# Electrolysis, Electrode Potentials & Cells

## Question Paper 6

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|---|---|
| **Level** | International A Level |
| **Subject** | Chemistry |
| **Exam Board** | CIE |
| **Topic** | Electrochemistry |
| **Sub-Topic** | Electrolysis, Electrode Potentials & Cells |
| **Paper Type** | Theory |
| **Booklet** | Question Paper 6 |

**Time Allowed:** **64 minutes**

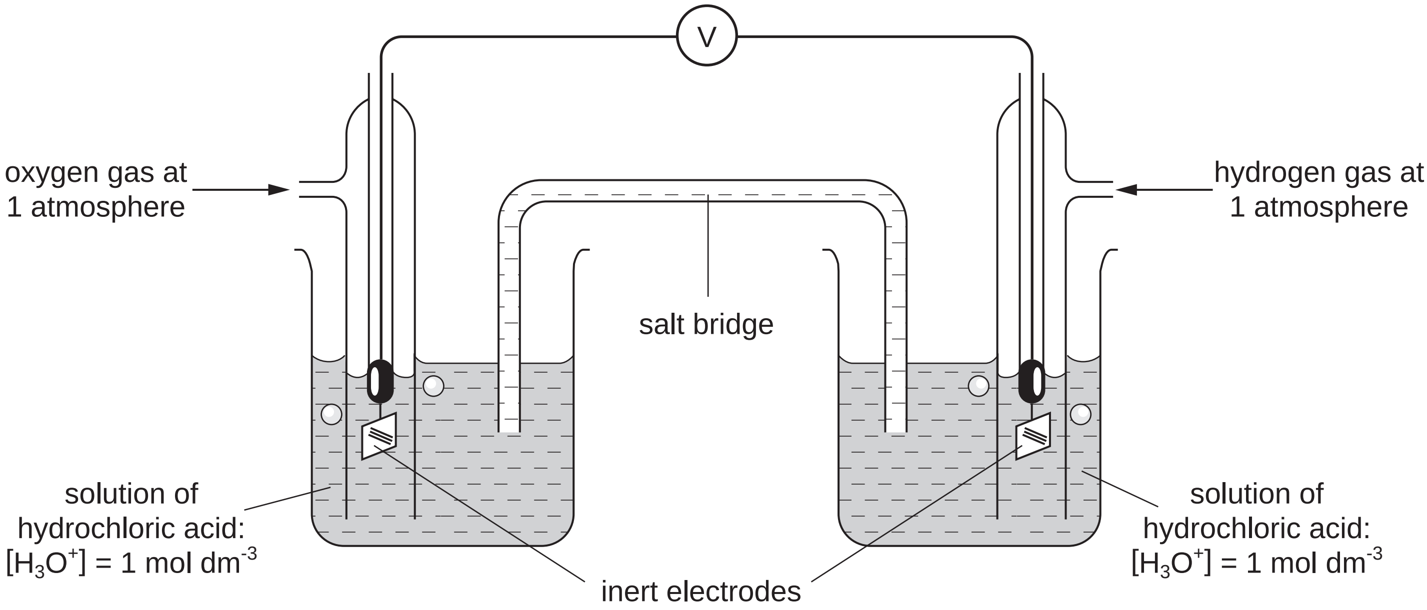
**Score:** **/53**

**Percentage:** **/100**

**Grade Boundaries:**

| A* | A | B | C | D | E | U |
|---|---|---|---|---|---|---|
| >85% | 777.5% | 70% | 62.5% | 57.5% | 45% | <45% |

**1** The diagram shows a laboratory illustration of a simple hydrogen-oxygen fuel cell.




**(a)** Write the half equation for the reaction occurring at the left hand (oxygen) electrode when the cell operates.

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**(b)** State the polarity (+ or –) of the left hand (oxygen) electrode. .................................... [1]

**(c)** Use the *Data Booklet* to calculate the voltage produced by this cell.

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**(d)** Only a very small current can be drawn from this laboratory cell. Suggest **one** way in which it could be modified to enable a larger current to be drawn from it.

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**(e)** A fuel cell in an orbiting satellite is required to produce a current of 0.010 A for 400 days. Calculate the mass of hydrogen that will be needed.

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.......................................................................................................................... [3]

**(f)** State **one** advantage, and **one** disadvantage of using fuel cells to power road vehicles compared to hydrocarbon fuels such as petrol.

advantage: ..........................................................................................................

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disadvantage: ......................................................................................................

