

1. (a) (i) The potential difference between a standard hydrogen electrode and the (half-) cell (1)
all concentrations measured at 1 mol dm^{-3} and any gases are at 1 atm pressure (1) 2
- (ii) Fluorine or F_2 (1) 1
- (b) (i) all/listed (1) 1
- (ii) iodine **and** bromine (1) 1
- (iii) *This answer is consequential on part (ii)*
Mix solution of Cr(II) - blue with the oxidising agent given in (ii) (1)
goes green and **stays** green / but does not go orange (1) 2
- [7]
2. (a) (i) $[\text{Ar}]3d^6$ (1) 1
allow $1s^2$ etc
- (b) (i) • Zn / Iron (1) not the zinc ion or iron ion
• more negative potential than -0.28V (1)
NB this mark must show evidence of use of the data
gives +E for reduction reaction (1)
consequential on second mark 3
- (ii) • rate too slow / activation energy too high / kinetically stable /
allow oxide layer if metal electrode specified (1)
• non-standard conditions (1) 2
- (c) (i) $\text{Co}(\text{H}_2\text{O})_6^{2+}$ (1) 1
- (ii) Example:
 $\text{Co}(\text{H}_2\text{O})_6^{2+} + 4\text{Cl}^- \rightarrow \text{CoCl}_4^{2-} + 6 \text{H}_2\text{O}$
Any valid equation that shows a ligand exchange but begins with
 $\text{Co}(\text{H}_2\text{O})_6^{2+}$ (1)
ligand exchange correctly balanced (1) 2
- [9]
3. (a) (i) Use E^θ values for reduction of Fe^{3+} to Fe^{2+} by Zn ($E^\theta_{\text{cell}} = +1.53\text{V}$) (1)
and Fe^{2+} to Fe by Zn ($E^\theta_{\text{cell}} = +0.32\text{V}$)(1)
They have positive E^θ so are feasible (1) *NOT* “will happen”
OR
ALLOW Zn^{2+}/Zn is more negative than both $\text{Fe}^{3+}/\text{Fe}^{2+}$ and Fe^{2+}/Fe (1)
so zinc is a stronger reducing agent (1)
so zinc reducing both is feasible (1) 3

- (ii) Reduction of Fe^{2+} has high activation energy / kinetically stable 1
- (b) (i) $\text{MnO}_4^- + 5\text{Fe}^{2+} + 8\text{H}^+ \rightarrow \text{Mn}^{2+} + 5\text{Fe}^{3+} + 4\text{H}_2\text{O}$
 Species (1)
 Balance (1)
 Any state symbols ignored. 2
- (ii) purple colour of MnO_4^- lost (1)
 end point when yellow / colourless solution (1)
 becomes (permanently) pink (1) 3
- (c) Amount MnO_4^- in 1st titration = $0.0182 \text{ dm}^3 \times 0.0200 \text{ mol dm}^{-3}$
 = $3.64 \times 10^{-4} \text{ mol}$ (1)
 Amount Fe^{2+} in original solution = $5 \times$ above value = $1.82 \times 10^{-3} \text{ mol}$ (1)
 Amount Fe^{2+} in 2nd titration = amount of Fe^{2+} and Fe^{3+} original solution (1)
 = $0.0253 \text{ dm}^3 \times 0.0200 \text{ mol dm}^{-3} \times 5 = 2.53 \times 10^{-3} \text{ mol}$
 Amount of Fe^{3+} in original solution = $0.00253 - 0.00182 = 7.10 \times 10^{-4} \text{ mol}$ (1)
 Amount zinc needed to reduce $\text{Fe}^{3+} = \frac{1}{2} \times 0.000710 = 0.000355 \text{ mol}$
 Mass of zinc = $0.000355 \text{ mol} \times 65.4 \text{ g mol}^{-1} = 0.0232 \text{ g}$ (1) 2,3 or 4 SF
 Consequential on their moles iron
The marks are for the following processes:
Either volume of MnO_4^- to moles of MnO_4^- (1)
Convert to moles of Fe^{2+} by multiplying either moles of MnO_4^- by 5 (1)
Realising that 2nd titration measures total number of moles of iron (1)
Subtracting to get original moles Fe^{3+} (1)
Going to moles Zn then mass Zn (1)
- OR
 Volume MnO_4^- for Fe^{3+} , which has been reduced by zinc (1) 3rd point
 = $25.3 \text{ cm}^3 - 18.2 \text{ cm}^3 = 0.0253 \text{ dm}^3 - 0.0182 \text{ dm}^3 = 0.0071 \text{ dm}^3$ (1) 4th point
 Amount of $\text{MnO}_4^- = 0.0071 \text{ dm}^3 \times 0.0200 \text{ mol dm}^{-3} = 1.42 \times 10^{-4} \text{ mol}$ (1) 1st point
 Amount Fe^{3+} reduced by zinc = $5 \times$ above value = $7.10 \times 10^{-4} \text{ mol}$ (1) 2nd point
 Amount zinc needed = $\frac{1}{2} \times 7.10 \times 10^{-4} = 3.55 \times 10^{-4} \text{ mol}$
 mass of zinc needed = $3.55 \times 10^{-4} \text{ mol} \times 65.4 \text{ g mol}^{-1} = 0.0232 \text{ g}$ (1) 5th point 5
- (d) (i) $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + \text{H}_2\text{O} \rightarrow [\text{Fe}(\text{H}_2\text{O})_5\text{OH}]^+ + \text{H}_3\text{O}^+$

