x 10^{-4} mol TE on mol ratio in equation in (b) Amount of $H_2C_2O_4$ (in 250 cm^3) = 5.95875 x 10^{-4} x 10 = 5.95875 x 10^{-3} mol Relative molecular mass of acid = 0.747 / 5.95875 x 10^{-3} = 125.4 So relative mass of water of crystallisation = 125.4 – 90 = 35.4 35.4/18 = 1.97 so **x** = 2 Do not award **x** = 1.97	**5**

Question Number	Acceptable Answer	Additional Guidance	Mark
(e)	An answer that makes reference to the following point: • more MnO_4^- would show greater amount of $H_2C_2O_4$ (1) • so molecular mass of **x**H_2O would seem to be less, so value for **x** would be less (1) **or** • more MnO_4^- means lower molecular mass (1) • therefore mass of water of crystallisation is less so **x** is less than 2 (1)		**2**

Q8.

Question Number	Answer	Additional guidance	Mark
(a)	• Fe^{2+} / $Fe(H_2O)_6^{2+}$ (1) • Cr^{3+} / $Cr(H_2O)_6^{3+}$ (1)	Allow Ni^{2+} / $Ni(H_2O)_6^{2+}$ V^{3+} / $V(H_2O)_6^{3+}$ Ignore names	**2**
(b)(i)	Cr^{3+} / $Cr(H_2O)_6^{3+}$	Ignore names	**1**
(b)(ii)	$Cr(OH)_3$/ $Cr(H_2O)_3(OH)_3$	Ignore names	**1**
(b)(iii)	$Cr(OH)_6^{3-}$	Accept other correct species Ignore names (no ecf from (b)(i))	**1**
(c)	Any **one** from: • purple to colourless • purple (solution) decolourised	Allow final colour of solution to be orange Allow pink for purple	**1**
(d)(i)	Cl^-	Reject Cl Ignore names	**1**
(d)(ii)	An explanation that makes reference to the following points: ammonia solution cannot be used because: • ammonia reacts with the iron ions to form a precipitate (1) **or** • a precipitate of (Iron(II) hydroxide/ $Fe(OH)_2$/ $Fe(H_2O)_4(OH)_2$ forms (1) **Plus** • and so obscures the dissolving of the white precipitate (1)		**2**

Q9.

Question Number	Answer	Additional Guidance	Mark
	• both platinum symbols and salt bridge **(1)** • rest of diagram **(1)**	$Pt(s) \mid C_2O_4^{2-}(aq), 2CO_2(g) \,\vdots\, [MnO_4^-(aq) + 8H^+(aq)], [Mn^{2+}(aq) + 4H_2O(l)] \mid Pt(s)$ Allow solid lines for salt bridge Allow half cells shown correctly on opposite side Ignore omission of square brackets / state symbols if neither marked scored allow 1 mark for all four 'redox' species in ROOR order, separated by commas or dashed lines, but not solid lines	**(2)**

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• +5		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (i)	• choice of suitable reducing agent	From Data Booklet of the standard electrode potentials, the right hand substance in numbers 16-24	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (ii)	An answer that makes reference to the following point: • may be kinetically hindered **or** activation energy may be too high	Allow reaction may be too slow	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (iii)	An explanation that makes reference to the following points: • (yellow to) green then blue (1) • when the blue colour initially forms, it mixes with the yellow unreacted VO_2^+ (to turn green) (1)	Ignore colours caused by contamination with reducing agent chosen	**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (iv)	An explanation that makes reference to the following point: • justification of choice (1) • correct equation for reaction (1)	$E^\ominus$ value is between +0.34 V and −0.26 V Allow by comparison of electrode potentials / calculation of E_{cell} / use of anti-clockwise rule $S_2O_3^{2-} + VO^{2+} + 2H^+ \rightarrow V^{3+} + H_2O + \frac{1}{2}S_4O_6^{2-}$ or multiples	**2**

Q11.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	**First two marks** Cl in Cl_2 is 0 Goes to +1 in HClO Goes to −1 in HCl **(2)** All three correct for two marks Any two correct for one mark Ignore correct oxidation numbers for other elements If three correct numbers given without saying what species they are in max 1 for these two marks **Third mark** Cl/Cl_2/the same element is both oxidized and reduced Allow same molecule/species/ type of atom is both oxidized and reduced if answer elsewhere has been in terms of chlorine OR Cl/Cl_2/the same element both increases and decreases in oxidation number OR Chlorine both loses and gains electrons **(1)**	Only 'Cl^+' for oxidation number +1 Only 'Cl^-' for oxidation number -1 (treat each separately) For each incorrect oxidation number change for O and H, lose one mark. 0 to +1 described as reduction and/or 0 to -1 described as oxidation (for third mark)	**3**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	Equilibrium moves to the left / moves in reverse direction / moves to increase concentration of reactants **(1)** To use up (some of) added HCl/ to react with added HCl/ to stop formation of HCl/ restores equilibrium by producing more chlorine and water **(1)** Second mark depends on first Allow 'moves to decrease concentration of products/HCl' for both marks	Just "reverse reaction is **favoured**" Just "to counteract the change in the system" To minimise effect of HCl	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	$ClO^- + 2H^+ + 2e^{(-)} \rightarrow Cl^- + H_2O$ ALLOW $ClO^- + 2H^+ \rightarrow Cl^- + H_2O - 2e^{(-)}$ **(1)** $2I^- \rightarrow I_2 + 2e^{(-)}$ ALLOW $2I^- - 2e^{(-)} \rightarrow I_2$ **(1)** Allow multiples Ignore state symbols even if incorrect	Equations without electrons	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	$ClO^- + 2H^+ + 2I^- \rightarrow Cl^- + H_2O + I_2$ Mark independently. No TE on 21(b)(i)	Equations including electrons	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(iii)	Moles thiosulfate = (24.20 x 0.0500 / 1000) = 1.21×10^{-3} /1.2×10^{-3} /0.00121/ 0.0012 (mol) **(1)** Moles iodine = half moles of thiosulfate = 6.05×10^{-4} / 6.1×10^{-4} / 0.000605 / 0.00061 (mol) **(1)** Correct answer without working **(2)**	1.20×10^{-3} (mol) $1x\ 10^{-3}$/ 0.001 6.0×10^{-4} (mol) 6×10^{-4} (mol)	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(iv)	Moles ClO^- = 6.05×10^{-4} (mol) TE on (b)(ii) and (b)(iii): If ratio ClO^- :I_2 = 2:1 answer is 2 x answer to (b)(iii) If ratio ClO^- :I_2 = 1:2 answer is half of answer to (b)(iii)		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(v)	Concentration = (6.05×10^{-4} x 1000/25) = 2.42×10^{-2} / 0.0242/ 0.024/ 2.4×10^{-2} (mol dm^{-3}) TE. Answer to (b)(iv) x 1000÷ 25	Answers to 1 significant figure	**1**

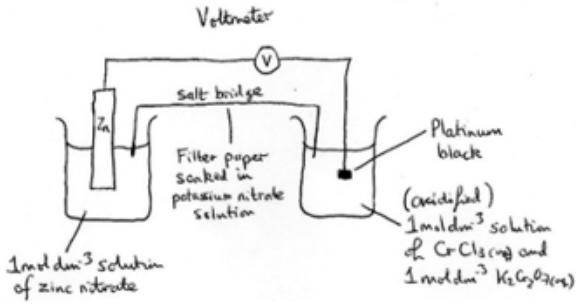
Question Number	Acceptable Answers	Reject	Mark
(b)(vi)	(Minimum) amount of I^- to react with OCl^- =2 x answer to (b)(iv) = 2 x 6.05 x 10^{-4} = 1.21 x 10^{-3} (mol) **(1)** Allow TE for 2 x answer to (b)(iv) Ignore s.f. Moles of I^- (9.04 x 10^{-3}) is more than this number of moles of ClO^- / I^- is in excess / KI is in excess / so that all the ClO^- can react **(1)** **OR** 9.04 x 10^{-3} mol I^- can react with 4.52 x 10^{-3} mol OCl^- **(1)** Ignore s.f. TE from incorrect equation in (b)(ii) Moles OCl^- (6.05 x 10^{-4}) is less than this/ I^- is in excess / KI is in excess / so that all the ClO^- can react **(1)**	"KI is in excess" if no calculation has been done.	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(vii)	0.30 x 100 / 24.2 (=1.2396694) = 1.24/ 1.2 %		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(viii)	Judgement (of colour change) at end point / adding starch too early in the titration / jet of burette not filled Errors must cause an increase in titre. Ignore Just "Human error" Just 'overshot endpoint' Transfer errors / spillage Errors due to misreading burette / pipette	Some potassium iodide did not dissolve Leaving funnel in burette Errors which affect both the students titre and an accurate titre using the same solutions e.g. impure solutions	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)	(Cl radicals) break down ozone (layer)/ ozone depletion / ozone (layer) thinning Allow damage ozone (layer)/ react with ozone	Global warming Causes acid rain	**1**

Q12.

