Mark schemes

Q1.

(a) (List of) electrode potentials/$E^\ominus$ in (numerical) order

OR half cells/equations in (numerical) order of electrode potential/$E^\ominus$

Do not allow EMF in order

1

(b) Any 2 from
298 K **or** 25 ^oC
$[H^+] = 1$ mol dm^{-3}
100 kPa

Ignore 1 atm

1

(c) $[Co(H_2O)_6]^{2+}$

Do not penalise absence of brackets

1

(d) $3\ VO_2^+ + 6\ H^+ + Fe + 3\ H_2O \rightarrow 3\ VO^{2+} + [Fe(H_2O)_6]^{3+}$

or

$3\ VO_2^+ + 6\ H^+ + Fe \rightarrow 3\ VO^{2+} + 3\ H_2O + Fe^{3+}$

1 mark for Fe^{3+} as product and one mark for equation.

Ignore state symbols

Allow 1 mark for balanced equation that gives Fe^{2+} as product

$2VO_2^+ + 4H^+ + Fe + 4H_2O \rightarrow 2VO^{2+} + [Fe(H_2O)_6]^{2+}$

or

$2VO_2^+ + 4H^+ + Fe \rightarrow 2VO^{2+} + Fe^{2+} + 2H_2O$

2

(e) $E^\ominus$ $Co^{3+}(/Co^{2+}) > Fe^{3+}(/Fe^{2+})$

*Allow electrode potential for Co^{3+} greater than for Fe^{3+} **OR** 1.81 > 0.77 / EMF cell = 1.04 V*

1

$[Co(H_2O)_6]^{3+} + [Fe(H_2O)_6]^{2+} \rightarrow [Co(H_2O)_6]^{2+} + [Fe(H_2O)_6]^{3+}$

Insist of reference to $E^\ominus$ in M1

1

(f) Different ligands

Penalise different concentrations/oxidation states

1

[8]

Q2.

(a) Lithium would react with the electrolyte/water

Allow water will oxidise Li to Li^+ or Li will reduce water to hydrogen

1

$E^\ominus$ for Li^+(/Li) more negative than for water or EMF= 2.21(V) or $E^\ominus$ Li^+ (/Li) < H_2O(/H_2 ,OH^-)

Ignore EMF is negative

1

(b) 0.54 – (–3.04) = <u>3.58</u> (V)

1

(c) Non-standard conditions

Allow non-aqueous conditions or different conditions

1

(d) (+) 7

Accept VII

1

(e) $Li^+ + CoO_2 + e^- \rightarrow Li^+CoO_2^-$ or
$Li^+ + CoO_2 + e^- \rightarrow LiCoO_2$

1

(f) $Li \rightarrow Li^+ + e^-$

1

[7]

Q3.

(a) $C_6H_{12}O_6 + 6\ H_2O \rightarrow 6\ CO_2 + 24\ H^+ + 24\ e^-$

Accept multiples

1

(b) $O_2 + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O$

Accept multiples

1

(c) $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

Accept multiples

1

(d) C(s) | $C_6H_{12}O_6$(aq), H^+(aq) | CO_2(g) || O_2(g) | H^+(aq),H_2O(l)| Pt(s)

OR

C|$C_6H_{12}O_6$, H^+| CO_2 || O_2 | H^+,H_2O| Pt

M1 *Must see following in correct order:*

C | $C_6H_{12}O_6$ CO_2 || O_2 H_2O | Pt

M2 *Cell completely correct*

Ignore H_2O on LHS

Ignore state symbols

Allow $H^+(aq) | H_2O(l)$ on RHS
0 marks if electrons included.

2

(e) (Constantly) add reactants/glucose (and oxygen) OR keep concentration of reactants constant

1

[6]

Q4.

(a) $H_2(g)$ **AND** 100kPa

Allow 1 bar
NOT 1 atm or 101kPa
0.5 mol dm^{-3} and H_2SO_4

1

1 mol dm^{-3} **AND** $HCl/HNO_3/H^+$

1

Pt electrode **AND** temperature of 298 K (25°C)

1

(b)

This question is marked using levels of response. Refer to the Mark Scheme Instructions for examiners for guidance on how to mark this question	
Level 3 **5-6 marks**	All stages are covered and the explanation of each stage is correct and virtually complete Answer communicates the whole explanation, coherently and shows a logical progression through all three stages. 'Coherence' requires clear practical details (e.g. weighing into beaker/ by difference/ plus washings, not straight into volumetric flask, saturated solution chosen for salt bridge, salt bridge solution is suitable)
Level 2 **3-4 marks**	All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** two stages covered and the explanations are generally correct and virtually complete Answer is coherent and shows some progression through all three stages. Some steps in each stage may be incomplete
Level 1 **1-2 marks**	Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** only one stage is covered but the explanation is generally correct and virtually complete Answer shows some progression between two stages
Level 0	Insufficient correct Chemistry to warrant a mark