H_3O^+ in equation (1)
 other ion in equation (1)
 (Fe^{2+}) polarises the O–H bond in ligand (1) 3

(ii) $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ more acidic than $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ (1)
 Fe^{3+} higher charge density than Fe^{2+} (1)
 Fe^{3+} ion if more polarising (1) 3

[20]

4. (a) (i) The potential (difference) / e.m.f. (of a half-cell) relative to the standard hydrogen electrode (1)
 Concentrations (of all ions) 1 mol dm^{-3} and
 (any gases at) pressure 1 atm (1)
 Ignore any references to temperature 2

(ii) **One from:**
 Can only measure a potential **difference**
Or
 So that comparisons can be made between any half cells 1

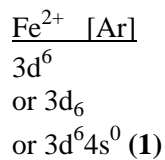
(b) (i) $5\text{H}_2\text{O}_2 + 2\text{MnO}_4^- + 6\text{H}^+ \rightarrow 5\text{O}_2 + 2\text{Mn}^{2+} + 8\text{H}_2\text{O}$ (2)
 (1) for species
 (1) for balancing the correct species
 $\Delta E^\ominus_{\text{reaction}} = +0.84 \text{ (V)}$ (1)
 or if just states “0.84”, must mention that this is a positive value 3

(ii) Fizzing/bubbles (1)
 (pink) colour lost / stays colourless (1)
 (end point) solution remains pink / pale purple (1) 3

(iii) $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$ (1)
 O (in H_2O_2) oxidised from -1 to 0 (in O_2) (1)
 O (in H_2O_2) reduced from -1 to -2 (in H_2O) (1) 3

[12]

5. (a) (i) $\text{Fe} [\text{Ar}]$
 $3d^6 4s^2$
 or $3d_6 4s_2$
 or $3d6 4s2$
 or $4s^2 3d^6$ (1)

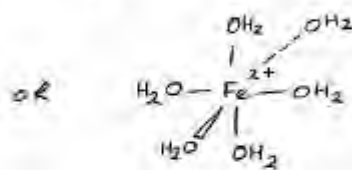
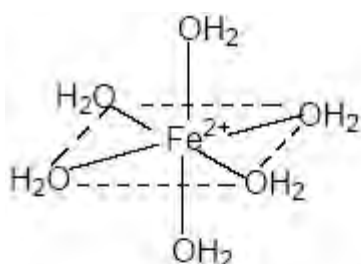


Letter d must be lower case

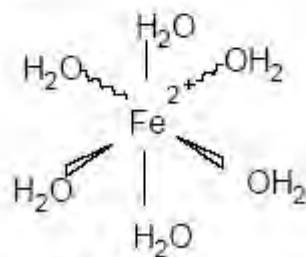
Any additional letters or numbers (0)

