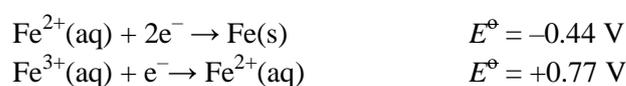




IB Chemistry HL Topic 9 Questions and Answers

1. Aqueous solutions of AgNO_3 , $\text{Cu(NO}_3)_2$ and $\text{Cr(NO}_3)_3$ are electrolyzed using the same quantity of electricity. How do the number of moles of metal formed compare?
- A. $\text{Ag} = \text{Cu} = \text{Cr}$
B. $\text{Ag} > \text{Cu} > \text{Cr}$
C. $\text{Ag} < \text{Cu} < \text{Cr}$
D. $\text{Cu} > \text{Ag} > \text{Cr}$

2. The standard electrode potentials for two half-cells involving iron are given below.



What is the equation and the cell potential for the spontaneous reaction that occurs when the two half-cells are connected?

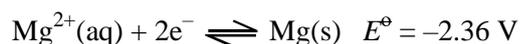
- A. $3\text{Fe}^{2+}(\text{aq}) \rightarrow \text{Fe}(\text{s}) + 2\text{Fe}^{3+}(\text{aq})$ $E^{\ominus} = +1.21 \text{ V}$
B. $\text{Fe}^{2+}(\text{aq}) + \text{Fe}^{3+}(\text{aq}) \rightarrow 2\text{Fe}(\text{s})$ $E^{\ominus} = +0.33 \text{ V}$
C. $\text{Fe}(\text{s}) + 2\text{Fe}^{3+}(\text{aq}) \rightarrow 3\text{Fe}^{2+}(\text{aq})$ $E^{\ominus} = +0.33 \text{ V}$
D. $\text{Fe}(\text{s}) + 2\text{Fe}^{3+}(\text{aq}) \rightarrow 3\text{Fe}^{2+}(\text{aq})$ $E^{\ominus} = +1.21 \text{ V}$
3. Metallic tin can be produced by the electrolysis of a molten salt containing Sn^{2+} ions. Which change(s) would double the amount of tin produced?
- I. Doubling the current passed during electrolysis
II. Doubling the time used for electrolysis
III. Using Sn^{4+} ions instead of Sn^{2+} ions
- A. I only
B. II only
C. I and II only
D. I, II and III



4. Which of the following factors affect the amount of product formed during electrolysis?
- I. The current used
 - II. The duration of electrolysis
 - III. The charge on the ion
- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III
5. The cyanide ion, CN^- , can form two complex ions with iron ions. The formulas of these ions are $[\text{Fe}(\text{CN})_6]^{4-}$ and $[\text{Fe}(\text{CN})_6]^{3-}$. What is the oxidation number of iron in the two complex ions?

	$[\text{Fe}(\text{CN})_6]^{4-}$	$[\text{Fe}(\text{CN})_6]^{3-}$
A.	-4	-3
B.	+2	+3
C.	+3	+2
D.	-3	-4

6. Consider the following reactions.

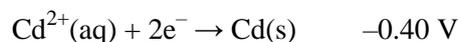
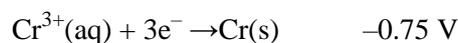


Which statement is correct?

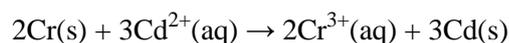
- A. $\text{Cu}^{2+}(\text{aq})$ will oxidize both $\text{Mg}(\text{s})$ and $\text{Zn}(\text{s})$.
- B. $\text{Zn}(\text{s})$ will reduce both $\text{Cu}^{2+}(\text{aq})$ and $\text{Mg}^{2+}(\text{aq})$.
- C. $\text{Mg}^{2+}(\text{aq})$ will oxidize both $\text{Cu}(\text{s})$ and $\text{Zn}(\text{s})$.
- D. $\text{Cu}(\text{s})$ will reduce both $\text{Mg}^{2+}(\text{aq})$ and $\text{Zn}^{2+}(\text{aq})$.



7. Consider the standard electrode potentials of the following reactions.



What is the value of the cell potential (in V) for the following reaction?



