Electricity & Chemistry

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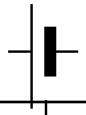
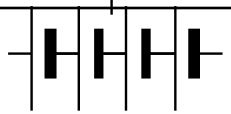
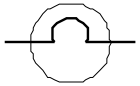
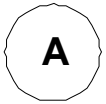
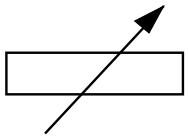
Simple Electrical Devices and Circuit Symbols

Electrical Device	*Circuit Symbol*	*Function*
Cell		*Source of electricity*
Battery		*A collection of cells*
Bulb		*To register whether electricity is flowing*
Switch		*To start or stop flow of electricity*
Ammeter		*Measure amount of current*
Voltmeter		*Measure voltage of cells*
Rheostat		*Ensure suitable, constant current of electricity is flowing*

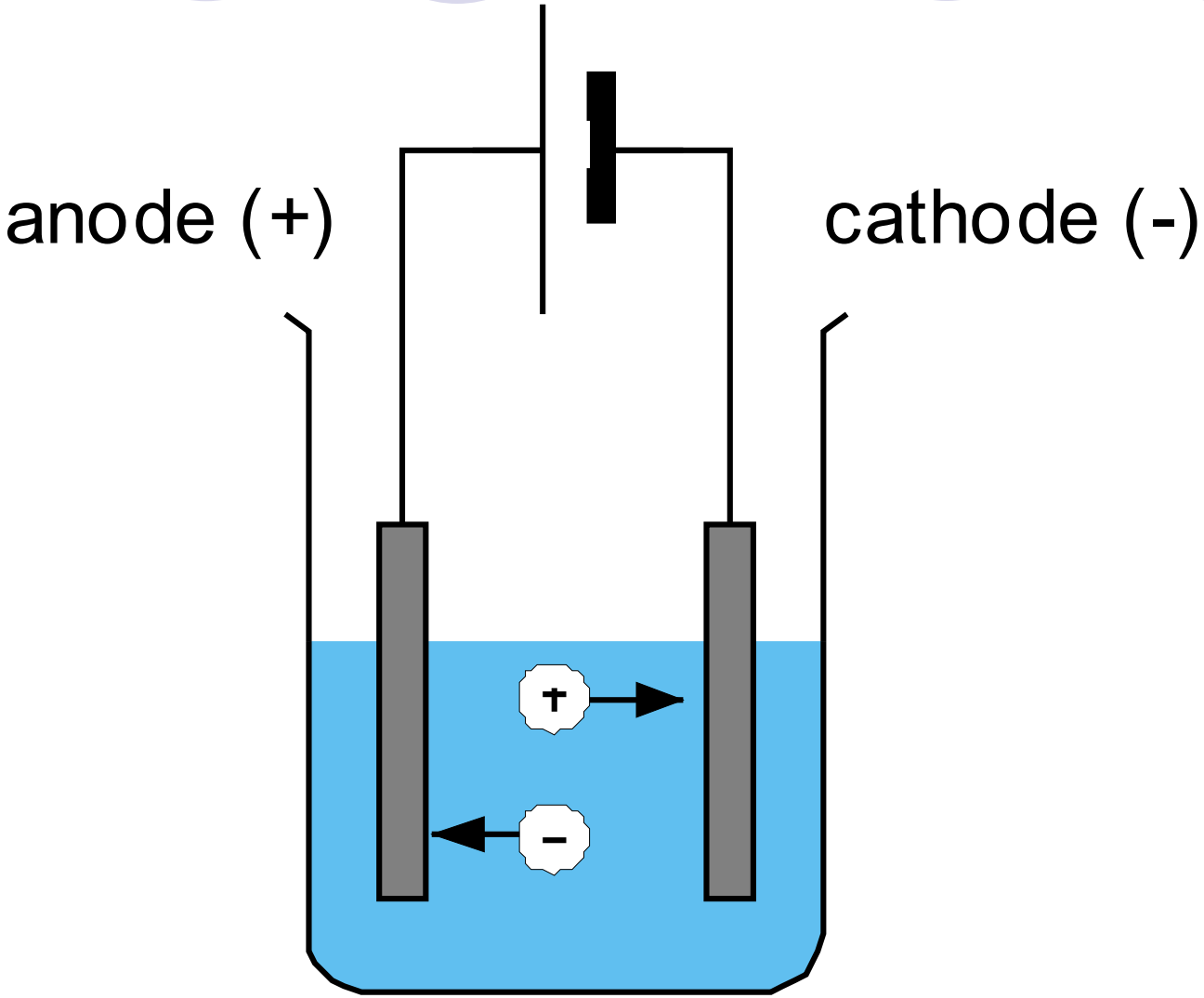
Electrolysis

- Electricity is passed from a battery through a liquid which may be a solution/molten solid.
- The plates which carry the electricity into the liquid are called electrodes
- Molten ionic compounds or aqueous solution of ionic compounds that allows electricity to pass through are called electrolytes

Electrodes

- Metal plates or graphite rods that conduct electricity into the electrolyte
  - Eg. Platinum, copper
- Cathode:
  - Electrode that is connected to the negative terminal of the battery. Postively charged ions, cations, moved towards the cathode
- Anode:
  - Electrode that is connected to the positive terminal of the battery. Negatively charged ions, anions, moved towards the

Electrolysis



Conduction of electricity

- Conductor is a substance which conducts electricity but is not chemically changed during the conduction
  - Presence of freely moving valence electrons
  - Eg. All metals and graphite