2

- (ii) The mark is for the shape



OR



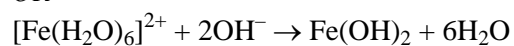
Instead of dotted line

ALLOW bond to H of H_2O (except on left side if OH_2 is given)
 IGNORE charge unless incorrect

1

- (iii) $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow [\text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4] + 2\text{H}_2\text{O}$

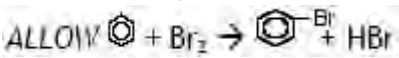
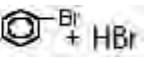
OR



OR equations with 2NaOH as reactant and 2Na^+ as product

IGNORE state symbols

1

- (iv) Green precipitate / solid → foxy-red / red-brown / brown / orange
Both colours and precipitate / solid needed
NOT darkens 1
- (v) $N_2 + 3H_2 \rightarrow / \rightleftharpoons 2NH_3$
 ALLOW  $+ Br_2 \rightarrow$ 
OR equation with Cl₂ 1
- (b) (i) Emf of cell / potential difference of cell containing Fe²⁺ and Fe (1)
and standard hydrogen electrode / half cell *NOT* 'SHE'
OR hydrogen electrode and 1 mol dm⁻³ H⁺ and 1 atm H₂ (1)
 1 mol dm⁻³ Fe²⁺
IGNORE temperature 3
- QWC*(ii) Emf of hydrogen electrode is zero – *stated or implied* (e.g. if
 calculate $E_{cell} = +0.44(V)$) (1)
 $Fe + 2H^+ \rightarrow Fe^{2+} + H_2$ (1) – *equation stand alone*
 Potential for the reaction is positive so reaction is feasible (1)
OR
 H⁺ and (1/2)H₂ has a more +ve electrode potential than Fe²⁺ and Fe (1)
 H⁺ will oxidise Fe / H⁺ is an oxidising agent / Fe is a reducing
 agent for H⁺ / other correct redox statement (1)
 $Fe + 2H^+ \rightarrow Fe^{2+} + H_2$ (1) – *stand alone* 3
- (iii) High E_a so slow reaction / reactants are kinetically stable
IGNORE any mention of non-standard conditions 1
- (c) $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ or words $E^0 = (+) 0.23V$ (1)
 So I⁻ would reduce Fe³⁺ / Fe³⁺ would oxidise I⁻ / E^0 positive so reaction
 L → R (1)
OR reverse argument (2)
OR
 Fe³⁺ and Fe²⁺ has a more positive electrode potential than I₂ and I⁻ (1)
 I⁻ will reduce Fe³⁺ / Fe³⁺ will oxidise I⁻ (1) 2

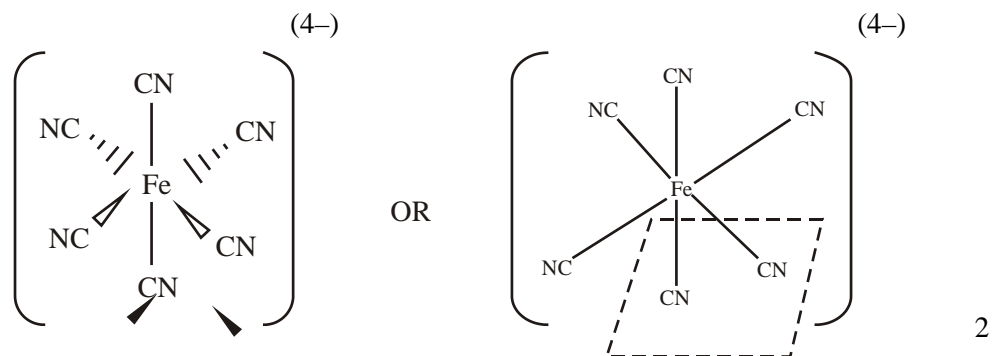
[15]