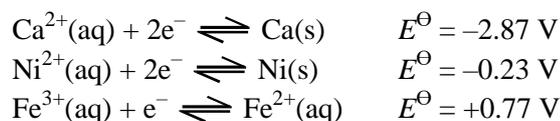
- A. -0.35
B. -1.15
C. $+0.30$
D. $+0.35$
8. Aqueous solutions containing different concentrations of NaCl were electrolysed using platinum electrodes. What is the **major** product at the positive electrode in each case?

	$0.001 \text{ mol dm}^{-3} \text{ NaCl}(\text{aq})$	$1.0 \text{ mol dm}^{-3} \text{ NaCl}(\text{aq})$
A.	H_2	Na
B.	H_2	H_2
C.	O_2	Cl_2
D.	Cl_2	O_2

9. Which is a feature of the standard hydrogen electrode?
- A. hydrogen gas at $1.01 \times 10^5 \text{ Pa}$ (1 atm) pressure
B. 1.0 mol dm^{-3} sulfuric acid
C. a temperature of 273 K
D. a magnesium electrode
10. Which pair of factors both affect the amount (in mol) of chlorine produced in the electrolysis of aqueous sodium chloride?
- A. current and temperature
B. temperature and chloride ion concentration
C. chloride ion concentration and length of time of electrolysis
D. pressure and length of time of electrolysis



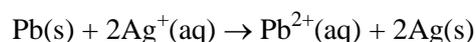
11. From the given standard electrode potentials which statement is correct?



- A. $\text{Ca}^{2+}(\text{aq})$ can oxidize $\text{Ni}(\text{s})$
- B. $\text{Ni}^{2+}(\text{aq})$ can reduce $\text{Ca}^{2+}(\text{aq})$
- C. $\text{Fe}^{3+}(\text{aq})$ can oxidize $\text{Ni}(\text{s})$
- D. $\text{Fe}^{3+}(\text{aq})$ can reduce $\text{Ca}^{2+}(\text{aq})$
12. Which statement is correct about the electrolysis of copper(II) sulfate solution using graphite electrodes?
- A. A colourless gas is produced at the negative electrode.
- B. The electrolyte does not change colour.
- C. The negative electrode decreases in mass.
- D. A colourless gas is produced at the positive electrode.
13. A metallic object is electroplated with copper using a solution of copper(II) sulfate. Which statement is correct?
- A. The positive electrode increases in mass.
- B. The concentration of Cu^{2+} ions in the solution decreases.
- C. Reduction occurs at the positive electrode.
- D. The reaction occurring at the negative electrode is $\text{Cu}^{2+} + 2\text{e}^{-} \rightarrow \text{Cu}$.
14. Two half-equations and their standard electrode potentials are shown in the table.

Half-equation	E^{\ominus} / V
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{Pb}(\text{s})$	-0.13
$\text{Ag}^{2+}(\text{aq}) + \text{e}^{-} \rightleftharpoons \text{Ag}(\text{s})$	+0.80

What is the cell potential, in V, for the reaction below?



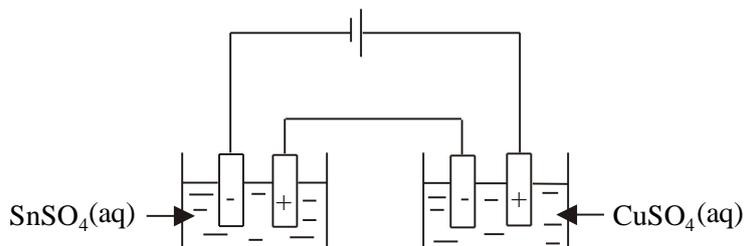
- A. 0.67
- B. 0.93



C. 1.47

D. 1.73

15. Two electrolytic cells are connected in series so that the same current flows through both cells for the same length of time.



The amount of tin deposited is 0.01 mol. How much copper is deposited?

A. 0.005 mol

B. 0.01 mol

C. 0.02 mol

D. 0.05 mol

16. Which are used for the electroplating of a metal spoon with copper?

I. an electrolyte containing aqueous copper(II) ions

II. a copper anode (positive electrode)

III. a copper cathode (negative electrode)

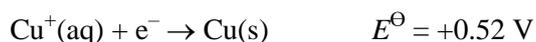
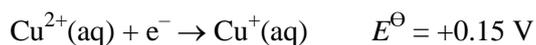
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

17. Consider these standard electrode potentials.



What is the standard cell potential when the two half-cells are connected?