- Non-conductor does not allow the passage of electricity, a.k.a insulator
  - Valence electrons are held in fixed positions
  - Eg. Sulphur, phosphorus, diamond, solid state crystalline salts, wood and glass

Electrolytes and non-Electrolytes

- Electrolytes:
  - Molten ionic compounds or aqueous solution of ionic compounds that allows electricity to pass through and are decomposed in the process
  - Eg. Acids, Alkali, Salts dissolved in water, molten salts
- Non-electrolytes:
  - Does not allow passage of electricity
  - Eg. Distilled water, alcohol, turpentine, oil, paraffin, organic solvents

Strong and weak Electrolytes

- Strong Electrolytes
- Fully ionised
- Strong acids
- Strong alkalis
- Salt solution

- Weak Electrolytes
- Partially ionised
- Weak acids
  - Ethanoic acid
  - Sulphurous acid
  - Carbonic acid
- Weak alkalis
  - Limewater
  - Ammonia

Electrolysis

- When electricity is passed through an electrolyte, chemical decomposition occurs
- This involves the ‘splitting up’ of the electrolyte
- Since all electrolytes are ionic, composed of positively and negatively charged ions

Electrolysis

- The process: When an electric current pass through the electrolyte, ions in the solution migrate towards the oppositely charged electrode
- This discharge of ions at the electrodes results in the chemical decomposition of the electrolyte to form its elements.

Electrolysis

- At the anode, negatively charged ions lose their electron(s) to the anode (connected to positive terminal of battery) to form neutral atoms.
- The negatively charged ions are said to be oxidised and discharged at the anode.
- Oxidation occured at the anode.

