Electrode potentials and cells

AQA 7405 · Full A-level

Show your working where needed. Check the worked answers when you finish.

Name _____ Date _____

1. The standard reference half-cell

Define standard electrode potential relative to its reference electrode. State the usual temperature, gas pressure and aqueous ion concentration used. Name the metal used in the reference electrode.

2. Follow the electrons

A cell uses $Zn^{2+} + 2e^- \rightarrow Zn$ with $E^\circ = -0.76$ V and $Cu^{2+} + 2e^- \rightarrow Cu$ with $E^\circ = +0.34$ V.

Identify the negative electrode, give the direction of electron flow in the wire and calculate the standard EMF.

3. Tin and iron half-cells

$Sn^{4+} + 2e^- \rightarrow Sn^{2+}$, $E^\circ = +0.15$ V. $Fe^{3+} + e^- \rightarrow Fe^{2+}$, $E^\circ = +0.77$ V.

Predict the favoured direction under standard conditions. Write the overall ionic equation and calculate E°cell.

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4. Measure an unknown E°

Under standard conditions an M^{2+}/M half-cell is paired with the standard hydrogen electrode. The voltmeter reads +0.44 V with its positive lead on the hydrogen electrode. What is E° for M^{2+}/M? Explain.

5. Choose a salt bridge

A cell uses a silver electrode in $AgNO_3(aq)$ and a copper electrode in $Cu(NO_3)_2(aq)$. A student can fill the salt bridge with either $KCl(aq)$ or $KNO_3(aq)$.

Choose one solution and explain your choice. Describe how a working salt bridge keeps charge moving.

6. Two potential oxidising agents

Standard reduction potentials: Fe^{3+}/Fe^{2+} +0.77 V, Sn^{4+}/Sn^{2+} +0.15 V, I_2/I^- +0.54 V.

Which of Fe^{3+} and Sn^{4+} is predicted to oxidise I^- to I_2 under standard conditions? Justify both decisions.

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7. Zinc and an aqueous iron half-cell

A cell oxidises Zn(s) to $Zn^{2+}(aq)$ and reduces $Fe^{3+}(aq)$ to $Fe^{2+}(aq)$. State the electrode material to use on the iron side and explain why it works.

Write the conventional cell representation, including state symbols.

8. An alkaline hydrogen-oxygen fuel cell

An alkaline hydrogen-oxygen fuel cell uses H_2 and O_2.

Write both half-equations and the overall equation. Explain why the cell needs a continuous supply of reactants.

9. Extra challenge · A gas half-cell and a salt bridge

Standard reduction potentials: Sn^{4+}/Sn^{2+} +0.15 V, Cl_2/Cl^- +1.36 V and I_2/I^- +0.54 V.

For the Sn^{4+}/Sn^{2+} half-cell connected to Cl_2/Cl^-, write the overall ionic equation and conventional cell representation. Calculate the standard EMF. Use the data to explain why KI is unsuitable as a salt bridge in contact with the chlorine half-cell.

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Worked answers

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1. The standard reference half-cell

It is the potential difference measured against the standard hydrogen electrode, which is assigned E° = 0.00 V.

The hydrogen electrode uses platinum in contact with H_2 at 100 kPa and $H^+(aq)$ at 1.00 mol dm^{-3}, at 298 K.

2. Follow the electrons

Zinc is oxidised and its electrode is negative. Electrons flow from zinc to copper through the wire.

E°cell = 0.34 − (−0.76) = +1.10 V.

3. Tin and iron half-cells

Fe^{3+} is reduced and Sn^{2+} is oxidised. Reverse the tin half-equation and double the iron half-equation.

$Sn^{2+} + 2Fe^{3+} \rightarrow Sn^{4+} + 2Fe^{2+}$. E°cell = 0.77 − 0.15 = +0.62 V. Potentials are kept at their given values when coefficients change.

4. Measure an unknown E°

The hydrogen electrode is 0.44 V more positive than the metal half-cell. Since E° of the hydrogen electrode is zero, E° of M^{2+}/M is −0.44 V.

5. Choose a salt bridge

Choose $KNO_3(aq)$. Chloride would remove Ag^+ from solution by forming AgCl(s). The nitrate solution provides mobile ions without precipitating ions from these half-cells.

Ions move through the bridge and maintain electrical neutrality in the half-cells, completing the circuit. Electrons move through the external wire.

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Worked answers

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6. Two potential oxidising agents

Fe^{3+} is predicted to oxidise I^- because the combination gives 0.77 − 0.54 = +0.23 V.

The corresponding combination for Sn^{4+} gives 0.15 − 0.54 = −0.39 V, so that direction is not favoured.

7. Zinc and an aqueous iron half-cell

Both iron species are aqueous. An inert platinum electrode conducts electrons to the iron half-cell without reacting.

Zn(s) | Zn^{2+}(aq) || Fe^{3+}(aq), Fe^{2+}(aq) | Pt(s). The double line represents the salt bridge.

8. An alkaline hydrogen-oxygen fuel cell

At the negative electrode: $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$.

At the positive electrode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$.

Double the oxidation equation and add. The overall reaction is $2H_2 + O_2 \rightarrow 2H_2O$. The fuel and oxygen are used up, so a fresh supply sustains the current.

9. Extra challenge · A gas half-cell and a salt bridge

Sn^{2+} is oxidised, and chlorine is reduced: $Sn^{2+}(aq) + Cl_2(g) \rightarrow Sn^{4+}(aq) + 2Cl^-(aq)$. E°cell = 1.36 − 0.15 = +1.21 V.

Pt(s) | Sn^{2+}(aq), Sn^{4+}(aq) || Cl^-(aq) | Cl_2(g) | Pt(s). Aqueous ions of the same half-cell are separated by a comma, and both half-cells use inert platinum.

Cl_2 can oxidise I^-. The difference 1.36 − 0.54 = +0.82 V predicts a favourable side reaction under standard conditions.

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