A. -0.67 V

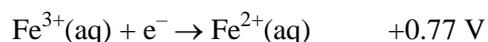
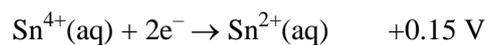
B. -0.37 V

C. $+0.37 \text{ V}$



D. + 0.67 V

18. Consider the standard electrode potentials of the following reactions:



What is the value of the cell potential (in volts) for the spontaneous reaction?

A. +1.69

B. +1.39

C. +0.92

D. +0.62

19. In the electrolysis of acidified water, if 8.4 cm^3 of hydrogen gas is evolved, what volume of oxygen gas is evolved?

A. 4.2 cm^3

B. 8.4 cm^3

C. 12.6 cm^3

D. 16.8 cm^3

20. Which factors affect the amount of metal formed during electrolysis?

I. Charge on the metal ion

II. Current

III. Time

A. I and II only

B. I and III only

C. II and III only

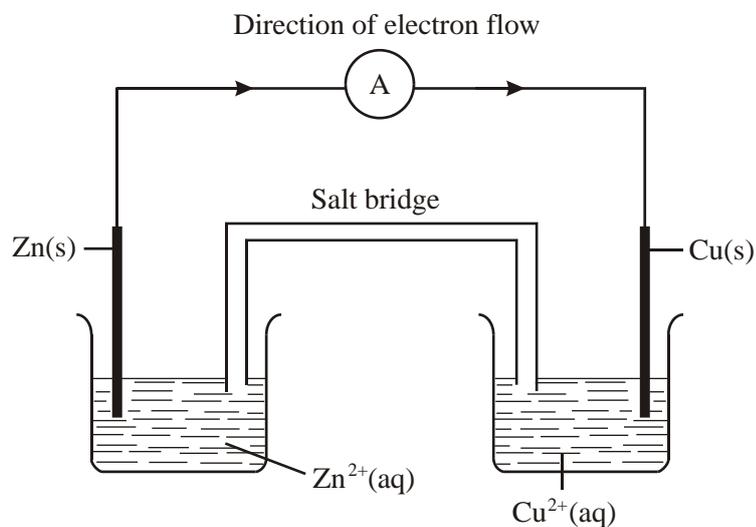
D. I, II and III



21. Which changes lead to the production of more moles of metal during the electrolysis of a molten salt?
- I. using a metal ion with a higher charge
 - II. increasing the current
 - III. using a longer time
- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III
22. Which equation represents the reduction process occurring in the standard hydrogen electrode?
- A. $\text{H}_2(\text{g}) \rightarrow 2\text{H}^+(\text{aq}) + 2\text{e}^-$
 - B. $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$
 - C. $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$
 - D. $\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l})$
23. Which statement is correct about the value of E^\ominus ?
- A. The more positive the value of E^\ominus , the greater the driving force for reduction.
 - B. The more negative the value of E^\ominus , the greater the driving force for reduction.
 - C. The more positive the value of E^\ominus , the greater the rate of reaction.
 - D. The more negative the value of E^\ominus , the greater the rate of reaction.



24.



(a) The apparatus shown above may be used to carry out a redox reaction.

(i) State the function of the salt bridge.

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(1)

(ii) Write a half-equation for the oxidation reaction.

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(1)

(iii) The above reactions are carried out under *standard conditions*. State what the standard conditions are for the cell.

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(2)

(iv) Using the Data Booklet, calculate the cell potential for the above cell.

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..... (2)

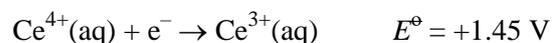
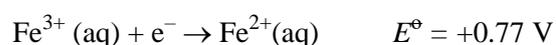
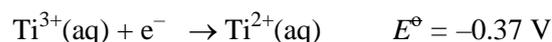
- (v) State and explain what happens to the concentration of the copper(II) ions when the cell is producing an electric current.