Question Number	Answer	Additional Guidance	Mark
	A diagram that includes • **(M1)** (high resistance) voltmeter/V **(1)** • **(M2)** salt bridge to complete circuit **(1)** • **(M3)** filter paper soaked in (saturated) potassium nitrate/KNO_3 solution **(1)** **(M4)** zinc electrode of zinc metal and suitable zinc salt **(1)** • **(M5)** platinum (black) electrode **(1)** • **(M6)** suitable chromium salts **(1)** • **(M7)** all solutions to be 1 mol dm^{-3} (wrt ions) **(1)**	Example of diagram  Salt bridge must dip into the solutions Allow sodium chloride/potassium chloride for potassium nitrate e.g. $ZnSO_4$ e.g. $CrCl_3$ / $K_2Cr_2O_7$ if $Cr_2(SO_4)_3$ is used then M7 can only be awarded if its concentration is 0.5 mol dm^{-3} Allow electrodes drawn the other way round Ignore temperature is 298 K Penalise use of just names once only	**(7)**

Q13.

Question Number	Answer	Additional Guidance	Mark
(i)	• four correct species **(1)** • balancing and the correct number of electrons **(1)**	<u>An example of equation</u> $[Cr(OH)_6]^{3-} + 2OH^- \rightarrow CrO_4^{2-} + 4H_2O + 3e^-$ Accept multiples	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• equation	An example of equation $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ Accept $\rightleftharpoons$ / multiples	(1)

Question Number	Answer	Additional Guidance	Mark
(iii)	• oxidation half equation **(1)** • reduction half equation **(1)** • overall equation **(1)**	$H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$ $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ $Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$ for M3 do not award if H^+/ e^- left on both sides Accept multiples Allow $\rightleftharpoons$ Ignore state symbols even if incorrect Oxidation and reduction half equations scores (2) if not identified but in correct order Award (1) only for M1 and M2 if half equations are not in correct order No TE on incorrect half equations	(3)

Q14.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>* (a)</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
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The following table shows how the marks should be awarded for structure and lines of reasoning.

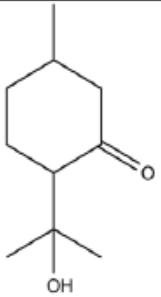
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
Indicative Content:

• technique A allows heating for a longer time period / technique B is suitable for a shorter time period

• technique A ensures oxidation / technique B may result in loss of reactant before oxidation</td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>6</td></tr>
</table>

	• technique A minimises release of flammable **or** harmful vapours / technique B allows release of flammable **or** harmful vapours, unless carried out in fume cupboard • technique A involves more expensive equipment **or** is more complex to set up / technique B is simpler to set up **or** uses less expensive equipment • as complete oxidation is not necessary to qualitatively show it is an alcohol that can be oxidised • technique B is most appropriate as simpler / technique A is most appropriate as oxidation is guaranteed		

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	An explanation that makes reference to the following pairs: **either** • no, as chloride ions could be oxidised by dichromate(VI) ions (reducing amount of oxidant / producing toxic chlorine) (1) • $E^{\ominus}$ values for dichromate(VI) and chloride ions being oxidised to chlorine are sufficiently close (even though $E^{\ominus}$ is negative = -0.03 V) for chlorine to be formed (1) **or** • yes, as reaction is dependent on H^+ ions (not anions) (1) • $E^{\ominus}$ value is negative (-0.03 V) (1)		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)			**1**

Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• substitution of correct values into expression **(1)** • calculation of $\ln[Ag^+(aq)]$ **(1)** • calculation of $[Ag^+(aq)]$ **(1)**	Example of calculation $0.72 = 0.80 + \frac{8.31 \times 293}{96500} \times \ln[Ag^+(aq)]$ $\ln[Ag^+(aq)] = (0.72 - 0.80) \times \frac{96500}{8.31 \times 293}$ $= -3.1707$ $[Ag^+(aq)] = e^{\ln[Ag+(aq)]}$ $= 0.041976 / 4.1976 \times 10^{-2}$ (mol dm^{-3}) TE on $\ln[Ag^+(aq)]$ Ignore SF except 1 SF Correct answer with no working scores full marks Expression can be rearranged before substitution of values	**(3)**

Q16.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	• bottom of meniscus between 23.8 and 23.9 (cm^3) **(1)** • meniscus curved downwards **(1)**	Example of diagram  Ignore shading below the meniscus Do not award M2 if there is shading above the meniscus	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: • 23.15 (cm^3) should be used as it is the mean of the concordant titres / titres 2 and 4 /23.10 and 23.20 (cm^3) **(1)** • 23.43 (cm^3) should not be used as it includes the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) **(1)**	Allow other descriptions of concordant e.g. titres within 0.1 / 0.2 cm^3 Allow (23.1(0) + 23.2(0))/2 = 23.15 (cm^3) Allow only the concordant titres / titres 2 and 4 / 23.20 and 23.20 (cm^3) should be used / are used(in the mean) Allow the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) should not be used / are used (in the mean)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iii)	• calculation of percentage uncertainty	Example of calculation $\frac{2 \times 0.05}{23.20} \times 100$ = (±)0.431 / 0.43 / 0.4 (%) Ignore SF including 1 SF Correct answer with no working scores (1)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a) (iv)	• calculation of moles of MnO_4^- **(1)** • calculation of moles $C_2O_4^{2-}$ in 25.0 cm^3 **(1)** • calculation of moles $C_2O_4^{2-}$ in 1.00 dm^3 **(1)** • calculation of **y** to nearest whole number **(1)**	Example of calculation moles MnO_4^- = 23.15 x 0.0203/1000 = 0.00046995 / 4.6995 x 10^{-4} (mol) moles $C_2O_4^{2-}$ in 25.0 cm^3 = 4.6995 x 10^{-4} x 5/2 = 0.0011749 / 1.1749 x 10^{-3} (mol) TE on moles MnO_4^- moles $C_2O_4^{2-}$ in 1.00 dm^3 = 1.1749 x 10^{-3} x $\frac{1000}{25.0}$ = 0.046995 / 4.6995 x 10^{-2} (mol) TE on moles $C_2O_4^{2-}$ in 25.0 cm^3 Ratio moles salt : moles $C_2O_4^{2-}$ = 0.0235 : 0.046995 = 1 : 1.9998 **y** = 2 TE on moles $C_2O_4^{2-}$ in 1.00 dm^3 Alternative method for M3 and M4 moles salt in 25.0 cm^3 = 0.0235 x 25.0/1000 = 5.875 x 10^{-4} (1) Ratio moles salt : moles $C_2O_4^{2-}$ = 5.875 x 10^{-4} : 1.1749 x 10^{-3} = 1 : 1.9998 **y** = 2 TE on moles salt and $C_2O_4^{2-}$ in 25.0 cm^3 (1) Ignore SF in working except 1 SF Correct answer with no working scores (1) Allow M4 for correct answer using charges on ions	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• calculation of mol of anhydrous salt **(1)** • calculation of mol H_2O **(1)** • calculation of ***z*** to nearest whole number **(1)**	<u>Example of calculation</u> mol anhydrous salt = 2.96/218.1 = 0.013572 / 1.3572 x 10^{-2} (mol) TE on M_r of anhydrous salt from value of **y** in (a)(iv) or an assumed value of ***y*** Allow 0.013578 from M_r 218 mol H_2O (= 0.45/18) = 0.025 / 2.5 x 10^{-2} (mol) Ratio mol salt : mol H_2O = 0.013572 : 0.025 = 1 : 1.842 **z** = 2 TE on moles anhydrous salt and moles H_2O Ignore SF in working except 1 SF Correct answer with some working scores (3) Penalise **y** and **z** not given to nearest whole number once only in (a)(iv) and (b)(i) Allow alternative correct methods	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	An answer which includes the following points: Crystals jumped out of crucible • value of ***z*** increases **and** because it appears that more mass / mol / water is lost (than expected) **(1)** • (this can be prevented by) placing a lid on the crucible **or** **(1)** heat more gently / carefully Not all water of crystallisation lost • less mass / mol /water is lost (than expected) **(1)** • (this can be prevented by) heating to constant mass **or** description of heating to constant mass **(1)** • so this accounts for the lower value of ***z*** / value of ***z*** decreases **(1)**	Ignore just 'loss in mass / mol' Stand alone mark Allow just 'cover the crucible' Ignore use an electrical heater / larger crucible / evaporating basin / conical flask / test tube etc Do not award add anti-bumping granules Stand alone mark Ignore just 'heat for longer' Do not award the idea of repeating the experiment / using a drying agent Conditional on M3	**(5)**

