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) [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) $Co(H_2O)_6^{2+}$ **(1)** 1

(ii) Example:
$Co(H_2O)_6^{2+} + 4Cl^- \rightarrow CoCl_4^{2-} + 6\ H_2O$
Any valid equation that shows a ligand exchange but begins with $Co(H_2O)_6^{2+}$ **(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 ($E^\theta_{cell} = +1.53V$) **(1)**
and Fe^{2+} to Fe by Zn ($E^\theta_{cell} = +0.32V$)**(1)**
They have positive E^θ so are feasible **(1)** *NOT* "will happen"
OR
ALLOW Zn^{2+}/Zn is more negative than both Fe^{3+}/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) $MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$
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 dm^3 × 0.0200 mol dm^{-3}
= 3.64×10^{-4} mol **(1)**

Amount Fe^{2+} in original solution = 5 × above value = 1.82×10^{-3} mol **(1)**

Amount Fe^{2+} in 2nd titration = amount of Fe^{2+} and Fe^{3+} original solution **(1)**

= 0.0253 dm^3 × 0.0200 mol dm^3 × 5 = 2.53×10^{-3} mol

Amount of Fe^{3+} in original solution = 0.00253 – 0.00182 = 7.10×10^{-4} mol **(1)**

Amount zinc needed to reduce Fe^{3+} = ½ × 0.000710 = 0.000355 mol
Mass of zinc = 0.000355 mol × 65.4 g mol^{-1} = 0.0232 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 cm^3 – 18.2 cm^3 = 0.0253 dm^3 – 0.0182 dm^3 = 0.0071 dm^3 **(1)** 4th point

Amount of MnO_4^- = 0.0071 dm^3 × 0.0200 mol dm^{-3} = 1.42×10^{-4} mol **(1)** 1st point

Amount Fe^{3+} reduced by zinc = 5 × above value = 7.10×10^{-4} mol **(1)** 2nd point

Amount zinc needed = ½ × 7.10×10^{-4} = 3.55×10^{-4} mol
mass of zinc needed = 3.55×10^{-4} mol × 65.4 g mol^{-1} = 0.00232 g **(1)** 5th point 5

(d) (i) $[Fe(H_2O)_6]^{2+} + H_2O \rightarrow [Fe(H_2O)_5OH]^+ + H_3O^+$

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

(ii) $[Fe(H_2O)_6]^{3+}$ more acidic than $[Fe(H_2O)_6]^{2+}$ **(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) $5H_2O_2 + 2MnO_4^- + 6H^+ \rightarrow 5O_2 + 2Mn^{2+} + 8H_2O$ **(2)**
(1) for species
(1) for balancing the correct species
$\Delta E^{\ominus}_{reaction} = +\ 0.84$ (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

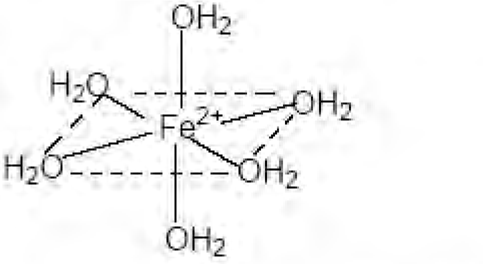
(iii) $2H_2O_2 \rightarrow 2H_2O + O_2$ **(1)**
O (in H_2O_2) oxidised from –1 to 0 (in O_2) **(1)**
O (in H_2O_2) reduced from –1 to –2 (in H_2O) **(1)** 3

[12]

5. (a) (i) <u>Fe [Ar]</u>
$3d^6 4s^2$
or $3d_6 4s_2$
or 3d64s2
or $4s^2 3d^6$ **(1)**

<u>Fe^{2+} [Ar]</u>
$3d^6$
or $3d_6$
or $3d^6 4s^0$ **(1)**
Letter d must be lower case
Any additional letters of numbers **(0)** 2