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..... (2)

- (vi) State **two** observations that could be made if the zinc rod were placed in a solution of copper(II) ions.

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..... (2)

- (b) The standard electrode potentials for three electrode systems are given below.



- (i) Using the data above, deduce which species is the best reducing agent, giving a reason in terms of electrons for your answer.

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..... (2)

- (ii) Write an equation, including state symbols, for the overall reaction with the greatest cell potential.

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..... (2)

- (iii) State and explain the sign of ΔG° for the reaction in (b) (ii).

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..... (2)



- (c) (i) State the name of a solution that would produce **only** hydrogen and oxygen when electrolyzed using platinum electrodes.

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(1)

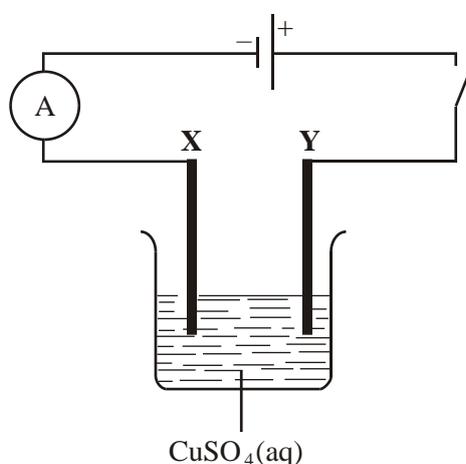
- (ii) Draw a diagram of apparatus that would allow the gases produced in the reaction in (c) (i) to be collected separately. Annotate your diagram to show the polarity of each electrode and the names and relative volumes of each gas.

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(3)

(Total 20 marks)

25.



Two copper strips **X** and **Y** are placed in an aqueous solution of copper(II) sulfate and electrolyzed for a certain time. **X** was then dried and weighed.

- (i) State and explain what would happen to the mass of **X**.

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(3)

- (ii) State **two** ways in which the change in the mass of **X** could be increased.

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(2)



(Total 5 marks)

26. (a) Some standard electrode potentials are shown in Table 15 of the Data Booklet.

(i) State three conditions under which the hydrogen electrode is assigned a potential of zero.

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(3)

(ii) Calculate the cell potential of a cell made by connecting standard copper and zinc electrodes. State the direction of electron flow in the external circuit when the cell produces current. Outline the changes occurring at the electrodes and in the solutions during the process.

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(5)

(b) Using information from Table 15, determine whether or not there is a spontaneous reaction between copper metal and a solution containing hydrogen ions.

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(2)

(c) Using information from Table 15, identify a substance that will oxidize bromide ions but not chloride ions. Explain your choice, and write an equation for the redox reaction you have chosen.

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(5)

(Total 15 marks)

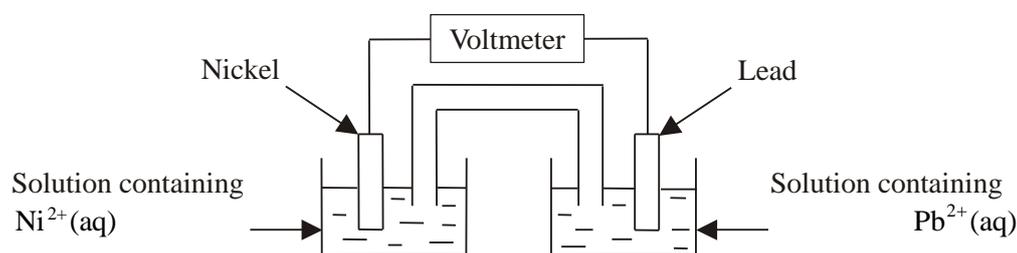


27. (a) In one experiment involving the electrolysis of molten sodium chloride, 0.1 mol of chlorine was formed. Deduce, giving a reason, the amount of sodium formed at the same time. (2)
- (b) In another experiment involving the electrolysis of molten sodium chloride, the time of the electrolysis was halved and the current increased from 1 amp to 5 amp, compared to the experiment in (a). Deduce the amount of chlorine formed, showing your working. (2)
- (c) If dilute aqueous sodium chloride is electrolyzed, a different product is obtained at each electrode. Identify the product formed at each electrode and write an equation showing its formation. (4)
- (Total 8 marks)

28. Define the term *standard electrode potential* of an element. Table 15 of the Data Booklet contains E^\ominus values for two reactions involving $O_2(g)$. Identify the E^\ominus value of the reaction that could be used to oxidize bromide ions and explain your reasoning. Construct a balanced equation for the oxidation of bromide ions using this reaction and calculate the cell potential. (Total 8 marks)

29. Use information from Table 15 of the Data Booklet, where relevant, in answering this part.

- (i) The diagram shows the apparatus used in an experiment involving half-cells.