6. (a) The emf of a half-cell measured relative to the standard hydrogen electrode (1)
 all solutions at 1 mol dm^{-3} concentration and gases at 1 atm pressure / 101 kPa
 and at a stated temperature / 298K (1) *Standalone mark*
 ALLOW pressure of 100 kPa 2
- (b) Introducing another metal wire would set up its own p.d. / can
 only measure a potential difference / need source and sink for
 electrons / voltmeter requires two connections 1
- (c) (i) $2\text{Fe}(s) + \text{O}_2(g) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{Fe}^{2+}(\text{aq}) + 4\text{OH}^-(\text{aq})$ or multiples
OR
 $2\text{Fe}(s) + \text{O}_2(g) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{Fe}(\text{OH})_2(s)$
 Species (1)
 balancing (1)
 Do not allow species mark if electrons still in equation, but allow
 balancing mark if $4e$ on both sides 2
- (ii) $\Delta E^\ominus_{\text{react}} = (+) 0.84 \text{ (V)}$ (1)
 Greater than zero therefore feasible (1) 2
- QWC (iii) Zn oxidises preferentially to Fe / Zinc acts as sacrificial (anode) (1)
 If Sn used (and damaged), Fe oxidises; preferentially (1)
 Disallow “oxidises more readily”
 $E^\ominus \text{Zn}^{2+} / \text{Zn}$ more negative than for Fe
OR
 $E^\ominus \text{Zn} / \text{Zn}^{2+}$ more positive than for Fe
OR
 E^\ominus_{cell} for Zn being oxidised by O_2 is more positive than for Fe
 being oxidised by O_2
OR
 similar E^\ominus arguments related to preferential oxidation with Sn (1)
 disallow “higher” or “bigger” for more negative or more positive 3
7. (a) (i) Forms **ions** which have partially filled *d*-orbitals
OR
 Forms ions which have a partially filled *d*-subshell 1
- (ii) Scandium / Sc **and** Zinc / Zn 1

[10]

- (b) (i) $\text{Fe}^{2+} [\text{Ar}] 3d^6$
 $\text{Mn}^{2+} [\text{Ar}] 3d^5$ (1) for both correct 1
- (ii) Fe^{3+} is $3d^5$ / half filled d -subshell which is more stable than $3d^6$ (1)
 Mn^{2+} is (already) $3d^5$ (which is more stable than $3d^4$) (1) 2

- (c) Shape (1)
 Bonding to correct atoms (1)



- (d) Two As atoms oxidised from +3 to +5 per mole of As_2O_3
 (loss of $4e^-$) (1)
 \therefore if 5 moles oxidised, total $20e^-$ Lost / change in oxidation no. = 20 (1)
 \therefore 4 moles MnO_4^- reduced, total $20e^-$ gained / change in oxidation no. 20
 \therefore each Mn(VII) gains $5e^-$ / change in oxidation no. 5 (1)
 $\therefore \text{Mn(II)} / \text{Mn}^{2+}$ (1) NOT standalone mark 4

- (e) (i) $\text{VO}_3^- + 2\text{H}^+ / 2\text{H}_3\text{O}^+ \rightarrow \text{VO}_2^+ + \text{H}_2\text{O} / 3\text{H}_2\text{O}$ 1
- (ii) No because oxidation no. of V is +5 in VO_2^+ / Oxidation no. of V unchanged (at +5) 1
- (iii) First green colour : VO_2^+ and VO^{2+} (1)
 Second green colour : $\text{V}^{3+} / [\text{V}(\text{H}_2\text{O})_6]^{3+}$ (1)
 Violet colour : $\text{V}^{2+} / [\text{V}(\text{H}_2\text{O})_6]^{2+}$, (1) 3

[16]

8. (a) $3\text{OCl}^- \rightarrow 2\text{Cl}^- + \text{ClO}_3^-$ (1)
 chlorine (in OCl^-) is (simultaneously) oxidised from +1 to +5 (1)
 and reduced from +1 to -1 (1)
 If only oxidation numbers given max 1 (out of 2)
 If oxidation numbers omitted max 1 (out of 2) 3
- (b) (i) blue / black to colourless 1

