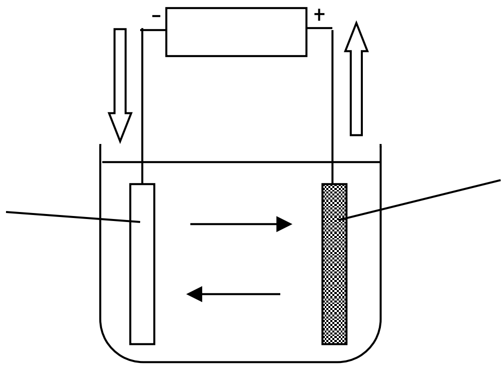
# Oxidation & Reduction - 3. - Class Worksheet

## 1. Electrolytic cells

During electrolysis, electricity is used to make a .................................................... redox reaction occur. In this process, ...................................... energy is converted to ....................................... energy. (In an electrochemical cell, ....................................... energy is converted to ..................................... energy.)

In an electrolytic cell, the ................................ electrode is the one connected to the negative terminal of the external power source. .................................... that are pushed into this electrode by the power source react with chemicals in the cell. That is, a ................................. reaction occurs at the negative electrode, which means this electrode is the ................................... . Normally, the strongest ...................................... present in the cell reacts at the cathode or negative electrode.




The ................................ electrode is the one connected to the positive terminal of the external power source. .................................. are formed at this electrode and they then move from this electrode back to the power source. That is, an ................................. reaction occurs at the positive electrode, which means this electrode is the ................................... . Normally, the strongest ...................................... present in the cell reacts at the anode or positive electrode.

In the internal part of the circuit, the current is due to the movement of ................................... and ........................... ............................ in the electrolyte. In the above cell, the negative ions will move towards the ........................ hand side electrode i.e. the ................................. electrode and the positive ions will move towards the ............................... electrode.

In an electrolytic cell, because the oxidant and reductant do not react spontaneous, there is no need to put them in ....................................... sections of the cell.

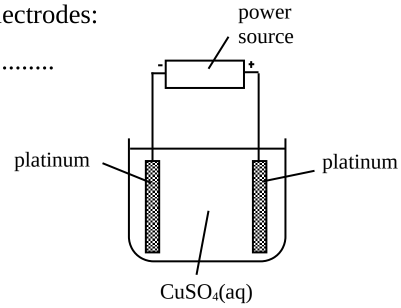
For example

- when electricity is passed through a solution of copper sulfate, using platinum electrodes:
  - at the <u>negative electrode</u> (the ..........................) the strongest ................................. is reduced.

    The oxidants present are ......................... and ............................, with the strongest being ...................................

    The reaction that occurs at the cathode is therefore

    ........................................................................................




  - at the <u>positive electrode</u> (the ..........................) the strongest ................................. is oxidised.

    The reductant present is .........................

    The reaction that occurs at the anode is therefore ........................................................................................

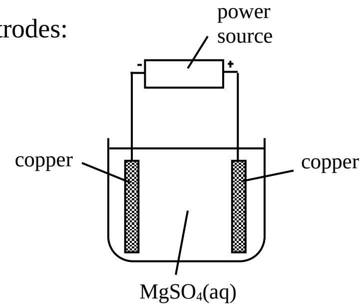
The overall reaction will be ...............................................................................................

The voltage required to make this reaction occur is determined by subtracting the smaller E° from the larger E° i.e.

.......................................................... = ................................

Within the solution, the ........................... ions will move towards the left and the .............................. ions will move towards the right.

- when electricity is passed through a solution of magnesium sulfate, using copper electrodes:




- at the <u>negative electrode</u> (the ..........................) the strongest .................................. is reduced.

The oxidants present are ......................... and ............................., with the strongest being ....................................

The reaction that occurs at the cathode is therefore

.........................................................................................

- at the <u>positive electrode</u> (the ..........................) the strongest .................................. is oxidised.

The reductants present are ......................... and ............................., with the strongest being ....................................

The reaction that occurs at the anode is therefore .........................................................................................

The overall reaction will be ...............................................................................................

The minimum voltage required to make this reaction occur is .......................................... = ................................

Within the solution, the ........................... ions will move towards the left and the .............................. ions will move towards the right.

(Your E° table contains two half equations for water acting as an oxidant and for water acting as a reductant. The *equations and E° values given in italics refer to* .............................. *solutions*, the non-italicised equations and E° values refer to the substances being present as 1 mol $L^{-1}$ solutions.)