The reading on the voltmeter is 0.10 V. State **two** standard conditions that apply for this reading to be obtained. (2)

- (ii) The voltmeter is replaced by a 2 volt power supply, so that non-spontaneous reactions occur. Deduce the half-equations for these reactions. (2)
- (iii) Chlorine gas is formed when potassium manganate(VII) is added to concentrated hydrochloric acid. Calculate the cell potential for this reaction and deduce the equation



for the reaction.

(3)

- (iv) Explain why potassium dichromate(VI) does not react with concentrated hydrochloric acid.

(1)

(Total 8 marks)

30. (a) When a concentrated aqueous solution of sodium chloride is electrolyzed using inert electrodes, a different gas is produced at each electrode.

- (i) Write equations for the oxidation and reduction half-reactions.

Oxidation half-reaction:

.....

Reduction half-reaction:

.....

(2)

- (ii) Explain why sodium is not formed during the electrolysis of aqueous NaCl solution.

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(1)

- (b) Deduce the products formed during the electrolysis of an aqueous solution of sodium fluoride. Write an equation for the reaction at the positive electrode (the anode) and give your reasoning.

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(4)

(Total 7 marks)



31. The following are standard electrode potentials.

Half-equation	E^\ominus / V
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Cr}(\text{s})$	-0.74
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$	-0.44
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$	-0.14
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77

(a) These values were obtained using a standard hydrogen electrode. Describe the materials and conditions used in the standard hydrogen electrode. (A suitably labelled diagram is acceptable.)

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(5)

(b) Define the term *oxidizing agent* in terms of electron transfer and identify the strongest oxidizing agent in the list above.

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(2)

(c) A cell was set up using zinc in zinc sulfate solution and copper in copper(II) sulfate solution, both solutions being under standard conditions.

(i) Calculate the cell potential.

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..... (1)

(ii) Write an equation for the spontaneous cell reaction.

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.....
..... (2)

(d) Both zinc and tin are used to coat iron to prevent it from rusting. Once the surface is scratched, oxygen and water containing dissolved ions come into contact with the iron and the coating metal.

(i) State and explain whether zinc or tin would be more effective in preventing iron from rusting under these conditions.

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..... (2)

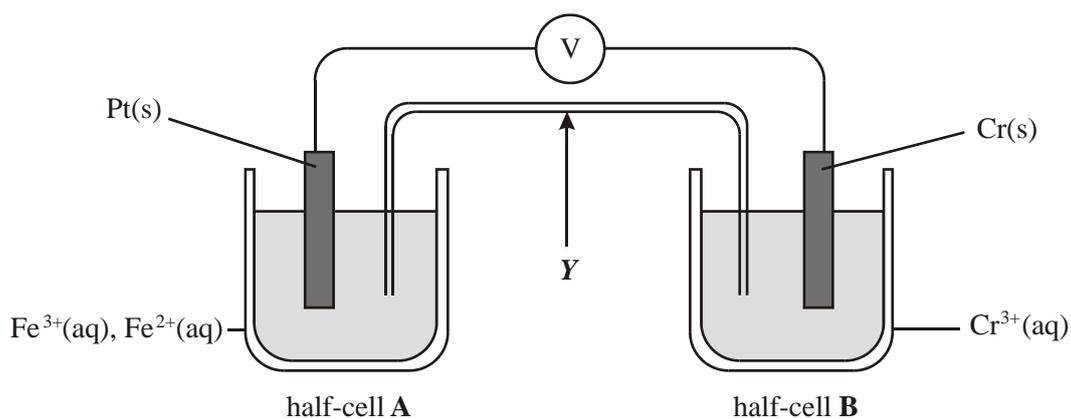
(ii) Electroplating may be used to coat one metal with another metal. Identify the **three** factors affecting the amount of metal discharged during electroplating.