- (ii) no. moles $\text{S}_2\text{O}_3^{2-}$ used = $12.5 \times 0.1 / 1000 = 1.25 \times 10^{-3}$ (1)
 no. moles $\text{I}_2 = 1.25 \times 10^{-3} / 2 = 6.25 \times 10^{-4}$ (1)
 no. moles $\text{ClO}^- = \text{no. moles } \text{I}_2$ (1)
 no. moles ClO^- in original $10 \text{ cm}^3 = 10 \times 6.25 \times 10^{-4}$
 $= 6.25 \times 10^{-3}$ (1)
 no. moles ClO^- in $1 \text{ dm}^3 = 100 \times 6.25 \times 10^{-3}$ (1) = 0.625 5

- (iii) mass $\text{Cl}_2 = 0.625 \times 71$
 $= 44.4 \text{ (g)}$
mark consequentially on (ii)
must be 3s.f. in final answer 1

- (c) Cl_2 is the stronger oxidising agent because Cl_2 oxidises S from (+)2 to (+)6 (1)
 but I_2 oxidises S from (+)2 to (+)2.50 (1) 2

- QWC (d) O_2 oxidises KI / iodide to I_2 . or balanced equation (1)
 I_2 reacts with starch / paper to give blue / black (1) 2

[14]

9. (a) (i) **EITHER**

$\Delta E^\theta = (+) 0.15 \text{ (V)}$ OR $E^\theta (\text{MnO}_4^- / \text{Mn}^{2+})$ more positive or greater than E^θ

($\text{Cl}_2 / \text{Cl}^-$); accept reverse argument (1)

(so) MnO_4^- reacts with Cl^- OR Cl^- ions form Cl_2

OR KMnO_4 reacts with HCl (1)

OR

$2\text{MnO}_4^- + 16\text{H}^+ + 10\text{Cl}^- \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 5\text{Cl}_2$ (1)

$E^\theta = (+) 0.15 \text{ (V)}$ (1) 2

- (ii) stated colour change of colourless to (pale) pink NOT purple OR stays (pale) pink
 OR pink to colourless
 OR first excess of (coloured) manganate((VII))
 IGNORE "self-indicating"
 IGNORE references to Mn^{2+} 1

- (b) (i) (Multiply iron half-equation by five to) cancel out electrons
OR balance electrons 1

(ii)
$$\text{Moles MnO}_4^- = \frac{0.0200 \times 20.10}{1000}$$

$$= 0.000402 \text{ mol MnO}_4^- \text{ (1)}$$

Moles Fe^{2+} per 25.0 cm^3 $= 5 \times 0.000402$

$$= 0.00201 \text{ mol Fe}^{2+} \text{ (1)}$$

Moles Fe^{2+} per $200 \text{ cm}^3 = 0.00201 \times \frac{200}{25} \text{ mol Fe}^{2+}$

$$= 0.01608 \text{ mol Fe}^{2+} \text{ (1)}$$

Mass of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O} = 0.01608 \times 278$

$$= 4.47 \text{ g or via concentrations (1)}$$

Percentage purity $= \frac{4.47}{6.00} \times 100\%$

$$= 74.5\% \text{ (1) ALLOW } 74.7\% / 75\%$$

Correct answer + working (5)
 ALLOW 2 or more sig figs

If start by dividing $\frac{6.00}{278}$, and final answer is **incorrect**, candidate can
 access first three marks only.

If third step omitted, answer 9.3% OR 9.33% OR 9.4% 5

- (c) (i) $E^\theta = +1.46 - (-0.13) = (+) \mathbf{1.59} \text{ (V)}$
 Correct answer alone (1) 1

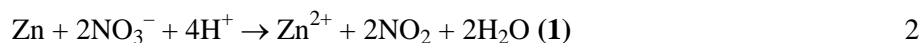
- (ii) PbSO_4 precipitated (1)
 $[\text{H}^+_{(\text{aq})}]$ not 1 mol dm^{-3} (1)
 $[\text{Pb}^{2+}_{(\text{aq})}]$ not 1 mol dm^{-3} (1)
 the conditions (in the car battery) are not standard (1) } *any of these*

“temperature non-standard” alone or “not 1 atm pressure”
 alone does not score 1

[11]