E° values can not always be used to accurately predict the reactions that will occur in an electrolysis cell. For example, when an electric current is passed through a solution of **sodium chloride**, the predicted reactions are:

anode: .........................................................................................

cathode: .........................................................................................

However, at the ........................................, the ...................... ions react instead of ................................, to give an electrode reaction of .............................................................

## 2. Electrolysis of molten substances

If an ionic substance is melted, it ...................... conduct electricity and so can act as the ................................ in an electrolysis cell.

For example, when electric current is passed through molten calcium chloride, using graphite as the electrodes, because the only two ions present are .............................. and ................................, they undergo reaction:

anode half equation:

cathode half equation:

overall equation:

(Note: metals with E° values .......................... than approx 0.8 volts must be prepared by electrolysis of the appropriate molten salt. Electrolysis of an aqueous solution of the salt does not produce the metal because..........................................
............................................................................................................................................ )

**3. The extraction of aluminium**

The extraction of aluminium involves two major processes:

a) purification of the ore to produce pure .......................... ...................... (or ......................) - the Bayer process

b) ..................................... of aluminium oxide (.......................) to produce aluminium - the Hall-Héroult Process

(Note: hydrated aluminium oxide $Al_2O_3.3H_2O$ = aluminium hydroxide $Al(OH)_3$
alumina = aluminium oxide, $Al_2O_3$
bauxite = aluminium-containing ore = impure hydrated aluminium oxide )

## Bayer Process

**ORE** (Bauxite) -
.............. + impurities of mainly $Fe_2O_3$ and $SiO_2$

added to ...................... solution and heated

Purpose:

Chemistry:

solution containing ...................
plus insoluble $Fe_2O_3$ + $SiO_2$

mixture allowed to .......................,
then .......................

Purpose:

insoluble "red mud"
$Fe_2O_3$ + $SiO_2$

hot, concentrated solution
of ........................

cooled then .....................................
of $Al(OH)_3$ added

Purpose:

Chemistry:

crystals of ................

crystals filtered off, and .......................
to approx ...................ºC

Purpose:

Chemistry:

pure .............. (alumina)

## Hall-Héroult Process

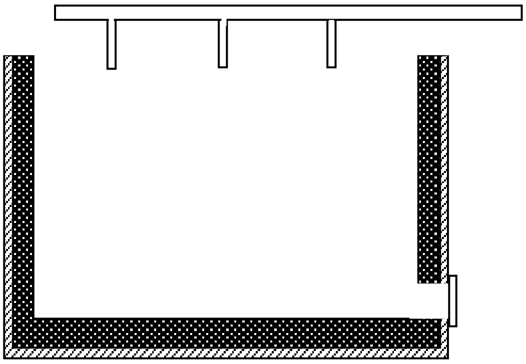
The purpose of this process is to produce ............................................. from ............................................ .

Electrolysis is used as the method of reduction because ................................................................................................

.......................................................................................................................

Electrolysis of a molten mixture rather than electrolysis of an aqueous solution containing aluminium ions because

..................................................................................................................................................................



**4. Electrorefining of copper**

The process involves producing 99% pure copper from 98% pure 'blister' copper by using an ..........................................
.....................................

The main impurities in the blister copper are metals that are .................................. reactive than copper, such as iron and zinc together with metals that are less reactive, such as .................................. and ..............................

The anode is the .............................. .................................. and the cathode is a ......................... ............................ of ......................... ............................. The electrolyte is an ................................. .............................. ................................ solution.

At the **anode** - the main reaction is ......................................................................................

- also the ...................... reactive metals...........................................................
  - e.g. .......................................................................
- the ................................. reactive metals ..............................................................................................

At the **cathode** - the main reaction is ..........................................................................

- by controlling the ................................... the ...................... and ...................... ions do not react to reform the metal.

5. Properties and uses of copper and aluminium

| Property | Aluminium | Zinc | Copper |
|---|---|---|---|
| Colour<br>Conduction<br>Malleablity<br>Density<br>General reactivity<br>Redox properties<br>Reaction with $O_2$<br>Reaction with water<br>Reaction with acid | | | |

| | | | |
|---|---|---|---|
| Reaction with $OH^-$<br><br>Colour of compounds<br><br>Reactions of ions<br><br>Uses | | | |

## 6. Electroplating

Metals are often electroplated with other metals such as ............................ and ............................ to produce a b................................. appearance as well as providing a physical barrier to ......................................
In silver plating, the anode is made of .......................... .................................... , the cathode is the .................................. to be .................................... and the electrolyte used contains ............................ ............................... and potassium ....................................... . In this solution, the following equilibrium exists:

..............................................................................................................