(ii) *The mark is for the shape*



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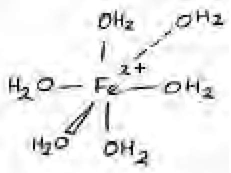

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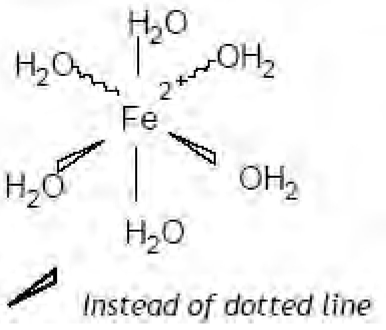


ALLOW bond to H of H_2O (except on left side if OH_2 is given)
IGNORE charge unless incorrect 1

(iii) $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow [Fe(OH)_2(H_2O)_4] + 2H_2O$

OR
$[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$
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) $N_2 + 3H_2 \rightarrow / \rightleftharpoons 2NH_3$

OR equation with Cl_2 1

(b) (i) Emf of cell / potential difference of cell containing Fe^{2+} <u>and</u> Fe **(1)**
and standard hydrogen electrode / half cell *NOT* 'SHE'
OR hydrogen electrode and 1 mol dm^{-3} H^+ and 1 atm H_2 **(1)**
1 mol dm^{-3} Fe^{2+}
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 (½)H_2 has a more +ve electrode potential than Fe^{2+} 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 = **(+) 0.23**V **(1)**
So I^- would reduce Fe^{3+} / Fe^{3+} would oxidise I^- / E^0 positive so reaction L → R **(1)**
OR reverse argument **(2)**
OR
Fe^{3+} and Fe^{2+} has a more positive electrode potential than I_2 and I^- **(1)**
I^- will reduce Fe^{3+} / Fe^{3+} 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) $2Fe(s) + O_2(g) + 2H_2O(l) \rightarrow 2Fe^{2+}(aq) + 4OH^-(aq)$ or multiples

OR

$2Fe(s) + O_2(g) + 2H_2O(l) \rightarrow 2Fe(OH)_2(s)$

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) $\Delta E^\ominus_{react} = (+)\ 0.84\ (V)$ **(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"*

$E^\ominus$ Zn^{2+} / Zn more negative than for Fe
OR

$E^\ominus$ Zn / Zn^{2+} more positive than for Fe
OR
E^θ_{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)** 3
disallow "higher" or "bigger" for more negative or more positive

[10]

7. (a) (i) Forms **ions** which have partially filled *d*-orbitals
OR
Forms ions which have a partially filled *d*-subshell 1

(ii) Scandiurn / Sc **and** Zinc / Zn 1

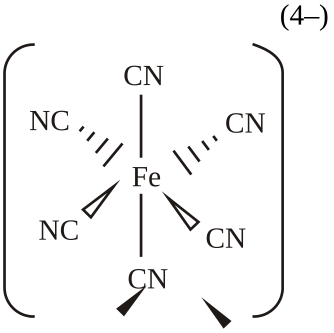
(b) (i) Fe^{2+} [Ar] $3d^6$

Mn^{2+} [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)**



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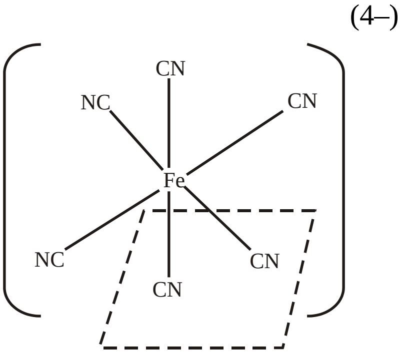


2

(d) Two As atoms oxidised from +3 to +5 per mole of As_2O_3
(loss of $4e^-$) **(1)**

∴ if 5 moles oxidised, total $20e^-$ Lost / change in oxidation no. = 20 **(1)**

∴ 4 moles MnO_4^- reduced, total $20e^-$ gained / change in oxidation no. 20
∴ each Mn(VII) gains $5e^-$ / change in oxidation no. 5 **(1)**