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• (high resistance) voltmeter **(1)** • platinum /Pt (electrode) **(1)** • manganese(II) **and** manganese(III) ions / Mn^{2+} **and** Mn^{3+} **(1)**	Allow potentiometer / Wheatstone bridge / just 'V' Ignore high voltage Do not award voltameter Ignore just 'inert metal' Do not award manganese / Mn Allow any named manganese(II) salt **and** manganese(III) salt Ignore concentration and units	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (i)	• potassium nitrate / KNO_3	If name and formula are given, both must be correct If more than one substance given, all must be correct Allow potassium chloride / KCl sodium nitrate / $NaNO_3$ sodium chloride / NaCl ammonium nitrate / NH_4NO_3 ammonium chloride / NH_4Cl Ignore concentration	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (ii)	• wire does not allow the flow of ions **or** wire (only) allows flow of electrons **or** salt bridge allows flow of ions **or** salt bridge does not allow the flow of electrons **or** a flow of ions is needed to complete the circuit **or** ions (need to) flow between the half-cells / between the solutions	Allow any indication of movement for flow in all points Allow the salt bridge donates / removes ions (to balance the charges in the solution and the wire does not do this) Ignore just 'the circuit is not complete' Ignore references to changes in potential difference / $E^{\ominus}$ / $E^{\ominus}_{cell}$	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c) (i)	• correct equation	Example of equation $2Mn^{3+} + Cu \rightarrow 2Mn^{2+} + Cu^{2+}$ Allow multiples Allow ⇌ provided equation is written in the direction shown Ignore state symbols, even if incorrect Ignore cancelled electrons e.g. $2Mn^{3+} + Cu \rightarrow 2Mn^{2+} + Cu^{2+} + 2e$ Do not award equation with uncancelled electrons	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)(ii)	• $E^{\ominus} = 1.15 - (-0.34) = (+)1.49$ (V)	Stand alone mark Correct answer with no working scores the mark	(1)

Q18.

Question Number	Correct Answer	Mark
	A	**1**

Q19.

Question Number	Correct Answer	Reject	Mark
(a)	C		**1**
(b)	A		**1**

Q20.

Question Number	Correct Answer	Reject	Mark
(a)	C		**1**
(b)	A		**1**
(c)	B		**1**

Q21.

Question Number	Answer	Additional Guidance	Mark
(i)	• identification of oxidising agent	Either acidified (potassium) manganate(VII) / MnO_4^- and H^+ Or acidified hydrogen peroxide / H_2O_2 and H^+ Allow H^+ shown in equation in (i) or (ii) If the acid is specified it must be sulfuric acid	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	• value of $E^{\ominus}_{cell}$	Either $E^{\ominus}_{cell}$ = (+)0.15 (V) for acidified (potassium) manganate(VII) Or $E^{\ominus}_{cell}$ = (+)0.41 (V) for acidified hydrogen peroxide No TE on any other reagent in (i)	(1)

Q22.

Question Number	Correct Answer	Reject	Mark
	A		1

Q23.

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

Q24.

Question Number	Acceptable Answers	Additional Guidance	Mark
	A description that makes reference to the following points: **M1 and M2 –colours** Yellow → blue → green → violet / lavender / purple / mauve 2 or 3 colours linked to correct species / oxidation states / reactions **(1)** 4 colours linked to correct species / oxidation states / reactions **(1)** **M3 - statement** Statement that sequence is from +5 to +4 to +3 to +2 **or** (step-wise) reduction / zinc is a reducing agent **(1)** **M4, M5 and M6 - equations** These three equations, **with** appropriate $E^{\ominus}$ values $Zn + 2VO_3^- + 8H^+ \rightarrow Zn^{2+} + 2VO^{2+} + 4H_2O$ **and** $E^{\ominus}$ = (+)1.76 (V) **(1)** $Zn + 2VO^{2+} + 4H^+ \rightarrow Zn^{2+} + 2V^{3+} + 2H_2O$ **and** $E^{\ominus}$ = (+)1.1(0) (V) **(1)**	M3 can be implied from species in explanation or equations Allow multiples Ignore state symbols even if incorrect 3 correct equations with incorrect $E^{\ominus}$ scores 2 2 correct equations with incorrect $E^{\ominus}$ scores 1 3 correct $E^{\ominus}$ with incorrect equations scores 1	**(7)**
	$Zn + 2V^{3+} \rightarrow Zn^{2+} + 2V^{2+}$ **and** $E^{\ominus}$ = (+)0.5(0) (V) **(1)** **M7 – stops at V^{2+}** No (further) reduction (feasible) to V metal / V(0) **or** $Zn + V^{2+} \rightarrow Zn^{2+} + V$ not feasible **or** $E^{\ominus}$ = −0.42 (V) **(1)**		

Q25.

Question number	Answer	Additional guidance	Marks
(i)	An explanation that makes reference to the following points: • $E^{\ominus}$ of redox system 5 is more negative / less positive than that of both redox systems 4 and 3 (but not than that of redox systems 2 and 1) (1) • therefore SO_2 releases electrons to / reduces VO_2^+ to VO^{2+} and then VO^{2+} to V^{3+} (1) • (yellow to) blue <u>then</u> green (1)	Accept explanations based on calculating $E^{\ominus}_{cell}$ for the reactions Accept correct use of anticlockwise rule Ignore green colour before blue	3
(ii)	The reaction is **<u>not</u>** feasible because: • $E^{\ominus}$ of redox system 2 is less negative than that of redox system 1 (1) • therefore V^{2+} ions in system 2 will not release electrons to the V^{2+} ions in system 1 (1)	Accept explanations based on calculating $E^{\ominus}_{cell}$ for the reactions Accept correct use of anticlockwise rule	2

Q26.

Question Number	Acceptable Answers	Reject	Mark
(a)	−285.8 / −286 ($kJ\ mol^{-1}$)		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	$H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^{(-)}$ **(1)** $O_2(g) + 2H_2O(l) + 4e^{(-)} \rightarrow 4OH^-(aq)$ **(1)** **For state symbols mark:** Two of the four stated equations (see the two equations above and the two equations below) must be quoted even if reversed or unbalanced. All state symbols must be correct in **both** equations for correct species for the state symbol mark (penalise once only) **(1)** Both equations for an **acid** fuel cell score max 2 (1 for correct equations and 1 for states) e.g. $H_2(g) \rightarrow 2H^+(aq) + 2e^{(-)}$ OR $H_2(g) - 2e^{(-)} \rightarrow 2H^+(aq)$ $O_2(g) + 4H^+(aq) + 4e^{(-)} \rightarrow 2H_2O(l)$ ALLOW Equation multiples Equations in reverse direction Any order of equations Reversible arrows		**3**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	Electrolyte / to allow the movement of ions (between electrodes) ALLOW Movement of hydrogen ions/ oxonium ions / hydroxonium ions / hydronium ions / H^+ / H_3O^+ / hydroxide ions / OH^- (between electrodes) IGNORE References to electron transfer	Catalyst Just 'conducts electricity' Movement of other ions / charged species	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(iii)	Any two of Both involve breaking / weakening bonds OR Both involve active site(s) (on the catalyst surface) OR **Ad**sorption **(2)** IGNORE Lowers the activation energy Both heterogeneous References to surface area or "surface for the reaction" References to orientation of reactant molecules "Reaction pathway is similar"	**Ab**sorption	**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	Water is the **only** product (at the point of use) / **no** oxide(s) of carbon IGNORE Reference to efficiency and/or high energy density Greener	**Less** oxide(s) of carbon	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	**Any two from:** Fuel cell is more efficient / 70% efficient ALLOW Any % between 70% and 100% It produces electricity directly OR **Less** heat loss Releasing energy in a more controlled manner **(2)** IGNORE References to safety	Any mention of carbon emissions	**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(iii)	**Either** High cost / expensive OR Cost of catalyst OR Short life-span IGNORE References to liquefaction and / or storage of hydrogen / size / weight		**1**

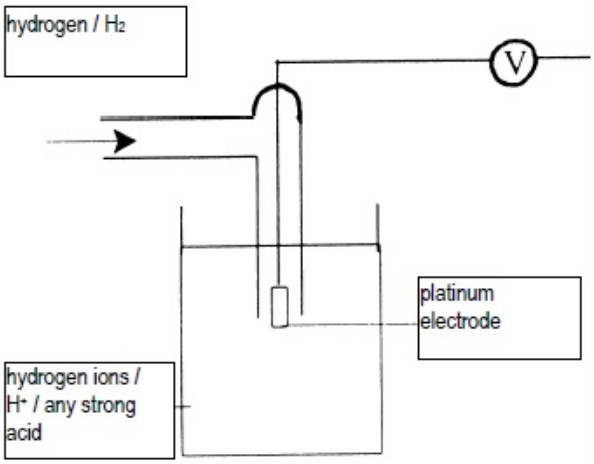
Question Number	Acceptable Answers	Reject	Mark
(c)(iv)	**Any two from** Ethanol renewable / sustainable / carbon neutral / availability of raw materials / low(er) carbon footprint / made from natural processes e.g. fermentation or biomass Less explosive / less flammable / safe(r) Easier to store / pressure not needed for storage / easier to transfer Fuel tank light(er) / small(er) New petrol stations not required ALLOW Reverse arguments for hydrogen IGNORE Reference to cost References to energy density		**2**

Q27.