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..... (3)

(iii) Explain why electrolysis of aqueous zinc sulfate is not used for coating with zinc metal.

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..... (2)

(e) Another cell was set up as shown below.



(i) Identify the part of the cell labelled *Y* and outline its function.

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(2)

(ii) Write an equation for the initial reactions at each electrode and hence write an equation for the cell reaction.

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(4)

(iii) Describe the direction of electron flow in the external circuit.

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(1)

(iv) Calculate the cell potential.

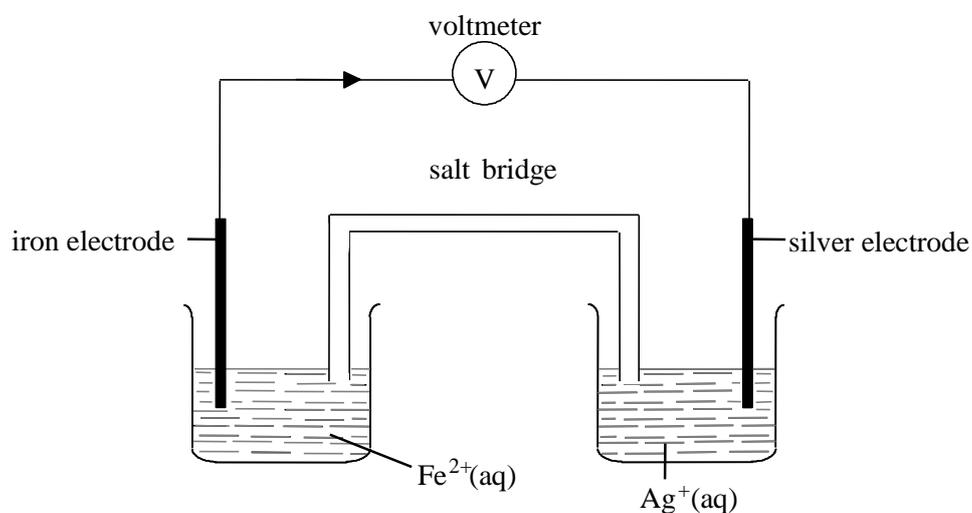
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(1)

(Total 25 marks)



32. The following diagram shows a voltaic cell.



(a) State an equation to represent the spontaneous reaction occurring in the cell.

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(1)

(b) Define the term *standard electrode potential*.

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(1)

(c) Use Table 15 from the Data Booklet to calculate the standard cell potential for the spontaneous reaction in (a).

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(1)

(d) Draw arrows on the above diagram to indicate the direction of electron flow.

(1)

(Total 4 marks)

33. (a) Iodide ions, $\text{I}^-(\text{aq})$, react with iodate ions, $\text{IO}_3^-(\text{aq})$, in an acidic solution to form molecular iodine and water.



(i) Determine the oxidation number of iodine in I^- and in IO_3^- .

..... (1)

(ii) Identify, with a reason, the species that undergoes:

oxidation

.....

reduction

.....

(2)

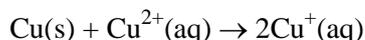
(iii) Write an ionic equation for the reaction of I^- with IO_3^- in an acidic solution.

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(2)

(b) Use information from Table 15 of the Data Booklet to calculate the cell potential for the following reaction and state whether or not the reaction is spontaneous.



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(3)

(Total 8 marks)

34. A table of standard electrode potentials can be found in Table 14 of the Data Booklet.

(a) Describe the materials and conditions used in the standard hydrogen electrode.

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(5)

(b) Define the term *oxidizing agent* in terms of electron transfer and identify the strongest oxidizing agent in Table 14 of the Data Booklet.



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(2)

(c) A cell was set up using tin in tin(II) sulfate solution and copper in copper(II) sulfate solution, with both solutions under standard conditions.

(i) Calculate the cell potential.

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(1)

(ii) Write an equation for the spontaneous cell reaction.

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(2)

(Total 10 marks)