This equilibrium lies strongly towards the ....................... and keeps the concentration of ..................... ions low. The low concentration of .............. ions is important in ensuring that an ............................ deposit of ........................ metal forms on the .......................... to be ................................
The cathode reaction is ...................................................................
The anode reaction is ..................................................................................

## 7. Quantitative aspects of electrolysis

The number of moles of electrons generated by a cell is related to the ........................................ involved in the cell and the .............................................. this current flows for:

moles of electrons generated by a cell = =

where the current is measured in ....................... and the time in .............................

The number $9.649 \times 10^4$ is called ........................ ...............................and it is a measure of the amount of charge (in coulombs) carried by .......... ........................... of electrons.

"Current x time" is equivalent to the amount of .....................................passed by/into the cell where the amount of charge is in ..........................., the current in .........................., and the time in .....................................

For example:

If an aqueous solution of hydrochloric acid is electrolysed with a current of 0.600 amps for 3.00 minutes, how many moles of electrons passed into the cell?

Once the number of moles of electrons passed through an electrolytic cell, or generated by an electrochemical cell, is known, then the number of moles of substances reacted or formed in the cell reactions can be calculated. These can be calculated from the electrode ............................ .................................... which relates the number of moles of .......................... to the number of moles of substance.

For example:

1. An aqueous solution of nickel sulfate was electrolysed with a current of 1.20 amps for 10.0 minutes. Calculate the mass of copper deposited on the cathode.

2. A current was passed through two cells in series. The first cell contained a solution of silver nitrate and the second cell contained a solution of copper nitrate. If 0.477 g of silver was deposited on the cathode in the first cell, what mass of copper would have been deposited on the cathode in the second cell?

5. Properties and uses of copper and aluminium

| Property | Aluminium | Zinc | Copper |
|---|---|---|---|
| Colour | silver | silver | orange |
| Conduction | good conductor | good conductor | good conductor |
| Malleablity | malleable | malleable | malleable |
| Density | not very dense for a metal | normal for metal | normal for metal |
| General reactivity | should be very reactive but protected by oxide layer | quite reactive<br>$2Zn + O_2 \rightarrow 2ZnO$ | not reactive |
| Redox properties | strong reductant | rather strong reductant | weak reductant |
| Reaction with $O_2$ | reacts very readily to produce 'strong' layer of oxide<br>$4Al + 3O_2 \rightarrow 2Al_2O_3$ | reacts readily to produce oxide<br>$2Zn + O_2 \rightarrow 2ZnO$ | not react |
| Reaction with water | protected by oxide layer, but reacts with steam<br>$2Al + 3H_2O(g) \rightarrow Al_2O_3 + 3H_2$ | not react with water, but reacts with steam<br>$Zn + H_2O(g) \rightarrow ZnO + H_2$ | not react with water or steam |
| Reaction with acid | protected by oxide layer - only reacts with hydrochloric acid<br>$2Al + 6H^+ \rightarrow 2Al^{3+} + 3H_2$ | reacts with acids<br>conc nitric $\rightarrow NO_2$<br>dil nitric $\rightarrow NO$<br>conc sulfuric $\rightarrow SO_2$<br>hydrochloric, dilute sulfuric $\rightarrow H_2$ | only reacts with<br>conc nitric $\rightarrow NO_2$<br>conc sulfuric $\rightarrow SO_2$ |
| Reaction with $OH^-$ | amphoteric,so reacts<br>$2Al + 2OH^- + 6H_2O \rightarrow 2Al(OH)_4^- + 3H_2$ | amphoteric,so reacts<br>$Zn + 2OH^- + 2H_2O \rightarrow Zn(OH)_4^{2-} + H_2$ | not react |
| Colour of compounds | colourless | colourless | blue |
| Reactions of ions | oxide and hydroxide are amphoteric<br>$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$<br>$Al(OH)_3 + OH^- \rightarrow Al(OH)_4^-$ | oxide and hydroxide are amphoteric<br>$ZnO + 2OH^- + H_2O \rightarrow Zn(OH)_4^{2-}$<br>$Zn(OH)_2 + 2OH^- \rightarrow Zn(OH)_4^{2-}$<br>react with ammonia solution to form complex ion<br>$Zn^{2+} + 4NH_3 \rightarrow Zn(NH_3)_4^{2+}$ | react with ammonia solution to form complex ion<br>$Cu^{2+} + 4NH_3 \rightarrow Cu(NH_3)_4^{2+}$ |
| Uses | | | |

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|---|---|---|---|
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