Question Number	Correct Answer	Reject	Mark
	A		1

Q28.

Question Number	Acceptable Answers	Reject	Mark
(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
(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**

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Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	• 1 atm / 100 kPa / 101 kPa /1 bar • 1 mol dm^{-3} ($[H^+]$ / [HCl]) ALLOW '1 molar' / '1M' • 298 K / 25 °C 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°C / 'room temperature'	**2**

Question Number	Acceptable Answers	Reject	Mark
(c)	**First mark:** Mentions / some evidence for the use of BOTH equations 1 AND 3 from the 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 $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ **(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
(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
(e)	Reaction / equation is the same OR Reaction / equation for both is $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ ALLOW $\rightleftharpoons$ for $\rightarrow$ 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
(f)	To **increase** the **surface area** /to increase the number of active sites		**1**

Question Number	Acceptable Answers	Reject	Mark
(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**

Q29.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• calculation of moles of Cr **(1)** **MP2, 3 & 4 are only available for answers using a 3:2 mole ratio** • deduction of mole ratio of **X** to Cr^{3+} **(1)** • calculation of moles of **X** **(1)** • calculation of molar mass / A_r of **X** **and** identification of **X** accordingly **(1)**	Example of calculation Moles Cr = $\frac{1.456}{52(.0)}$ = 0.028(0) **3** mol **X** : **2** mol Cr^{3+} / Cr Allow $2Cr^{3+} + 3\mathbf{X} \rightarrow 3\mathbf{X}^{2+} + 2Cr$ Moles **X** = 0.028(0) x 1.5 = 0.042(0) Correctly multiplying by 1.5 for MP3 implies MP2 $M_r = \frac{1.021}{0.042(0)}$ = 24.3 (g mol^{-1}) **and** (so) **X** is magnesium/Mg COMMENT: If transpose 3:2 ratio, **X** has M_r = 54.7 (g mol^{-1}) and **X** = Mn so scores M1, then M3 and M4 by TE (i.e. **(3)** marks overall)	**(4)**

Q30.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Na / sodium	Do not award Na^+	**(1)**

Q31.

Question Number	Acceptable Answers	Reject	Mark
(i)	Amount of $S_2O_3^{2-}$ = 9.65 x 0.00550 ÷ 1000 * (= 5.3075 x 10^{-5} mol) (1) Amount of Cl_2 (in 1 dm^3) = 0.5 x * = 0.5 x 9.65 x 0.00550 ÷1000 ** (= 2.65375 x 10^{-5} mol) (1) Mass of Cl_2 (in 1 dm^3) = 71 x 1000 x ** = 1.8842 (mg dm^{-3}) (1) (so within limits) ALLOW 1.8842x10^{-3} g dm^{-3} **and** so within limits An answer lower than 1 or higher than 2 mg dm^{-3} only scores a TE mark if there is a comment relating to the limits Correct answer with no working scores 1 Ignore SF except 1 SF **Note** If 0.5 omitted in MP2 and 35.5 used in MP3 then final answer is numerically correct; this scores only MP1	Incorrect units	3

Question Number	Acceptable Answers	Reject	Mark
(ii)	Concentration of chlorine might be different in different parts of the pool / at different times OR Sample size small in relation to pool volume IGNORE Just 'sample size is small' References to experimental uncertainty		1

Q32.

Question number	Acceptable Answer	Additional Guidance	Marks
(a)	• starch (1) • blue-black to colourless (1)	accept blue or black	**2**

Question number	Acceptable Answer	Additional Guidance	Marks
(b)	$(2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-)$	Ignore state symbols	**1**

Question number	Acceptable Answer	Additional Guidance	Marks
(c)	• calculation of moles of $S_2O_3^{2-}$ (1)	$n(S_2O_3^{2-}) = \frac{38.70 \times 0.00100}{1000}$ / 3.870×10^{-5} (mol)	**6**
	• calculation of moles of I_2 in excess (1)	$n(I_2)$ in excess = ½ x $n(S_2O_3^{2-})$ / 1.935×10^{-5} (mol)	
	• calculation of moles of initial I_2 and reacted I_2 (1)	$n(I_2)$ initial = $\frac{10.0 \times 0.00500}{1000}$ / 5.00×10^{-5} (mol)	
		$n(I_2)$ reacted (= $n(SO_2)$) = $n(I_2)$ initial – $n(I_2)$ in excess / 3.065×10^{-5} (mol)	
	• calculation of concentration of SO_2 in mol dm^{-3} (1)	$[SO_2] = \frac{3.065 \times 10^{-5}}{10} \times 1000 = 3.065 \times 10^{-3}$ (mol dm^{-3})	
	• calculation of concentration of SO_2 in mg dm^{-3} (1)	$[SO_2] = 3.065 \times 10^{-3} \times 64.1 \times 1000$ mg dm^{-3} = 196.47 mg dm^{-3}	
	• conclusion (1)	(196 < 400) so the wine can be sold	

Q33.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	**In (a) any units given must be correct. Penalise once only.** **IGNORE SF except 1SF. Penalise once only.** **TE throughout** ((0.1x11.6)/(1000) = 1.16 x 10^{-3}/ 0.00116/ 0.0012/1.2 x 10^{-3}(mol)		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	(1.16 x 10^{-3} / 2) = 5.8x10^{-4} / 0.00058 (mol I_2 react with thiosulfate) 6.0x 10^{-4} if 1.2 x 10^{-3} used	6 x 10^{-4}	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	((50x0.25)/1000) = 1.25x10^{-2} / 12.5x10^{-3} / 0.0125 (mol)	0.012	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(iv)	= Answer to (a)(iii)- answer to a(ii) (1.25 x 10^{-2} - 5.8x10^{-4}) = 1.192 x10^{-2}/0.01192 (mol reacted with tin) 1.19 x10^{-2} /0.0119 (mol) if 6.0x 10^{-4} used ALLOW 1.2 x 10^{-2}/0.012 (mol)	 1.20 x 10^{-2}	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(v)	Mass of tin = answer to (a)(iv) x118.7/ = 1.414904/ 1.415 g **(1)** % tin = $\frac{1.415 \times 100}{10.25}$ = 13.803941 = 13.8 % **(1)** TE from mass if only 1 error in its calculation 13.83/ 13.8% if 1.194 x10^{-2} used If answer to(a)(iv) = 5.8x10^{-4} mol I_2 this gives 0.068846 g Sn and 0.67167 % Sn scores (2) Correct answer without working scores (2) ALLOW (1) for 17.5% of SnO_2		**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	Divide solution into separate portions for titration	Just 'repeat the titration' Use starch	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	$\frac{0.05 \times 2 \times 100}{11.6}$ = (±) 0.86% ALLOW 0.9%	 0.90%	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(iii)	Use more dilute thiosulfate (to make titration reading bigger) / Use a larger volume or moles of excess iodine	Use more rock	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)	(Pale) yellow / straw-coloured to colourless	Clear for colourless Blue / black to colourless Orange / grey / brown	**1**

Q34.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• MnO_2, MnO_4^-, OH^- and MnO_4^{2-} species correct in a single equation **(1)** • H_2O on right **and** balancing **(1)**	Example of equation $MnO_2 + 2MnO_4^- + 4OH^- \rightarrow 3MnO_4^{2-} + 2H_2O$ Ignore state symbols, even if incorrect Do not award M1 if H^+ is on the left Allow cancelled electrons Allow multiples	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	An answer that makes reference to: • 2 different species are oxidised and reduced (to form the same species) **or** there is not 1 species that is being oxidised and reduced **or** 2 different oxidation states are not produced from one oxidation state **or** only 1 oxidation state / +6 is formed as a product **or** Mn changes from +4 and +7 to +6 (only)	This mark can be awarded even if (i) is incorrect Allow manganate(VI) / MnO_4^{2-} is oxidised and reduced in the reverse reaction Allow Mn in the same species is not being oxidised and reduced Ignore just 'Mn is not simultaneously oxidised and reduced' Ignore this is reverse disproportionation / comproportionation Do not award O / H is oxidised / reduced Do not award molecules / compounds for species	(1)

Q35.