∴ Mn(ll) / Mn^{2+} **(1)** *NOT standalone mark* 4

(e) (i) $VO_3^- + 2H^+ / 2H_3O^+ \rightarrow VO_2^+ + H_2O / 3H_2O$ 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 : V^{3+} / $[V(H_2O)_6]^{3+}$ **(1)**

Violet colour : V^{2+} / $[V(H_2O)_6]^{2+}$, **(1)** 3

[16]

8. (a) $3OCl^- \rightarrow 2Cl^- + ClO_3^-$ **(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 $S_2O_3^{2-}$ used = 12.5 × 0. 1 / 1000 = 1. 25 × 10^{-3} **(1)**

no. moles I_2 = 1.25 × 10^{-3} / 2 = 6.25 × 10^{-4} **(1)**

no. moles ClO^- = no. moles 1_2 **(1)**

no. moles ClO^- in original 10 cm^3 = 10 × 6.25 × 10^{-4}

= 6.25 × 10^{-3} **(1)**

no. moles ClO^- in 1 dm^3 = 100 × 6.25 × 10^{-3} **(1)** = 0.625 5

(iii) mass Cl_2 = 0.625 × 71
= 44.4 (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 l_2 oxidises S from (+)2 to (+)2.50 **(1)** 2

QWC (d) O_2 oxidises KI / iodide to l_2. or balanced equation **(1)**
ll_2 reacts with starch / paper to give blue / black **(1)** 2

[14]

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

ΔE^θ = (+) 0.15 (V) OR E^θ (MnO_4^- / Mn^{2+}) more positive or greater than E^θ

(Cl_2 / 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
$2MnO_4^- + 16H^+ + 10Cl^- \rightarrow^- 2Mn^{2+} + 8H_2O + 5Cl_2$ **(1)**
E^θ = (+) 0.15(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) Moles MnO_4^- = $\frac{0.0200 \times 20.10}{1000}$
= 0.000402 mol MnO_4^- **(1)**

Moles Fe^{2+} per 25.0 cm^3 = 5 × 0.000402
= 0.00201 mol Fe^{2+} **(1)**

Moles Fe^{2+} per 200 cm^3 = 0.00201 × $\frac{200}{25}$ mol Fe^{2+}
= 0.01608 mol Fe^{2+} **(1)**

Mass of $FeSO_4 . 7H_2O$ = 0.01608 × 278
= 4.47g or via concentrations **(1)**

Percentage purity = $\frac{4.47}{6.00}$ × 100%
= 74.5% **(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) $E^\theta = +1.46 - (-0.13) = (+)$ **1.59** (V)
Correct answer alone **(1)** 1

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

"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_{reaction} = (+) 1.57 (V) **(1)**

Reject – 1.57

$Zn + 2NO_3^- + 4H^+ \rightarrow Zn^{2+} + 2NO_2 + 2H_2O$ **(1)** 2

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)**

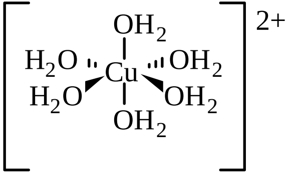
smaller than reaction in (i) so is less likely **(1)**

OR

NO_3^- being the oxidised form of a redox couple with a more positive $E^{\ominus}$ than $E^{\ominus}$ $H^+/\frac{1}{2} H_2$ **(1)**

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

(iii) hexaaquacopper(II) **(1)**



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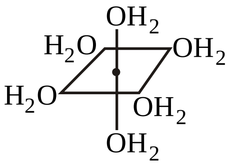


(1)

Both marks stand alone
[IGNORE charge] 2
[IGNORE how H_2O ligand is bonded to central cation]

Accept hexaquacopper(II)

Reject formula

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

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons CuCl_4^{2-} + 6H_2O$ **(1)**
OR
$[Cu(H_2O)_6]^{2+} + 4HCl \rightleftharpoons CuCl_4^{2-} + 4H^+ + 6H_2O$ **(1)** 2