10. (a) (i) uses E^\ominus values to find $E_{\text{reaction}} = (+) 1.57 \text{ (V)}$ (1)

Reject - 1.57



Accept equation with equilibrium sign

Rejection equation with Zn on the right

- (ii) E_{reaction} for the production of hydrogen is (+) 0.76 (V) (1)

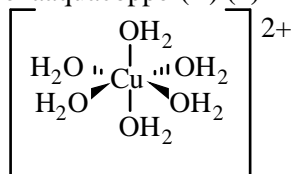
smaller than reaction in (i) so is less likely (1)

OR

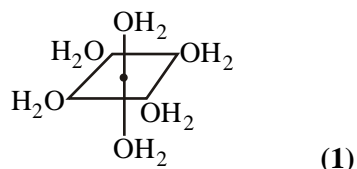
NO_3^- being the oxidised form of a redox couple with a more positive E^\ominus than $E^\ominus \text{H}^+/\frac{1}{2} \text{H}_2$ (1)

is a stronger oxidising agent than H^+ (1) 2

- (iii) hexaaquacopper(II) (1)



OR



Both marks stand alone

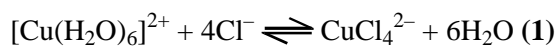
[IGNORE charge]

[IGNORE how H_2O ligand is bonded to central cation] 2

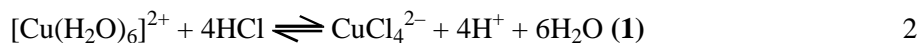
Accept hexaquacopper(II)

Reject formula

- (iv) **ligand** exchange/replacement/substitution (1)



OR



ALLOW →

Accept $\text{H}_2\text{CuCl}_4 + 2\text{H}^+$ for $\text{CuCl}_4^{2-} + 4\text{H}^+$

- (b) (i) E^\ominus for the reaction is -0.39 (V) (so not feasible) [value is required]. 1
Accept Cu^{2+} being the oxidised form of the redox couple with the more negative E^\ominus , will not oxidise I^-
- (ii) CuI is a solid (so conditions are not standard) (1)
 Equilibrium is pulled over/moves to favour the r.h.s. (1) 2
Reject just 'conditions not standard'
- (iii) $[\text{Cu}(\text{NH}_3)_4]^+$
 OR $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^+$ 1
Accept $[\text{Cu}(\text{NH}_3)_2]^+$
Reject $[\text{Cu}(\text{NH}_3)_6]^+$
Reject any 2+ complex
- (iv) (atmospheric) oxygen (1)
 oxidises Cu^+ to Cu^{2+} (1) 2
Reject air for oxygen
- (c) (i) starch (1)
 blue-black/blue/black to colourless (1) 2
Reject clear for colourless
- (ii) (If added too early) insoluble complex/black solid formed, making titre too low
 OR (If added too early) insoluble complex/black solid formed, removes iodine from solution
 OR (If added too early) insoluble complex/black solid formed, causes inaccurate titre.
 OR (If added too early) insoluble complex/black solid formed, not all the iodine is titrated. 1

- (iii) Amount thiosulphate = $0.01655 \text{ dm}^3 \times 0.1 \text{ mol dm}^{-3}$ (1)
 = amount Cu^{2+} in $25.0 \text{ cm}^3 = 1.655 \times 10^{-3} \text{ mol}$ (1)
 amount of Cu^{2+} in $250 \text{ cm}^3 = 1.655 \times 10^{-3} \times 10$ (1)
 mass of Cu (in sample) = $1.655 \times 10^{-2} \times 63.5$ (1) = 1.051 g
 % Cu in brass = $1.051 \times 100/1.5 = 70 \%$ (1)
 [IGNORE sf]
 [mass of 1.051g with working scores (4);
 correct answer with no working scores (3).]
 Mark consequentially

5

[22]

11. (a) e.m.f. of a **half** cell relative/compared to a (standard) hydrogen electrode
 OR
 voltage produced from a **half** cell joined to a hydrogen electrode (1)