Question Number	Answer	Additional Guidance	Mark
	• Calculation of moles of silver chloride **(1)** • Calculation of mass of silver moles of Cu^{2+} **(1)** • Calculation of mass of copper **(1)** • Calculation of mass of copper **(1)** • Calculation of percentage of gold **(1)**	Example of calculation moles AgCl = 0.706/(107.9 + 35.5) = 0.00492329 / 4.92329 x 10^{-3} mass Ag = 0.00492329 x 107.9 = 0.531223 (g) moles S_2O^{2-} **or** moles Cu^{2+} = 39.40 x 0.100 / 1000 = 0.00394 / 3.94 x 10^{-3} mass Cu = 0.00394 x 63.5 = 0.25019 (g) mass Au = 1.250 – (0.531223 + 0.25019) = 0.468587 (g) percentage of gold = 0.468587/1.250 x 100 = 37.5 (%) **or** percentage of silver = 0.531223/1.250 x 100 = 42.4978 / 42.5 (%) percentage of copper = 0.25019/1.250 x 100 = 20.0151 / 20 (%) percentage of gold = 100 – (42.5 + 20) = 37.5 (%) Allow TE for each step Allow final answer based on correct rounding at each stage (36.3 to 37.9%) Ignore SF except 1 SF in final answer Correct answer without working scores (5)	**(6)**

	• Deduction that alloy is 9 carat gold **(1)**	Conditional on some correct working to show the percentage of gold If calculated % is not 37.5, allow: calculated value of carat (24 x their percentage/100) or 'less than 9 carat gold' if calculated % is less than 37.5% or nearest carat value from table or a (rough) interpolated carat value or between the two relevant carat values	

Q36.

Question Number	Acceptable Answers	Reject	Mark
(a)	Oxygen atoms in water molecules have δ− charge. **(1)** Which form electrostatic / ion-dipole attractions with sodium (ion). **(1)** ALLOW for one mark copper(II) ions form dative covalent bonds but sodium ions do not (**both** needed)	 Ionic bonds / attractions Intermolecular forces Hydrogen bonds	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)	Additional (dative covalent bond) lone pairs are accommodated in vacant (3)d orbitals / (3)d sub-shell ALLOW Vacant **higher** energy orbitals / sub-shells IGNORE 3s/3p	'Partially filled' for 'vacant'	**1**

Question Number	Acceptable Answers	Reject	Mark
*** (c)(i)**	(3)d orbitals / (3)d subshell split (by the attached ligands) **(1)** Electrons are promoted (from lower to higher energy d orbital(s) / levels) OR Electrons move from lower to higher energy (d orbital(s) / levels) ALLOW d—d transitions occur /electrons are excited **(1)** Absorbing energy /photons of a certain frequency (in the visible region) ALLOW Absorbing light **(1)** Reflected / transmitted / remaining light is coloured / in the visible region ALLOW Complementary colour seen Reflected / transmitted / remaining light / frequency is seen **(1)** Penalise omission of (3)d once only. Ignore reference to electrons relaxing / dropping to the ground state	Orbital / shell is split Emitted	**4**

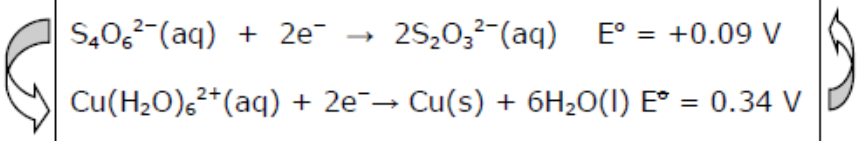
Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	Zn (3)d orbitals are / (3)d subshell is **full / complete** (so d–d transitions are not possible) / Zinc is $3d^{10}$	Zn does not have partially filled d subshell	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(iii)	(d–d) energy gap is large **(1)** the energy absorbed is outside the visible region / in the UV region **(1)** Stand alone marks		**2**

Question Number	Acceptable Answers	Reject	Mark
(d)	**<u>Method 1: cell emfs</u>** For the reaction $Cu(H_2O)_6^{2+}(aq) + 2S_2O_3^{2-}(aq)$ $\rightarrow Cu(s) + 6H_2O(l) + S_4O_6^{2-}(aq)$ * $E^{\circ}_{cell} = +0.34 - 0.09 = (+)0.25$ (V) **and** (Positive so) reaction is feasible **(1)** For the reaction $Cu(H_2O)_2(NH_3)_4^{2+}(aq) + 2S_2O_3^{2-}(aq)$ $\rightarrow Cu(s) + 2H_2O(l) + 4NH_3(aq) + S_4O_6^{2-}(aq)$ ** $E^{\circ}_{cell} = -0.05 - 0.09 = -0.14$ (V) **and** (Negative so) reaction is not feasible **(1)** If both values correct but feasibility omitted or incorrect award 1 mark **Both** equations (* & **) correct IGNORE Omission of H_2O and states from the equations **(1)**	electrons in equations	**3**

Method 2: anticlockwise rule

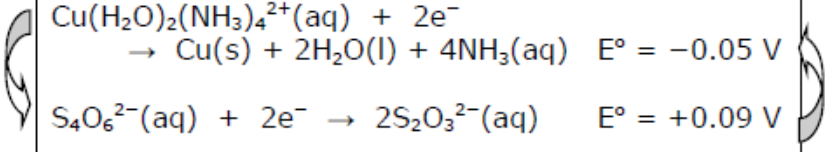
Place the reactions in order of increasing (more positive) $E^{\ominus}$ values and check which reaction occurs in the anticlockwise direction. **(1)**



$S_4O_6^{2-}(aq) + 2e^- \rightarrow 2S_2O_3^{2-}(aq)$ $E^{\circ} = +0.09$ V

$Cu(H_2O)_6^{2+}(aq) + 2e^- \rightarrow Cu(s) + 6H_2O(l)$ $E^{\ominus} = 0.34$ V

Reaction is feasible (desired reaction proceeds in anticlockwise direction) **(1)**



$Cu(H_2O)_2(NH_3)_4^{2+}(aq) + 2e^- \rightarrow Cu(s) + 2H_2O(l) + 4NH_3(aq)$ $E^{\circ} = -0.05$ V

$S_4O_6^{2-}(aq) + 2e^- \rightarrow 2S_2O_3^{2-}(aq)$ $E^{\circ} = +0.09$ V

Reaction is not feasible (proceeds in the opposite direction). **(1)**

Question Number	Acceptable Answers	Reject	Mark
(e)(i)	(coordination number =) 4 / four		**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(ii)	Amount of complex = 4.82 / 288.7 (= 0.0166955 mol) Mass of nickel = 58.7 x 4.82 / 288.7 = 0.98003 g **(1)** % Nickel in alloy = 100 x 0.98 / 1.02 = 96.08 % **(1)** Correct answer with no working scores 2 Ignore SF except 1 ALLOW TE unless %>100 Use of A_r(Ni) = 59 (gives 96.57%)		**2**

Q37.

Question number	Answer	Additional Guidance	Marks
(a)	**C** ([Ar] $3d^6 4s^0$)		**1**

Question number	Answer	Additional Guidance	Marks
(b)(i)	**D** (+6)		**1**

Question number	Acceptable Answer	Additional Guidance	Marks
(b)(ii)	• $E^\ominus$ for the reaction is +0.97 V (1) • because $E^\ominus$ is positive FeO_4^{2-} will react and so is unstable (in acidic conditions) (1) • $4FeO_4^{2-} + 20\ H^+ \rightarrow 4Fe^{3+} + 10\ H_2O + 3O_2$ – correct species (1) – balancing (1)	Accept correct use of 'anti-clockwise rule' Award 1 mark for: $4FeO_4^{2-} + 32H^+ + 6H_2O \rightarrow 4Fe^{3+} + 16H_2O + 3O_2 + 12H^+$ Ignore state symbols	**4**

Question number	Answer	Additional Guidance	Marks
(c)	**B** ($Cl_2(g)$)		**1**

Q38.

Question Number	Answer	Mark
(i)	**The only correct answer is A** ***B*** *is not correct because* Cl^- *is not an oxidising agent* ***C*** *is not correct because* I_2 *is not a powerful enough oxidising agent* ***D*** *is not correct because* Mn^{2+} is not an oxidising agent	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• all species on correct sides of equation **and** no electrons / electrons cancelled **(1)** • balancing correct species **(1)** • $E^{\ominus}_{cell}$ value **(1)**	Example of ionic equation $2MnO_4^- + 16H^+ + 10Br^- \rightarrow 2Mn^{2+} + 8H_2O + 5Br_2$ Allow ⇌ Allow correct species if shown in working with half-equations but slip made in final equation e.g. charge missing Ignore state symbols Allow multiples Allow M2 for almost correct species $E^{\ominus}_{cell}$ (= 1.51 – 1.09) = (+)0.42 (V) No TE on incorrect equation	(3)

Q39.