0 marks	

Indicative Chemistry content

Stage 1: Preparing solution

(1a) Weigh 7.995 / 8.00 g $TiOSO_4$

(1b) Dissolve in / add (allow react with) (0.50 mol dm^{-3}) sulfuric acid

(1c) transfer to volumetric flask and make up to the mark

Stage 2: Set up cell
Content can be shown in a labelled diagram
(2a) piece of Ti immersed in (1 mol dm^{-3} acidified) $TiO^{2+}(aq)$ / the solution

(2b) (connect solutions with) salt bridge or description

(2c) (connect metals through high R) voltmeter

Stage 3: Measurements and calculation

(3a) record voltage/potential difference/emf of the cell

(3b) $E_{cell} = E_{RHS} - E_{LHS}$
$E_{cell} = E_{copper} - E_{titanium}$

(3c) $E_{LHS} = E_{RHS} - E_{cell}$ OR E_{cell} should be +1.22 V if Cu on RHS (or −1.22 if Cu electrode on LHS)

6

(c) $TiO^{2+} + 2H^+ + 4e^{(-)} \rightarrow Ti + H_2O$

Allow reverse reaction

Ignore state symbols

Allow multiples or fractions

Allow equilibrium arrow

1

(d) ((+)0.34 compared with 0.00 shows that)
E_{cell} for $Cu + 2H^+ \rightarrow H_2 + Cu^{2+}$ / reaction of copper with most acids is negative / −0.34 / (+)0.34 shows Cu less powerful reducing agent than H_2

OR *M1* ***(****E^o****)*** *H^+/H_2 (or the hydrogen electrode) less +ve/< than* ***(****E^o****)*** *Cu^{2+}/Cu (or the copper electrode) so H^+ cannot oxidise Cu to Cu^{2+} / H^+ poorer oxidising agent (or reverse argument)*

1

((+)0.96 compared with (+)0.34 shows that)
E_{cell} for reaction of Cu with nitrate/nitric acid is positive / (+)0.62 V

M2 ***(****E^o****)*** *NO_3^-/NO (or the nitrate/nitric acid electrode) more +ve/> than* ***(****E^o****)*** *Cu^{2+}/Cu (or the copper electrode) so NO_3^- can oxidise Cu to Cu^{2+} (or reverse argument)*

1

$2NO_3^- + 8H^+ + 3Cu \rightarrow 2NO + 4H_2O + 3Cu^{2+}$

Allow multiples or fractions

Ignore state symbols

1

[13]

Q5.

(a) salt bridge

Allow description of salt bridge, e.g. filter paper / string / wick soaked in suitable solution

U tube (NOT YouTube) filled with suitable solution / gel

NOT U tube alone

1

(b) complete the circuit

Allow ions to flow / move / transfer

Allow to balance charge / to maintain electrical neutrality

Ignore current / charge to flow

NOT electrons to flow

1

(c) **B** = platinum

Allow Pt / platinum black

1

(d)

		Identity	Conditions
M1	**C**	HCl	1 mol dm^{-3}
M2	**D**	H_2 / hydrogen	100 kPa
M3	**E**	$FeCl_2$ and $FeCl_3$	1 mol dm^{-3}

NOT incorrect state symbols

Allow M or molar or mol/dm^3 for mol dm^{-3}

***M1** Allow 1 mol dm^{-3} H^+*

Allow 0.5 mol dm^{-3} H_2SO_4

Allow 1 mol dm^{-3} HNO_3

Ignore 100 kPa

1

***M2** Allow 1 bar*

NOT 1 atm / 101 kPa

NOT H for hydrogen

NOT 1 mol dm^{-3}

1

***M3** Allow 1 mol dm^{-3} Fe^{2+} and Fe^{3+}*

Allow other identified Fe(II) and Fe(III) compounds with appropriate concentrations, e.g. 1 mol dm^{-3} $FeSO_4$ and 0.5 mol dm^{-3} $Fe_2(SO_4)_3$

Ignore 100 kPa

1

M4 298 K (any mention)

1

(e) **M1** $H_2 + 2\ Fe^{3+} \rightarrow 2\ H^+ + 2\ Fe^{2+}$

__M1__ Ignore state symbols

Allow multiples / fractions

Allow equation with equilibrium sign if forward reaction shown is in this direction