Electrolysis

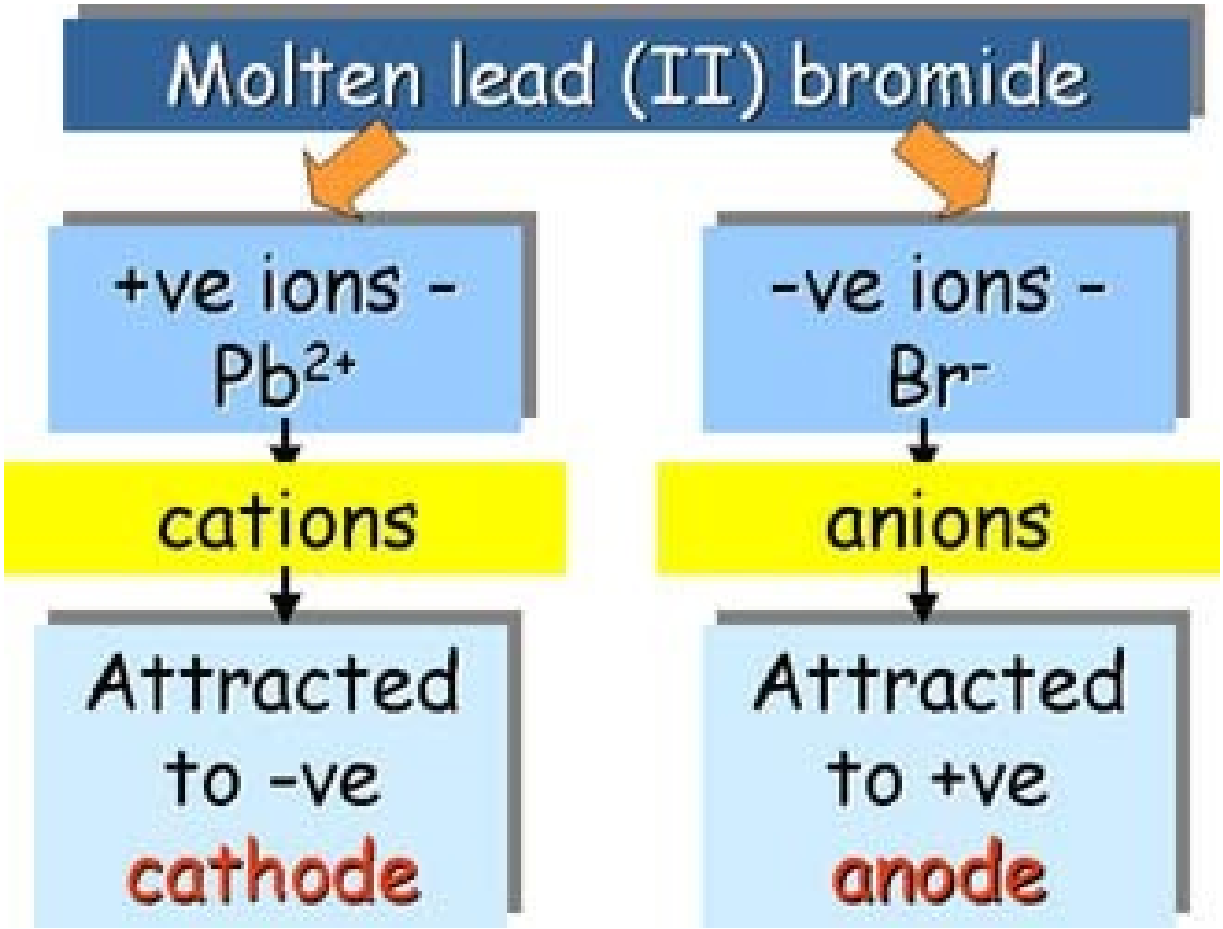
- At the cathode, positively charged ions gain electron(s) from the cathode (connected to negative terminal of battery) to form neutral atoms.
- The positively charged ions are said to be reduced and discharged at the cathode.
- Reduction occured at the cathode.

Electrolysis of Molten Compounds

- *Many ionic compounds are binary compounds.*
- *A binary compound is a compound containing only 2 elements. It contains a metal cation and a non-metal anion.*
- *The electrolysis of a molten binary compound will yield a metal and a non-metal as products.*

Electrolysis of Molten Lead(II) Bromide

Carbon rods as electrodes



At the cathode

- *Pb^{2+} ions gain electrons from the electrodes to become lead atoms*
- *The Pb^{2+} are reduced*
- *Pb^{2+} ions have been discharged and molten greyish globules of lead metal are formed below the electrolyte*
- *Electrode reaction at the cathode:*
  - *$Pb^{2+}(l) + 2e \rightarrow Pb(l)$*

At the anode

- *Br^- ions lose electrons to electrode to become bromine molecules*
- *The Br^- are oxidised.*
- *Bromide ions are discharged forming an effervescence of pungent, red-brown bromine gas.*
- *Electrode reaction at the anode:*
  - *$2\ Br^-\ (l) \rightarrow Br_2(g) + 2e^-$*