Question Number	Answer	Additional Guidance	Mark
(i)	• $C_8H_9NO_2$	Allow the symbols, with subscripts, in any order e.g. $C_8H_9O_2N$ Allow large numbers but not superscripts Ignore any other formulae as working	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of amount of Ce^{4+} (1) • calculation of amount of paracetamol in 25.0 cm^3 (1) • calculation of amount of paracetamol in 100.0 cm^3 (1) • calculation of molar mass of paracetamol **and** mass of paracetamol in 1 tablet (1) • calculation of percentage of paracetamol in 1 tablet **and** conclusion	Example of calculation amount Ce^{4+} used = $\frac{16.5 \times 0.100}{1000}$ = 0.00165 / 1.65 x 10^{-3} (mol) amount paracetamol in 25.0 cm^3 = $\frac{0.00165}{2}$ = 0.000825 / 8.25 x 10^{-4} (mol) TE on M1 amount paracetamol in 100.0 cm^3 = 4 x 0.000825 = 0.00330 / 3.30 x 10^{-3} (mol) TE on M2 molar mass of paracetamol, $C_8H_9NO_2$ = (8 x 12) + (9 x 1) + 14 + (2 x 16) = 151 **and** mass of paracetamol in 1 tablet = 0.00330 x 151 = 0.4983 g TE on M3 and (d)(i) percentage of paracetamol = $\frac{0.4983}{0.500}$ x 100 = 99.66 (%) **and** the tablet was from Brand **R** TE on M4 provided M4 < 0.500 g Ignore SF except 1 SF	(5)

Q40.

Question Number	Correct Answer	Reject	Mark
(a)	B		**1**
(b)	C		**1**

Q41.

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

Q42.

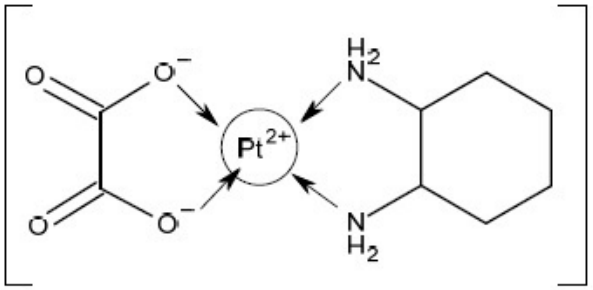
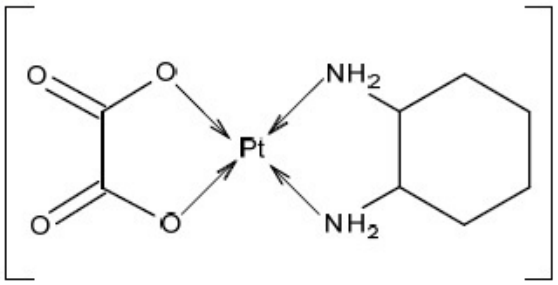
Question Number	Acceptable Answers	Reject	Mark
(a)(i)	The electron withdrawing effect of the (extra) COOH group / oxygen atoms **(1)** Increases the stability of the (hydrogenethanedioate) ion ALLOW Weakens the OH bond **(1)** IGNORE Reference to OH bond becoming more polar		**2**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	H^+ ions formed (in first dissociation) shifts (second equilibrium) to the left ALLOW H^+ formed suppresses (second) ionization		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	Colourless to (pale) pink ALLOW purple for pink	Clear for colourless	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	Amount of MnO_4^- = $28.55 \times 10^{-3} \times 0.0200$ (= 5.71×10^{-4} mol) **(1)** Amount of $C_2O_4^{2-}$ = $5.71 \times 10^{-4} \times \frac{5}{2}$ **(1)** = 1.4275×10^{-3} (mol) Amount of $C_2O_4^{2-}$ in 250 cm^3 / rhubarb leaves = $1.4275 \times 10^{-3} \times 10 = 1.4275 \times 10^{-2}$ (mol) **(1)** Mass $H_2C_2O_4$ in 250 cm^3 = $1.4275 \times 10^{-2} \times 90$ **(1)** = 1.28475 g % $H_2C_2O_4$ in rhubarb = $\frac{1.28475}{250} \times 100$ = 0.5139 % **(1)** IGNORE SF except 1 SF Correct answer with no working scores 5 TE on all parts of calculation If M_r = 88 used then final answer is 0.50248%		**5**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	(Ligand that) Has two lone pairs that can bond (separately) (to the central ion / atom) OR Occupies two coordination positions (around a central ion / atom) OR Two points of attachment (to the central ion / atom) OR Forms two **dative** bonds (to the central ion / atom) OR Two atoms of the same ion / molecule that bond with central metal ion / atom	Two ligands **Just** two lone pairs	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	 Or  Square planar shape around Pt drawn as above and zero net charge NOTE The structure of each ligand must be totally correct **(1)** Both nitrogen atoms attached **and** both C-O oxygen atoms attached from separate COO^- groups **(1)** **Dative** covalent bonds **(1)** **Mark each point separately**	Different oxygen atoms from the same carboxyl group attached to different coordination positions. If O attached from a C=O oxygen	3

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Question Number	Acceptable Answers	Reject	Mark
(d)(i)	(Alkaline or neutral or acidified) potassium manganate(VII) / $KMnO_4$ / MnO_4^- **(1)** Forms ethane-1,2-diol (name or structural / skeletal / displayed formula) **(1)** NOTE It does not matter how the ethane-1,2-diol has been formed (Oxidized by) (refluxing with) acidified potassium dichromate(VI) / $Cr_2O_7^{2-}$ and H^+ OR Acidified/alkaline potassium manganate(VII) / MnO_4^- with either H^+ or OH^- OR (Oxidized by) nitric acid (c.f. passage) **(1)** **Mark each point separately** Max 2 for a three step synthesis e.g. bromine followed by NaOH then oxidation ALLOW correct formulae instead of names	Molecular formula $C_2H_6O_2$ Air catalyzed by V_2O_5	**3**

Question Number	Acceptable Answers	Reject	Mark
(d)(ii)	Carbohydrates and / or glucose are obtained from renewable / sustainable resources (whereas ethene is obtained from crude oil) ALLOW Reverse argument for ethene		**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(iii)	**Ethanedioic acid** Will have one (singlet) peak / hydrogen environment (due to the COOH protons) **(1)** **Propanoic acid** Will have three peaks / three hydrogen environments **(1)** Triplet, quartet / quadruplet & singlet in any order OR Split(ting) pattern 3,4,1 in any order **(1)** NOTE If first mark for **propanoic acid** hasn't been awarded "triplet, quartet / quadruplet & singlet" **scores 2** Intensity in ratio 3:2:1 in any order **(1)** ALLOW labelled and annotated diagrams Max. 3 if not clear that hydrogens/protons give rise to the peaks		**4**

Q43.

Question Number	Correct Answer	Reject	Mark
	C		1

Q44.

Question number	Answer	Additional guidance	Marks
(a)	$Cl_2 + 2NaOH \rightarrow NaOCl + NaCl + H_2O$	Accept $Cl_2 + 2OH^- \rightarrow OCl^- + Cl^- + H_2O$ Ignore state symbols	1
(b)	An explanation that makes reference to the following points: • Cl has oxidation number +4 to in ClO_2 (1) • Cl (in ClO_2) changes oxidation number to +3 (ClO_2^-) and +5 (ClO_3^-) (1) • (therefore) chlorine/it (in ClO_2) has been both oxidised and reduced (1)	Accept 4+ Accept 3+ and 5+ Allow answers in any order	3
(c)(i)	A		1
(c)(ii)	An answer that makes reference to the following points: • Mn changes from +7 to +2 and Cl changes from -1 to 0 (1) • therefore ratio is MnO_4^- to $5Cl^-$ /the ratio of MnO_4^- to Cl^- is 1 to 5 (1)	Accept 7+ and 2+ Accept 1–	2
(d)(i)	An explanation that makes reference to the following points: • the HBr dissolves in water (in the air) (1) • and forms droplets (of hydrobromic acid) (1)		2
(d)(ii)	• the (conc.) H_2SO_4 is reduced to SO_2 (1)	Accept redox	1

Q45.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	$Fe^{2+} \rightarrow Fe^{3+} + e^{(-)}$ $½O_2 + 2H^+ + 2e^{(-)} \rightarrow H_2O$ OR $O_2 + 4H^+ + 4e^{(-)} \rightarrow 2H_2O$ ALLOW Reversible arrows Equations in other direction Electrons subtracted on LHS of first equation Multiples Ignore state symbols even if incorrect		1

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	$½O_2 + 2H^+ + 2Fe^{2+} \rightarrow 2Fe^{3+} + H_2O$ OR $O_2 + 4H^+ + 4Fe^{2+} \rightarrow 4Fe^{3+} + 2H_2O$ ALLOW Multiples Reversible arrows Ignore state symbols even if incorrect No TE from 20(a)(i)	Equation in the wrong direction, even with reversible sign	1

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$ Ignore state symbols even if incorrect		1