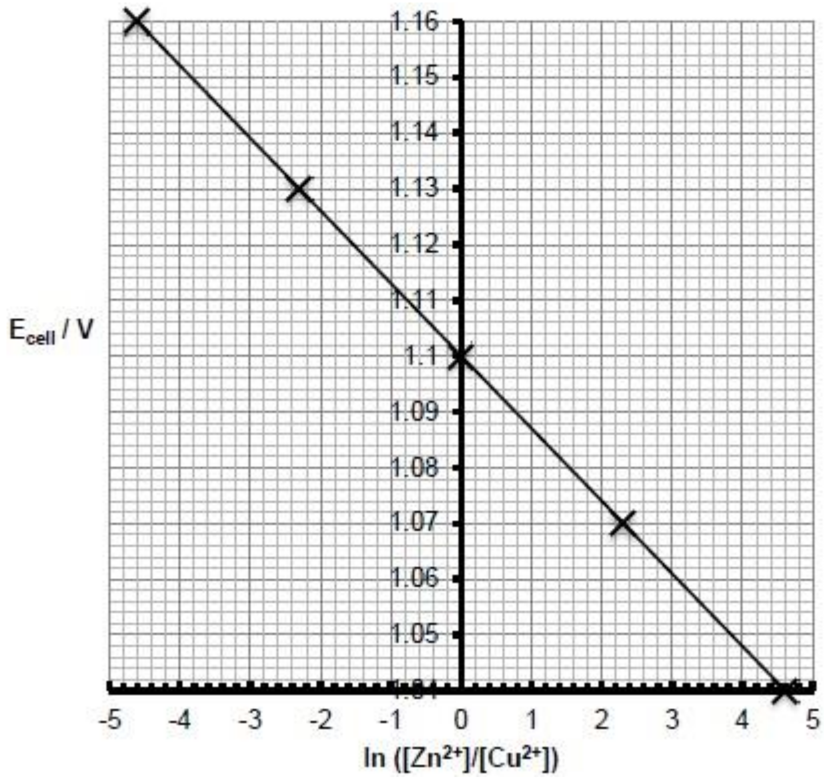
1

M2 replace voltmeter with lamp/wire/ammeter owtte

__M2__ Allow remove voltmeter

1

(f) **M1** missing value (+) 2.3(0)



1

M2 suitable scales (plotted points use at least half of grid)

__M2__ Allow scales which use half the grid for plotted points

1

M3 points plotted correctly (± ½ small square per point) and best fit line drawn (within one small square of each point)

__M3__ If __M1__ incorrect, should be plotted accordingly and best fit line Ignore if anomalous

1

(g) **M1** gradient = –0.013 (must be negative)

__M1__ Allow –0.0125 to –0.0136

Allow ECF from graph if outside this range

1

M2 M1 = (–) 4.3 × 10⁻⁵ T or $T = \frac{M1}{(-)4.3 \times 10^{-5}}$

1

M3 T = 302 or 303 (K)

__M3__ temperature must match gradient unless –0.016 used (Allow positive temperature if positive gradient used)

at least 2sf

Correct __M3__ also scores __M2__

NOT negative temperature

__M3__ (Alternate gradient = –0.016 gives) T = 372 (K)

1

(h) **M1** E = –0.8(0) V

1

M2 non standard conditions or

concentration (of Zn^{2+}) not 1 (mol dm^{-3}) or

concentration (of Zn^{2+}) less than 1 (mol dm^{-3})

__M2__ Allow temperature is not 298K

NOT concentration (of Zn^{2+}) greater than 1 (mol dm^{-3})

NOT concentration (of Zn^{2+}) is different

1

[17]

Q6.

A

[1]

Q7.

(a) It has mobile <u>ions</u> / <u>ions</u> can move through it / free <u>ions</u>

Do not allow movement of electrons.

1

(b) (+) 0.18 V

1

(c) The concentration is not <u>1</u>.(0) (mol dm^{-3})

1

(d) Cu (s)| Cu^{2+}(aq) ‖ Cu^{2+}(aq) | Cu(s)

1

(e) (Concentration) increases or ([Cu^{2+}] ions) increase

Mark independently

1

The $[Cu^{2+}]$ ions in the two solutions become <u>equal/same</u>

Not, concentrations are constant

1

[6]

Q8.

B

[1]

Q9.

(a) Cl_2

1

(b) $Pt|H_2|H^+||Sn^{2+}|Sn$

Award 1 mark for species and 1 mark for correct order including Pt

Ignore state symbols

2

(c) 0.94 V

1

$Sn \longrightarrow Sn^{2+} + 2e^-$

1

(d) $Ag^+ + Fe^{2+} \longrightarrow Ag + Fe^{3+}$

1

[6]

Q10.

(a) The ions in the ionic substance in the salt bridge move through the salt bridge

1

To maintain charge balance / complete the circuit

1

(b) F^-

1

(c) $E^\ominus$ SO_4^{2-} / SO_2 < $E^\ominus$ Br_2 / Br^-

Allow correct answer expressed in words, eg electrode potential for sulfate ions / sulfur dioxide is less than that for bromine / bromide

1

(d) 1.23 (V)

1

(e) A fuel cell converts more of the available energy from combustion of hydrogen into kinetic energy of the car / an internal combustion engine wastes more (heat) energy

1

[6]

Q11.

A

[1]