Accept potential (difference) /voltage for emf

Accept emf of a cell with standard hydrogen as the left electrode

Accept a description of the half cell e.g. a metal dipping into a solution of its ions

Reject SHE

(solutions at) 1 mol dm^{-3} concentration, (gases at) $1 \text{ atm}/100 \text{ kPa}/105 \text{ Pa}/1 \text{ Bar}$ pressure and stated temperature (1)

all 3 conditions needed STAND ALONE

2

Accept 101 kPa

Accept 298 K or 25 °C

If any other temperature is quoted it must be as an example of a stated temperature

Reject 'constant' pressure "STP"

Reject room temperature

Reject just "273 K"

- (b) Can only measure a potential **difference**/emf
 (if a reference electrode is present)

OR

voltmeter needs 2 connections

OR

Cannot measure the potential difference between a metal and a solution of its ions

1

Reject just "electron source and sink"

Reject to make comparisons between half cells

- (c) (i) **1st mark**
 (simultaneous) oxidation and reduction of a (single) species/
 substance/ reactant/compound/chemical
Reject oxidation and reduction occur at the same time
Or the oxidation state/number is both increased and
 decreased of a (single) species/ substance/ reactant/
 compound/chemical
Reject oxidation states are ...
Or a (single) species/ substance/ reactant/compound/
 chemical both loses and gains electrons (**1**)
- 2nd mark**
 For a given type of **atom** within an ion/ molecule
Or Illustrated by a suitable example in which the
 individual atom is identified (**1**) 2
- (ii) $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$ (**1**)
Reject 2H^+ on both sides of equation
 $E_{\text{cell}} = (+) 1.09$ (V) (**1**)
Reject greater than any other stated number
 E_{cell} is positive/greater than 0 so the reaction is feasible (**1**)
 3rd mark must be cq on sign of E_{cell} 3
- (iii) activation energy of the reaction may be high
 OR
 reaction too slow to be observed 1
*Reject just "Not enough energy to overcome the activation
 energy"*
Reject conditions are non-standard
Reject just "kinetically stable"
- [9]**
12. (a) (i) The activation energy for the reaction is high
or to ensure that more molecules have $E \geq E_a$. 1
Accept $E > E_a$
Reject to overcome E_a alone
Reject reactants kinetically stable;
reactants thermodynamically stable

- (ii) protonates the alcohol (1)
Reject 'as a catalyst' alone
 providing H₂O as the leaving group which is more easily displaced by the bromide ion/is a better leaving group than hydroxide (1)
 OR
 reacts with NaBr (1)
 to give HBr (which is the attacking reagent) (1) 2
- (iii) H-bonding between water and the alcohol not strong enough to overcome hydrophobic interactions /effect of alkyl group (1)
 acid and alcohol form ionic species/C₄H₉OH₂⁺ which is more soluble (1) 2
Accept butyl group
- (iv) Removes acid 1
Accept neutralises HCl /HBr
Accept neutralises acid
- (v) Removes water 1
Accept absorbs water
Accept dries the product
- (vi) Electric heating mantle **or** sand bath **or** oil bath (1)
Accept water bath
Reject heat under reflux
Reject no naked flame
Reject fume cupboard
 because the alcohol/reaction mixture/bromobutane is flammable **or** because the heating is uniform and less likely to crack the flask (1)
 This mark is conditional on the first being scored. 2
Reject 'volatile' for 'flammable'

(b) QWC

EITHERIntermediate (ion) in S_N1 is planar (1)*Accept intermediate carbocation is a planar molecule**intermediate **molecule alone** loses this mark*

equal attack (by hydroxide ions) from either side (1)

produces a racemic mixture (1)

*Reject attack by bromide ions***Note:** Statement that the S_N2 mechanism is consistent with the information cannot score any marks.**OR** S_N2 involves attack from one side (1)

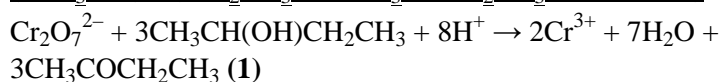
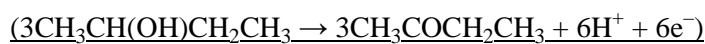
so configuration of the product would be inverted (1)

leading to retention of optical activity **so must be S_N1** (1)*Accept forms one optical isomer only*Statement that the reaction is S_N1 alone scores zero.