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	(Pale) pink	Purple / mauve	1

Question Number	Acceptable Answers	Reject	Mark
***(b)(iii)**	Amount of MnO_4^- = 24.90 x 0.0195 x 10^{-3} = 4.8555 x 10^{-4} (mol)* **(1)** Amount of Fe^{2+} = answer * x 5 in 25 cm^3 = 4.8555 x 10^{-4} x 5 = 2.42775 x 10^{-3} (mol) So in 250 cm^3 = 2.42775 x 10^{-2} (mol) **(1)** (M_r ($FeSO_4.7H_2O$) = 277.9) **ROUTE 1 (via moles)** Amount of Fe^{2+} used to prepare the solution = 6.90 / 277.9 = 2.4829 x 10^{-2} (mol) **(1)** EITHER % of Fe^{2+} remaining at titration = 100 x 2.42775 x 10^{-2} / 2.4829 x 10^{-2} = 97.7785 (%) **(1)** % Oxidized = 100 − 97.7785 = 2.221 (%) **(1)** OR Amount oxidized = 2.4829 x 10^{-2} − 2.42775 x 10^{-2} = 5.516 x 10^{-4} (mol) **(1)** % Oxidized = 5.516 x 10^{-4} x 100 / 2.4829 x 10^{-2} = 2.221 (%) **(1)**		5
	ROUTE 2 (via mass) mass from titration = 2.42775 x 10^{-2} x 277.9 = 6.7467 (g) **(1)** % of Fe^{2+} remaining at titration = 100 x 6.7467 / 6.9 = 97.7785 (%) **(1)** % Oxidized = 100 − 97.7785 = 2.221 (%) **(1)** Ignore SF except 1 SF unless justified in b(iv) Correct answer no working scores 5 marks 90.22% obtained from failure to multiply by 10 scores 4 marks		

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Question Number	Acceptable Answers	Reject	Mark
(b)(iv)	3 (significant figures) because all the data (except A_r(H)) is given to 3 SF OR 2 (significant figures) because the least precise data (A_r(H)) is 2 SF OR 2 (significant figures) because the data is to three figures. After processing only two figures are certain. OR 1 (significant figure) because of the subtraction of two similar numbers.		1

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	Alkali neutralizes the acid shifting the equilibrium to the left OR Alkali neutralizes the acid so E value for half cell becomes less (than +2.20 V) ALLOW 'Reacts with' and 'removes' for 'neutralizes' IGNORE Just "shifts equilibrium to the left"		1

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	$4Fe^{3+} + 4H_2O \rightarrow 3Fe^{2+} + FeO_4^{2-} + 8H^+$ OR Multiples Species **(1)** balance **(1)** Ignore state symbols even if incorrect		2

Question Number	Acceptable Answers	Reject	Mark
(c)(iii)	Required half cell value is $E^{\ominus}$ = (+)0.77 **(1)** $E^{\ominus}_{cell}$ = (0.77 – 2.20 =) −1.43 V ($E^{\ominus}_{cell}$ negative so disproportionation) not feasible **(1)** TE on calculated negative value of $E^{\ominus}_{cell}$ No TE on positive value for $E^{\ominus}_{cell}$ OR Correct application of anti-clockwise rule e.g. $Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$ $E^{\ominus}$ = +0.77 V $FeO_4^{2-}(aq) + 8H^+(aq) + 3e^- \rightleftharpoons Fe^{3+}(aq) + 4H_2O(l)$ $E^{\ominus}$ =+2.20 V Equations in order of increasing $E^{\ominus}$ value **and** arrows shown **(1)** Anti-clockwise rule shows top reaction moves left and bottom reaction moves right so disproportionation not feasible **(1)**		2

Q46.

Question Number	Correct Answer	Mark
	A	**1**

Q47.

Question Number	Answer	Additional Guidance	Mark
	• reduction half-equation	Example of half equation $½O_2 + H_2O + 2e^- \rightarrow 2OH^-$ Allow multiples Ignore state symbols even if incorrect	**(1)**

Q48.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• correct temperature **and** pressure	Examples of values Temperature: 298 K / 25°C Pressure: 1 atm / 1 bar 100 kPa/ 1 x 10^5 Pa / 101 kPa / 1.01 x 10^5 Pa / 1 x 10^5 Nm^{-2} / 1.01 x 10^5 Nm^{-2} Values **and** units are needed Ignore reference to concentration even if incorrect	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)		The mistakes can be in any order Ignore any other errors Ignore reasons for replacements	**(3)**
	• ammeter / symbol for ammeter **and** replace with (high resistance) voltmeter / symbol for voltmeter **(1)**	Allow replace with potentiometer / Wheatstone bridge Do not award voltameter	
	• ethanoic acid **and** replace with solution that is 1.0 mol dm^{-3} with respect to $H^+(aq)$ **(1)**	Allow replace with (1.0 / 1.16-1.18 mol dm^{-3}) hydrochloric acid / HCl / nitric acid / HNO_3 **or** Allow 0.5 mol dm^{-3} sulfuric acid / H_2SO_4 Ignore just 'replace with a strong acid'	
	• potassium chloride / chemical in salt bridge **and** replace with potassium nitrate / KNO_3 / sodium nitrate / $NaNO_3$ **(1)**	Allow replace chloride with a nitrate anion Ignore replace with a different anion that will not react with Ag^+	

Q49.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(i)</td><td>• titres calculated and both ticks correct
(1)
• mean calculated
(1)</td><td>
<table>
<tr><td>Run</td><td>Trial</td><td>One</td><td>Two</td><td>Three</td></tr>
<tr><td>Final volume / cm^3</td><td>17.50</td><td>34.10</td><td>17.20</td><td>34.10</td></tr>
<tr><td>Initial volume /cm^3</td><td>0.00</td><td>17.30</td><td>0.00</td><td>17.20</td></tr>
<tr><td>Titre / cm^3</td><td>17.50</td><td>16.80</td><td>17.20</td><td>16.90</td></tr>
<tr><td>Concordant titres (✓)</td><td></td><td>✓</td><td></td><td>✓</td></tr>
<tr><td>Mean titre /cm^3</td><td colspan="4">16.85</td></tr>
</table>
Both titres to 2 dp
mean = (16.90+16.80)÷2 = 16.85 (cm^3)
allow TE for M2 for mean of One, Two and Three = 16.97 (cm^3)
</td><td>(2)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of moles of $Na_2C_2O_4$(aq) **(1)** • calculation of moles of $KMnO_4$ in titre **(1)** • calculation of moles of $KMnO_4$ in 100 cm^3 **(1)** • calculation of M_r for $KMnO_4$ **(1)** • calculation of mass of 1 tablet in mg to 2 or 3SF **(1)**	<u>Example of calculation</u> (25.0÷1000) x 0.200 = 0.005 / 5.00 x 10^{-3} (mol) 5.00 x 10^{-3} x 2÷5 = 0.002 / 2.00 x 10^{-3} (mol) 2.00 x 10^{-3} x (100÷16.85) = 0.011869 (mol) 158 0.011869 x 158 = 1.8754 g (1.8754÷5) x 1000 = 375.07 mg = 380 / 375 (mg) Correct answer with or without working scores 5 marks 0.38 g scores 4 marks (M5 not awarded) TE at each stage and on mean titre 379 mg from 0.012 scores (5)	**(5)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following points • (reaction is slow initially) as MnO_4^- and $C_2O_4^{2-}$ are (both) negative (ions) so will repel (each other) **(1)** • when (sufficient) Mn^{2+} ions form they (auto) catalyse the reaction **(1)** • Mn^{2+} ions will reduce MnO_4^- ions (as $E^\ominus$ is more negative) forming Mn^{3+} ions OR $MnO_4^- + 8H^+ + 4Mn^{2+} \rightarrow 5Mn^{3+} + 4H_2O$ ($E^\ominus = +0.02V$) **(1)** • Mn^{3+} ions then oxidise $C_2O_4^{2-}$ ions (reforming Mn^{2+}) (as $E^\ominus$ is more positive) OR $C_2O_4^{2-} + 2Mn^{3+} \rightarrow 2Mn^{2+} + 2CO_2$ ($E^\ominus = +0.85V$) **(1)**	Allow 'heat is required to overcome high activation energy when catalyst is absent' Allow Mn^{2+} ions will react with MnO_4^- ions as $E^\ominus$ is more negative Allow Mn^{3+} ions then react with $C_2O_4^{2-}$ ions (reforming Mn^{2+}) as $E^\ominus$ is more positive May be shown in equations and / or by calculating $E^\ominus$	**(4)**

Q50.

Question Number	Answer	Additional Guidance	Mark
	• colourless to (permanent pale/light) pink	Do not award purple for pink	**(1)**

Q51.

