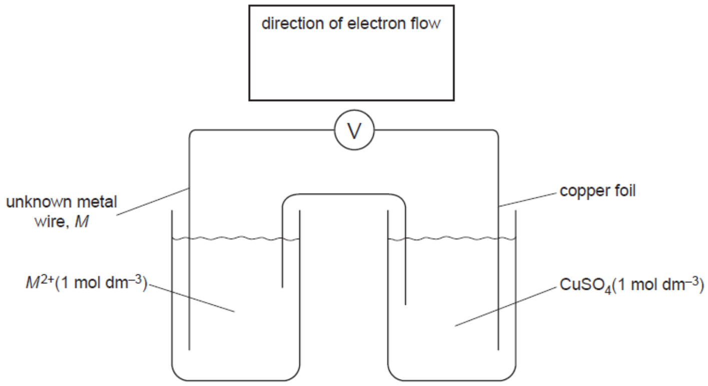
Q1 **(a)** What do you understand by the term *standard electrode potential*?

....

....

(b) The following cell was set up between a copper electrode and an unknown metal electrode M^{2+}(aq) /M(s). The standard cell potential was found to be 0.76 V, and the copper foil was the positive electrode.



(i) Use the *Data Booklet* to calculate the standard electrode potential of the M^{2+}(aq) /M(s) system.

....

(ii) Draw an arrow over the voltmeter symbol in the above diagram to show the direction of electron flow through the voltmeter.

(iii) Predict the outcomes of the following situations. Describe what you might see and write ionic equations for any reactions that occur.

I A rod of metal *M* is dipped into a solution of 1 $moldm^{-3}$ $CuSO_4$.

....

....

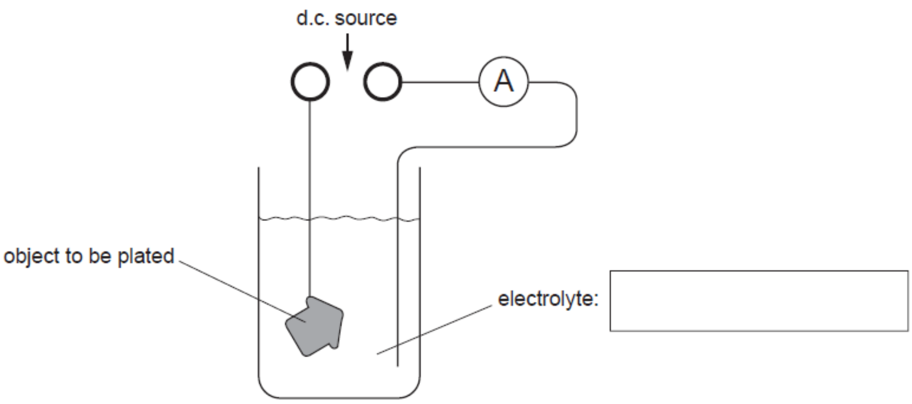
II Dilute sulphuric acid is added to a beaker containing a powdered sample of metal *M*.

....

....

(c) Because of its increased scarcity, cheaper copper ornaments are no longer made from the solid metal, but from iron that has been copper plated.

(i) Complete the following diagram showing the set-up for a copper electroplating process. Show clearly the polarity (+/–) of the power source, and suggest a suitable electrolyte.



(ii) A current of 0.500 A is passed through the electroplating cell. Calculate the time required to deposit a mass of 0.500 g of copper on to the ornament.

....

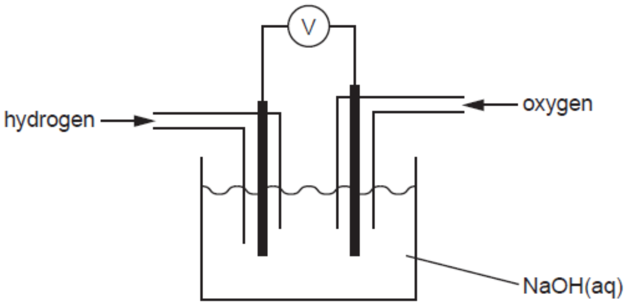
....

....