3

(c) (i) Orange \rightarrow green

1

(ii) $\text{Cr}_2\text{O}_7^{2-} + 6\text{e}^- + 14\text{H}^+ \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$ (1)

No consequential marking on incorrect equations.

2

Accept $\text{C}_4\text{H}_9\text{OH}$ and $\text{C}_4\text{H}_8\text{O}$ *Accept equation having non-cancelled H^+ ions**Reject equation having non-cancelled electrons*(iii) The broad peak/absorption/trough around 3400 cm^{-1} due to $-\text{OH}$ (1)*Accept 3230 – 3550**Reject broad transmission*has disappeared in the product to be replaced by $\text{C}=\text{O}$ at 1700 cm^{-1} (1)*Accept 1680 – 1750*

If no reference to both groups responsible for the peaks then max (1)

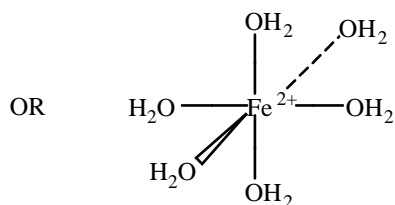
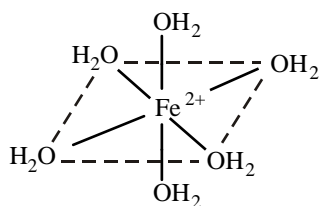
OR

If no reference to both wavenumbers responsible for the peaks then max (1)

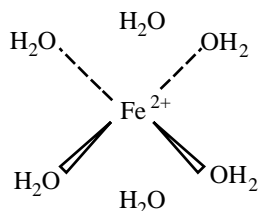
2

- (d) (i) Addition of barium ions pulls equilibrium to r.h.s. (1)
 increases $[H^+]$ **and** so lower pH/the pH falls (1) stand-alone mark 2
Reject ‘..so gets more acidic’
- (ii) lower pH/pH falls 1
Reject ‘mixture is more acidic’ for ‘lower pH’ [20]
13. A [1]
14. A [1]
15. C [1]
16. D [1]
17. (a) B 1
- (b) C 1 [2]
18. (a) (i) $Fe[Ar] 3d^6 4s^2$ in either order, allowing superscripts to be subscripts
 $Fe[Ar] 3d^6$ or $3d^6 4s^0$ in either order, allowing superscripts to be subscripts
 Letter d must be lower case 1
Reject any other letters

(ii)



OR

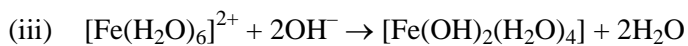


Instead of dotted line

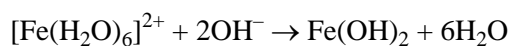
ALLOW bond to H of H₂O (accept on left side if OH₂ is given)

IGNORE charge unless incorrect

1



OR



1

(iv) Green precipitate/solid → Foxy-red/red-brown/
brown/orange

Both colours **and** precipitate/solid needed

1

Reject just "Darkens"

(b) (i) QWC

Emf of cell/ potential difference of cell containing Fe (1)

dipping into a 1 mol dm⁻³ Fe²⁺ solution (1)

And standard hydrogen electrode/half cell

OR hydrogen electrode and 1 mol dm⁻³ H⁺ and 1 atm

H₂

OR description of standard hydrogen electrode (1)

IGNORE temperature

3

Reject 'SHE'

(ii) QWC

Emf of hydrogen electrode is zero – *stated or implied*

e.g. if calculate $E_{\text{cell}} = +0.44 \text{ V}$ (1)

Potential for the reaction is positive so reaction is feasible

OR Fe half cell has more negative electrode potential

OR H^+ and $(\frac{1}{2})\text{H}_2$ has a more positive electrode potential (1)

2

(iii) High E_a so slow reaction / reactants are kinetically stable

IGNORE any mention of non-standard conditions

1

[10]