.................................................................................................................... [2]

[Total: 9]

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

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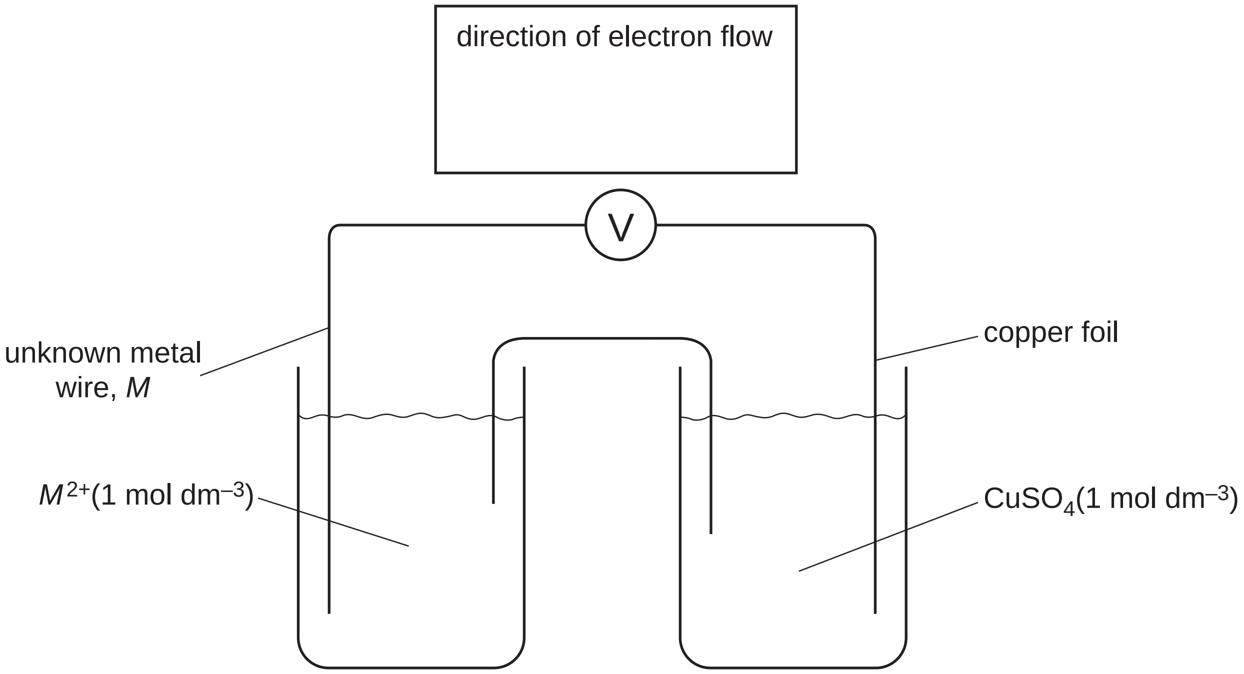
**(b)** The following cell was set up between a copper electrode and an unknown metal electrode $M^{2+}$(aq) / $M$(s). The standard cell potential was found to be 0.76 V, and the copper foil was the positive electrode.




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

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**(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 mol dm$^{-3}$ $CuSO_4$.

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

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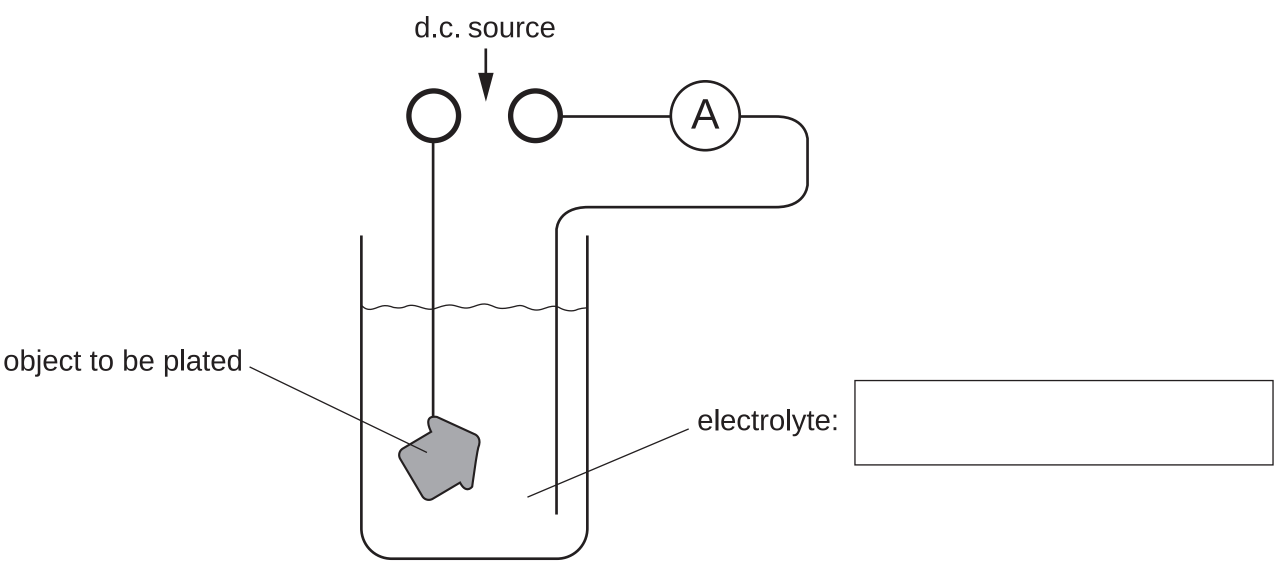
[6]