Question Number	Answer	Additional Guidance	Mark
	to provide the hydrogen ions (needed as a reactant in the balanced equation) / to prevent formation of MnO_2 / to prevent (brown) precipitate forming	Allow reaction needs acidic conditions Do not award 'acts as a catalyst' / just 'ensures reaction go to completion'	**(1)**

Q52.

Question Number	Answer	Additional guidance	Mark
(i)	• brown fumes (1) • a green/blue solution forming (1)		2
(ii)	• $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$	State symbols must be present	1
(iii)	• amount of thiosulfate (1) • uses amount of thiosulfate = amount of iodine to determine amount of thiosulfate = amount of copper(II) ions in 25 cm^3 portion (1) • evaluation of number of moles of Cu in sample (1) • calculates mass of Cu (1) • percentage copper to **3.s.f** (1)	Example of calculation amount of thiosulfate = $\frac{22.7 \times 0.25}{1000}$ = 5.675×10^{-3} (mol) 5.675×10^{-3} (mol) = amount of copper(II) ions in 25 cm^3 portion amount of Cu in sample = $5.675 \times 10^{-3} \times 10$ = 5.675×10^{-2} (mol) mass of Cu = $5.675 \times 10^{-2} \times 63.5$ = 3.603625 percentage copper = 3.603625 x 100 /5.00 = 72.0725 = 72.1% Allow ecf from 2nd mark Correct answer to 3.s.f with no working scores 5 marks	5
(iv)	• calculation of percentage uncertainty from balance = ±0.005x 2 x100/5.00 = 0.2% and percentage uncertainty in mean titre from burette = 2x±0.05 x 100 /22.7 = 0.44% (1) • so burette reading is most significant (1)		2

Q53.

Question Number	Correct Answer	Mark
	C	**1**

Q54.

Question Number	Correct Answer	Reject	Mark
	C		1

Q55.

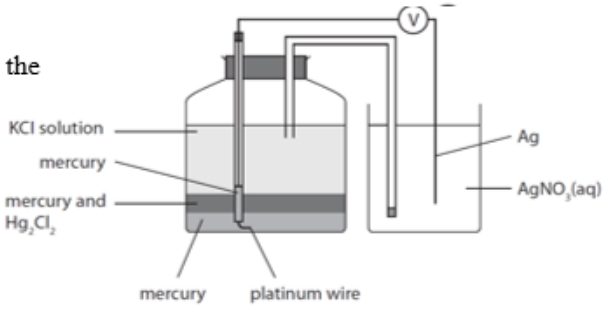
Question Number	Acceptable Answers		Reject	Mark
(i)	([VO^{2+}(aq) + $2H^+$(aq)], [V^{3+}(aq)+ H_2O(l)] |Pt)	+0.34		1
	([VO_2^+(aq) + $2H^+$(aq)], [VO^{2+}(aq)+ H_2O(l)] |Pt)	+1.00		
	Sign and value needed			

Question Number	Acceptable Answers	Reject	Mark
(ii)	**A:** (+)0.32 (V) (1) VO^{2+} (may be shown as a product in an overall equation) (1) EITHER Bubbles / effervescence (of colourless gas) OR Colour changes (from yellow) to blue TE on negative E_{cell} for 'stays yellow' ALLOW (from yellow) to green if justified by partial reduction (1) **B:** −0.2(0) (V) (1) no change / stays blue (1) If B=+0.2 or other positive value allow colour change from blue to green or brown. EITHER Consistent use of rule that reaction occurs when E_{cell} is positive OR Consistent use of rule that no reaction occurs when E_{cell} negative ALLOW If implied but not stated specifically (1)	Violet Stays violet	6

Q56.

Question Number	Correct Answer	Mark
	A	**1**

Q57.

Question Number	Answer	Additional guidance	Mark
(a)(i)	• (saturated) potassium nitrate	Allow potassium chloride	**1**
(a)(ii)	An explanation that makes reference to the following points: • to complete the circuit (1) • by allowing movement of (positive and negative) ions (1)		**2**
(b)(i)	• container/beaker containing the side arm and silver, both dipping into silver nitrate solution (1) • connecting wire from silver and calomel electrode to complete the circuit (1) • (high resistance/digital) voltmeter (1) 		**3**
(b)(ii)	• solution concentration 1.0 mol dm^{-3} (1) • temperature 298 K (1)	Ignore mention of pressure	**2**

(c)(i)	• correct equation (1) • emf = 0.80 – (+)0.27 = (+)0.53 (V) (1)	No sign in answer scores 1 mark, a minus sign given scores 0 marks Correct answer with no working scores 2 marks	**2**
(c)(ii)	• (+)0.03 (V)		**1**
(c)(iii)	• $Fe^{2+}(aq) + Ag^{+}(aq) \rightarrow Fe^{3+}(aq) + Ag(s)$	Allow reversible arrows	**1**
(c)(iv)	• rearrangement and substitution into equation (1) • evaluation of ln K and conversion to K (1)	Example of calculation $\ln K = \frac{2892}{8.31 \times 298}$ $= (+)1.1678$ $K = 3.21502$ $= 3.22$ Ignore sf except 1 Note if ln $K = 1.1678$ is used answer is 3.21 Correct answer with no working scores 2 marks	**2**

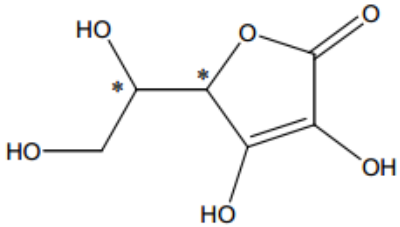
Q58.

Question Number	Acceptable Answers	Reject	Mark
15 (a)(i)	(vitamin C / ascorbic acid) oxidation / oxidized / oxidised ALLOW oxidisation	Redox / oxidation-reduction / reduction-oxidation	**1**

Question Number	Acceptable Answers	Reject	Mark
15 (a)(ii)	(very) pale yellow / straw coloured **(1)** IGNORE 'just before the end-point' blue-black to colourless (both needed) **(1)** Accept (dark) blue or black ALLOW pale yellow / straw coloured to colourless for 1/2	Just 'yellow' Clear	**2**

Question Number	Acceptable Answers	Reject	Mark
15 (a)(iii)	Moles $S_2O_3^{2-}$ = 27.85 x 10^{-3} x 0.0631 **(1)** (= 1.757335 x 10^{-3}) moles of I_2 remaining = Moles $S_2O_3^{2-}$ ÷ 2 = 27.85 x 10^{-3} x 0.0631 ÷ 2 = 8.786675 x 10^{-4} = 8.79 x 10^{-4} **(1)** Moles ascorbic acid = moles I_2 at start – moles I_2 remaining = 2.00 x 10^{-3} – 8.786675 x 10^{-4} = 1.1213325 x 10^{-3} = 1.12 x 10^{-3} **(1)** M_r (ascorbic acid) = 176 Mass ascorbic acid in 250 cm^3 = 10 x M_r x moles ascorbic acid = 10 x 176 x 1.1213325 x 10^{-3} **(1)** (= 1.97355) Percentage ascorbic acid in tablet 100 x mass ascorbic acid in 250 cm^3 ÷ 2 = 100 x 10 x 176 x 1.1213325 x 10^{-3} ÷ 2 = 98.67726 = 98.7% **(1)** IGNORE SF except 1 SF Premature rounding gives 98.5% (5) Correct answer with no working scores full marks TE at each stage of the calculation.	Answers greater than 100%	**5**

Question Number	Acceptable Answers	Reject	Mark
15(a)(iv)	EITHER Using larger **mass** reduces the percentage error / uncertainty (in weighing) OR Using larger amount reduces the percentage error / uncertainty in **weighing** OR Reverse discussion of two tablets ALLOW using four tablets gives a more representative sample	Just 'reduces the percentage error' Titration value will be larger (with four tablets) so reduces the percentage error (in volume measurement)	**1**

Question Number	Acceptable Answers	Reject	Mark
15 (b)(i)	 **(2)** Mark independently ALLOW any clear indication of chiral centres		**2**

Question Number	Acceptable Answers	Reject	Mark
15 (b)(ii)	**First mark** Use of (plane-)polarized light (mentioned somewhere) **(1)** ALLOW Use a polarimeter **Second mark** Pure optical isomer / enantiomer) **rotates** the **plane** of (plane-) polarized light OR racemic mixture has no effect on the **plane** of (plane-) polarized light **(1)** IGNORE optically active / inactive ALLOW rotates plane-polarized light scores 2		**2**

Question Number	Acceptable Answers	Reject	Mark
15(b)(iii)	(Ester group / vitamin C / it) is hydrolysed ALLOW Vitamin C is oxidized Ester / vitamin C is broken down to form carboxylic acid **and** alcohol (groups) IGNORE Just 'breaks down'	C=O is broken Just 'oxidation'	1

Q59.

Question Number	Correct Answer	Mark
	D	**1**