Electrolysis of other molten compounds with carbon electrodes

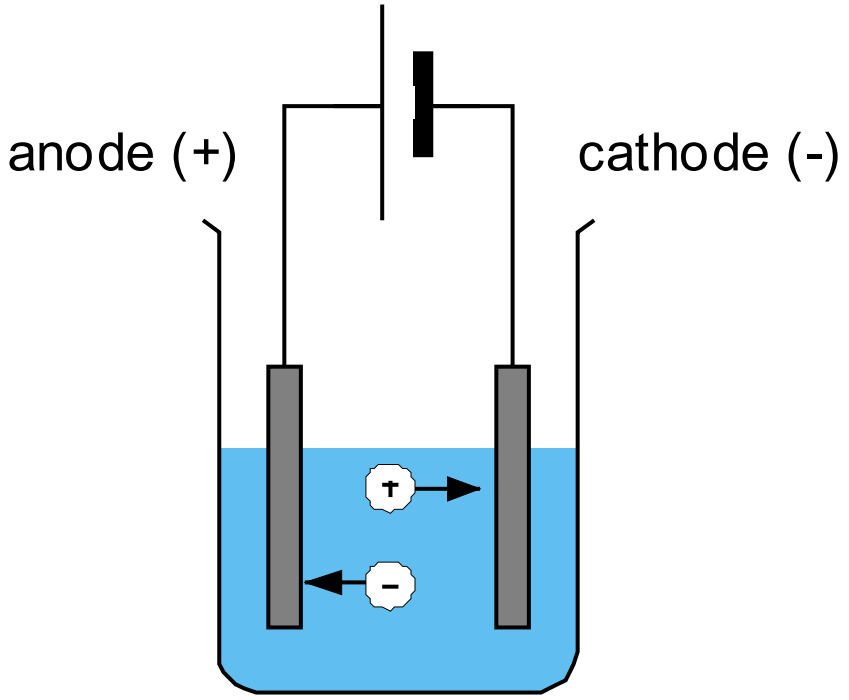
- Molten Sodium Chloride
- Product at cathode
  - Sodium
  - $Na^+ + e \rightarrow Na$
- Product at anode
  - Chlorine
  - $2Cl^- \rightarrow Cl_2 + 2e$

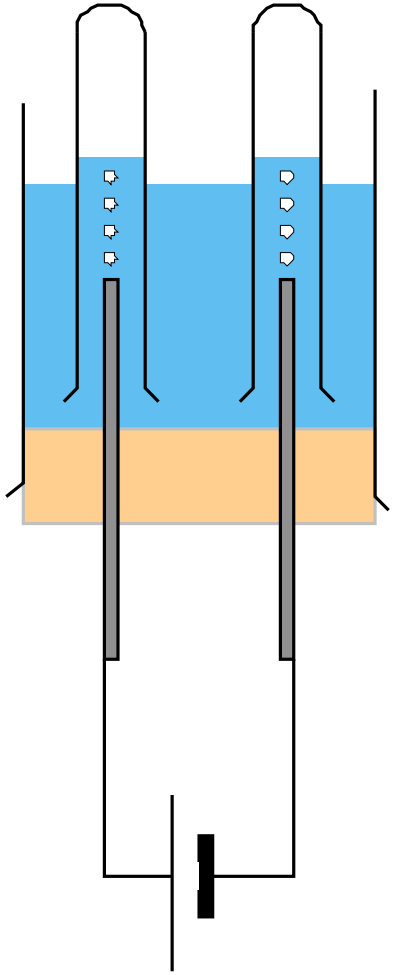
- Molten Lead (II) Oxide
- Product at cathode
  - Lead
  - $Pb^{2+} + 2e \rightarrow Pb$
- Product at anode
  - Oxygen
  - $2O^{2-} \rightarrow O_2 + 4e$

Evidence of Ions

Electrolysis provides evidence for the existence of ions which are held in a lattice when solid but which are free to move when molten or in solution.