**(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.

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[5]

[Total : 13]

**3** **(a)** Chemists recognise that atoms are made of three types of particle.

Complete the following table with their names and properties.

| name of particle | relative mass | relative charge |
|---|---|---|
| | | +1 |
| | 1/1836 | |
| | | |

[3]

**(b)** Most elements exist naturally as a mixture of isotopes, each with their own relative isotopic mass. The mass spectrum of an element reveals the abundances of these isotopes, which can be used to calculate the relative atomic mass of the element.

Magnesium has three stable isotopes. Information about two of these isotopes is given.

| isotope | relative isotopic mass | percentage abundance |
|---|---|---|
| $^{24}Mg$ | 24.0 | 79.0 |
| $^{26}Mg$ | 26.0 | 11.0 |

**(i)** Define the term *relative isotopic mass*.

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**(ii)** The relative atomic mass of magnesium is 24.3.

Calculate the percentage abundance and hence the relative isotopic mass of the third isotope of magnesium. Give your answer to **three** significant figures

percentage abundance = ................................

isotopic mass = ................................
[3]

**(c)** Magnesium can be produced by electrolysis of magnesium chloride in a molten mixture of salts.

**(i)** Give equations for the anode and cathode reactions during the electrolysis of molten magnesium chloride, $MgCl_2$.

anode ..............................................................................................................

cathode ..............................................................................................................
[2]

The electrolysis is carried out under an atmosphere of hydrogen chloride gas to convert any magnesium oxide impurity into magnesium chloride.

**(ii)** An investigation of the reaction between magnesium oxide and hydrogen chloride gas showed that an intermediate product was formed with the composition by mass Mg, 31.65%; O, 20.84%; H, 1.31% and Cl, 46.20%.

Calculate the empirical formula of this intermediate compound.

empirical formula ................................... [2]

**(d)** The acid/base behaviour of the oxides in the third period varies across the period.

**(i)** Describe this behaviour and explain it with reference to the structure and bonding of sodium oxide, $Na_2O$, aluminium oxide, $Al_2O_3$, and sulfur trioxide, $SO_3$.

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**(ii)** Write equations for reactions of these three oxides with hydrochloric acid and/or sodium hydroxide as appropriate.

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[Total: 18]

**4** **(a)** Silver sulfate, $Ag_2SO_4$, is sparingly soluble in water. The concentration of its saturated solution is $2.5 \times 10^{-2}\,mol\,dm^{-3}$ at 298 K.

**(i)** Write an expression for the solubility product, $K_{sp}$, of $Ag_2SO_4$, and state its units.

$K_{sp}$ =

units: .............................. [1]