(June 2003)

Q2 Although standard electrode potentials are measured for solutions where the concentrations of ions are 1.0 mol dm^{-3}, cells used as sources of battery power tend to operate with more concentrated solutions. This question concerns the electrode reactions involved in the hydrogen-oxygen fuel cell and the lead-acid car battery.

(a) In the hydrogen-oxygen fuel cell, H_2(g) and O_2(g) are fed onto two inert electrodes dipping into NaOH(aq).



The following reactions take place.

left hand electrode (cathode): $H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$

right hand electrode (anode): $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

(i) Use the *Data Booklet* to calculate $E^{\ominus}_{cell}$ for this reaction.

....

....

(ii) Construct an equation for the overall reaction.

....

(iii) By using **one** of the phrases *more positive*, *more negative* or *no change*, deduce the effect of increasing [OH^-(aq)] on the electrode potential of

• the left hand electrode ....

• the right hand electrode ....

(iv) Hence deduce whether the overall E_{cell} is likely to *increase*, *decrease* or *remain the same*, when [OH^-(aq)] increases. Explain your answer.

....

....

(v) Suggest **one** other reason why a high [NaOH(aq)] is used in the fuel cell.

....

(b) In the cells of a lead-acid car battery the following reactions take place.

cathode: $Pb(s) \rightarrow Pb^{2+}(aq) + 2e^-$

anode: $PbO_2(s) + 4H^+(aq) + 2e^- \rightarrow Pb^{2+}(aq) + 2H_2O(l)$

(i) Use the *Data Booklet* to calculate $E^{\ominus}_{cell}$ for this reaction.

....

(ii) Construct an equation for the overall reaction.

....

The electrolyte in a lead-acid cell is H_2SO_4(aq). Most of the Pb^{2+}(aq) ions that are produced at the electrodes are precipitated as the highly insoluble $PbSO_4$(s).

(iii) Construct an equation for the overall cell reaction in the presence of H_2SO_4.

....

(iv) By considering the effect of decreasing [Pb^{2+}(aq)] on the electrode potentials of the cathode and the anode, deduce the effect of the presence of H_2SO_4(aq) in the electrolyte on the overall E_{cell}.

State whether the E_{cell} will *increase*, *decrease* or *remain the same*.

Overall E_{cell} will ....

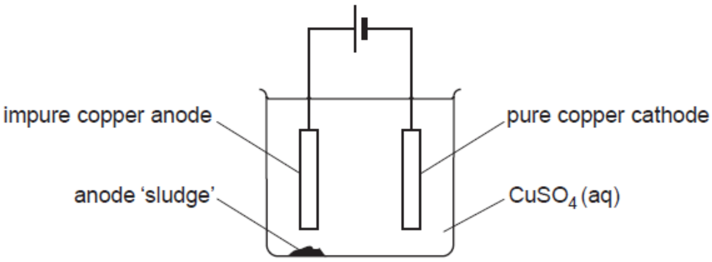
Explain your answer.

....

....

(June 2010 P41)

Q3 The electrolytic purification of copper can be carried out in an apparatus similar to the one shown below.



The impure copper anode contains small quantities of metallic nickel, zinc and silver, together with inert oxides and carbon resulting from the initial reduction of the copper ore with coke. The copper goes into solution at the anode, but the silver remains as the metal and falls to the bottom as part of the anode 'sludge'. The zinc also dissolves.

(a) (i) Write a half equation including state symbols for the reaction of copper at the anode.

....

(ii) Use data from the *Data Booklet* to explain why silver remains as the metal.

....

(iii) Use data from the *Data Booklet* to predict what happens to the nickel at the anode.

....

....

(iv) Write a half equation including state symbols for the main reaction at the cathode.

....
(v) Use data from the *Data Booklet* to explain why zinc is not deposited on the cathode.

....

....
(vi) Suggest why the blue colour of the electrolyte slowly fades as the electrolysis proceeds.

....

....
(b) Most of the current passed through the cell is used to dissolve the copper at the anode and precipitate pure copper onto the cathode. However, a small proportion of it is 'wasted' in dissolving the impurities at the anode which then remain in solution.When a current of 20.0 A was passed through the cell for 10.0 hours, it was found that 225 g of pure copper was deposited on the cathode.
(i) Calculate the following, using appropriate data from the *Data Booklet*.
• number of moles of copper produced at the cathode

• number of moles of electrons needed to produce this copper

• number of moles of electrons that passed through the cell

(ii) Hence calculate the percentage of the current through the cell that has been 'wasted' in dissolving the impurities at the anode.