ALLOW →

Accept $H_2CuCl_4 + 2H^+$ *for* $CuCl_4^{2-} + 4H^+$

(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) $[Cu(NH_3)_4]^+$

OR $[Cu(NH_3)_4(H_2O)_2]^+$ 1

Accept $[Cu(NH_3)_2]^+$

Reject $[Cu(NH_3)_6]^+$

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 dm^3 × 0.1 mol dm^{-3} **(1)**

= amount Cu^{2+} in 25.0 cm^3 = 1.655 × 10^{-3} mol **(1)**

amount of Cu^{2+} in 250 cm^3 = 1.655 × 10^{-3} × 10 **(1)**

mass of Cu (in sample) = 1.655 × 10^{-2} × 63.5 **(1)** = 1.051 g

% Cu in brass = 1.051 × 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 atm/100 kPa/ 105Pa/ 1 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) **<u>1st mark</u>**

(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 state**s** are …*

Or a (single) species/ substance/ reactant/compound/ chemical both loses and gains electrons **(1)**

<u>2nd mark</u>

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) $2H_2O_2 \rightarrow 2H_2O + O_2$ **(1)**

Reject $2H^+$ on both sides of equation

E_{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 H_2O 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/$C_4H_9OH_2^+$ 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

EITHER
Intermediate (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 SN1 (1)**

Accept forms one optical isomer only

Statement that the reaction is S_N1 alone scores zero. 3

(c) (i) Orange → green 1

(ii) $Cr_2O_7^{2-} + 6e^- + 14H^+ \rightarrow 2Cr^{3+} + 7H_2O$ **(1)**

$\underline{(3CH_3CH(OH)CH_2CH_3 \rightarrow 3CH_3COCH_2CH_3 + 6H^+ + 6e^-)}$
$Cr_2O_7^{2-} + 3CH_3CH(OH)CH_2CH_3 + 8H^+ \rightarrow 2Cr^{3+} + 7H_2O +$
$3CH_3COCH_2CH_3$ **(1)**

No consequential marking on incorrect equations. 2

Accept C_4H_9OH *and* C_4H_8O

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 –OH **(1)**

Accept 3230 – 3550

Reject broad transmission

has disappeared in the product to be replaced by C=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

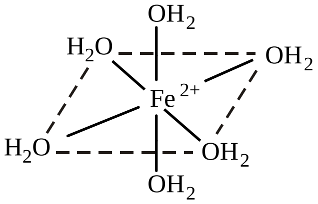
(b) C 1

[2]

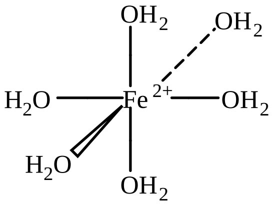
18. (a) (i) Fe[Ar] $3d^6 4s^2$ in either order, allowing superscripts to be subscripts
Fe[Ar] $3d^6$ or $3d^6 4s^0$ in either order, allowing
superscripts to be subscripts
Letter d must be lower case 1

Reject any other letters

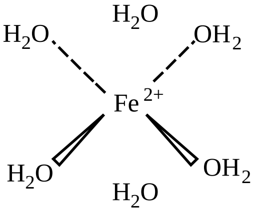
(ii)



OR



OR




Instead of dotted line

ALLOW bond to H of H_2O (accept on left side if OH_2 is given)
IGNORE charge unless incorrect 1

(iii) $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow [Fe(OH)_2(H_2O)_4] + 2H_2O$

OR

$[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$ 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} Fe^{2+} solution **(1)**

And standard hydrogen electrode/half cell
OR hydrogen electrode and 1 mol dm^{-3} H^+ and 1 atm H_2
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_{cell} = +0.44 V **(1)**

Potential for the reaction is positive so reaction is feasible
OR Fe half cell has more negative electrode potential
OR H^+ and (½)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]