**(ii)** Calculate the value for $K_{sp}(Ag_2SO_4)$ at 298 K.

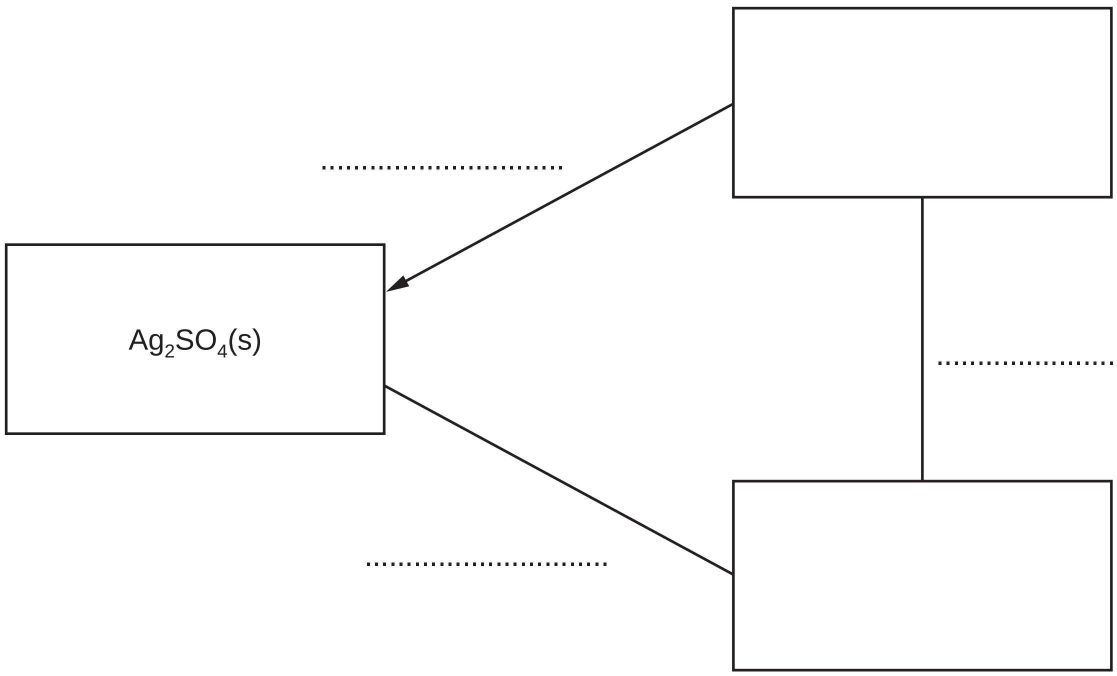
$K_{sp}$ = .............................................. [1]

**(b)** Using $Ag_2SO_4$ as an example, complete the following Hess' Law energy cycle relating the

- lattice energy, $\Delta H^{\ominus}_{latt}$,
- enthalpy change of solution, $\Delta H^{\ominus}_{sol}$, and
- enthalpy change of hydration, $\Delta H^{\ominus}_{hyd}$.

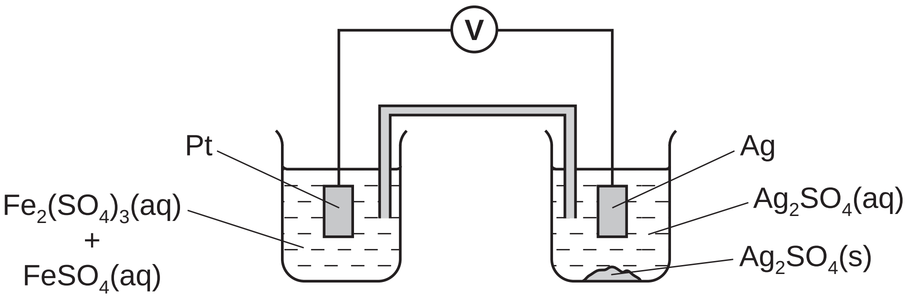
On your diagram:

- include the relevant species in the two empty boxes,
- label each enthalpy change with its appropriate symbol,
- complete the remaining two arrows showing the correct direction of enthalpy change.




[4]

**(c)** An electrochemical cell is set up as follows.




**(i)** Use the *Data Booklet* to calculate the value of $E^{\ominus}_{cell}$ under standard conditions, stating which electrode is the positive one.

$E^{\ominus}_{cell}$ = ............................. positive electrode: ............................. [1]

**(ii)** How would the actual $E_{cell}$ of the above cell compare to the $E^{\ominus}_{cell}$ under standard conditions? Explain your answer.

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**(iii)** How would the $E_{cell}$ of the above cell change, if at all, if a few $cm^3$ of concentrated $Na_2SO_4(aq)$ were added to

- the beaker containing $Fe^{3+}(aq) + Fe^{2+}(aq)$,

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- the beaker containing $Ag_2SO_4(aq)$?

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[2]

**(iv)** Explain any changes in $E_{cell}$ you have stated in **(iii)**.

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............................................................................................................................. [1]

**(d)** Solutions of iron(III) sulfate are acidic due to the following equilibrium.

$$[Fe(H_2O)_6]^{3+}(aq) \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+}(aq) + H^+(aq) \qquad K_a = 8.9 \times 10^{-4}\,mol\,dm^{-3}$$

Calculate the pH of a $0.1\,mol\,dm^{-3}$ solution of iron(III) sulfate, $Fe_2(SO_4)_3$.

pH = ........................
[2]

[Total: 13]