(c) Nickel often occurs in ores along with iron. After the initial reduction of the ore with coke, a nickel-iron alloy is formed.Use data from the *Data Booklet* to explain why nickel can be purified by a similar electrolysis technique to that used for copper, using an impure nickel anode, a pure nickel cathode, and nickel sulfate as the electrolyte. Explain what would happen to the iron during this process.

....

....

....

....
(Nov 2010 P41)

Q4 **(a)** What is meant by the term *standard electrode potential*, SEP?

....

....

(b) Draw a fully labelled diagram of the apparatus you could use to measure the SEP of the Fe^{3+} / Fe^{2+} electrode.

(c) The reaction between Fe^{3+} ions and I^- ions is an equilibrium reaction.

$$2Fe^{3+}(aq) + 2I^-(aq) \rightleftharpoons 2Fe^{2+}(aq) + I_2(aq)$$

(i) Use the *Data Booklet* to calculate E_{CELL} the for this reaction.

....

(ii) Hence state, with a reason, whether there will be more products or more reactants at equilibrium.

....

....

(iii) Write the expression for K_c for this reaction, and state its units.

An experiment was carried out using solutions of Fe^{3+}(aq) and I^-(aq) of equal concentrations. 100 cm^3 of each solution were mixed together, and allowed to reach equilibrium.

The concentrations at equilibrium of Fe^{3+}(aq) and I_2(aq) were as follows.

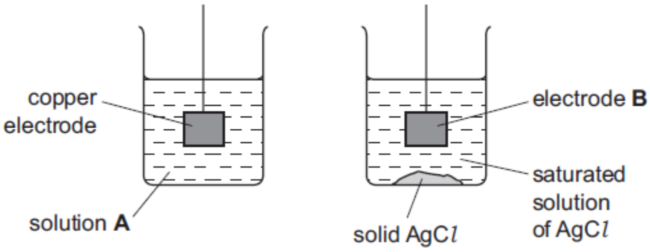
$$[Fe^{3+}(aq)] = 2.0 \times 10^{-4}\ mol\ dm^{-3}$$
$$[I_2(aq)] = 1.0 \times 10^{-2}\ mol\ dm^{-3}$$

(iv) Use these data, together with the equation given in **(c)**, to calculate the concentrations of Fe^{2+}(aq) and I^-(aq) at equilibrium.

(v) Calculate the K_c for this reaction.

(June 2013 P43)

Q5 **(a)** The diagram below shows an incomplete experimental set-up needed to measure the E_{cell} of a cell composed of the standard Cu^{2+}/Cu electrode and an Ag^{+}/Ag electrode.



(i) State the chemical composition of

solution **A**, ...

electrode **B**. ....

(ii) Complete the diagram to show the whole experimental set-up.

(b) The above cell is not under standard conditions, because the $[Ag^{+}]$ in a saturated solution of AgC*l* is much less than 1.0 mol dm^{-3}. The $E_{electrode}$ is related to $[Ag^{+}]$ by the following equation.

equation 1 $$E_{electrode} = E^{\ominus}_{electrode} + 0.06 \log[Ag^{+}]$$

(i) Use the *Data Booklet* to calculate the E_{cell} if the cell was operating under standard conditions.

In the above experiment, the E_{cell} was measured at +0.17V.

(ii) Calculate the value of $E_{electrode}$ for the Ag^{+}/Ag electrode in this experiment.

....

(iii) Use equation 1 to calculate $[Ag^{+}]$ in the saturated solution.

(c) **(i)** Write an expression for K_{sp} of silver sulfate, Ag_2SO_4, including units.

K_{sp} = ... units ....

Using a similar experimental set-up to that illustrated opposite, it is found that $[Ag^{+}]$ in a saturated solution of Ag_2SO_4 is 1.6×10^{-2} mol dm^{-3}.

(ii) Calculate the value of K_{sp} of silver sulfate.

(Nov 2012 P42)