Electrolysis of Aqueous Solutions





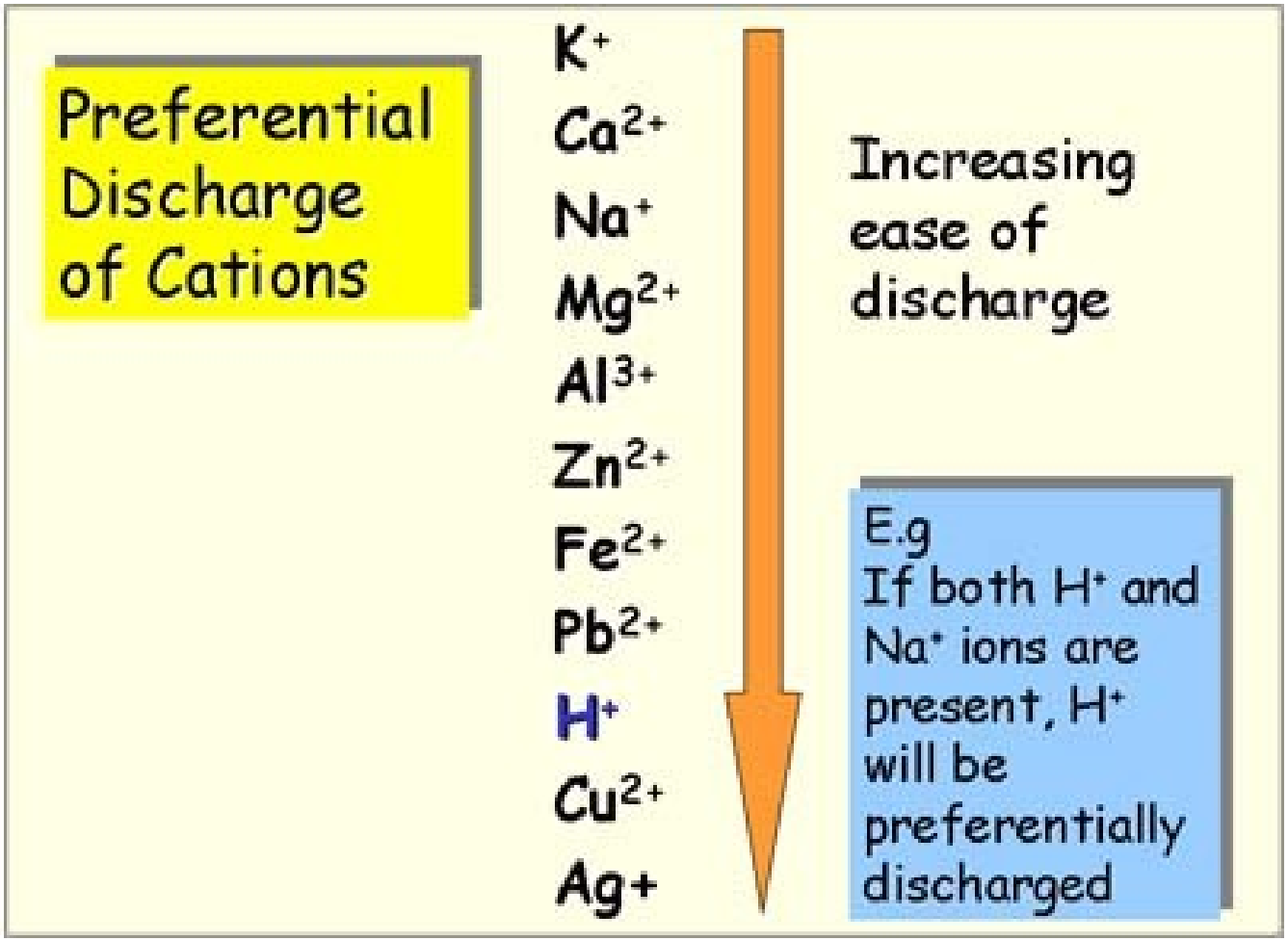
Electrolysis of Aqueous Solutions

- *An aqueous solution of a compound is a mixture of 2 electrolytes*
- *Eg. Aqueous copper (II) sulphate*
  - *Water*
    - *Hydrogen ions and hydroxide ions*
  - *Copper (II) sulphate*
    - *Copper (II) ions and sulphate ions*
- *Ions discharged depends on the position of the ions in the electrochemical series*

Rules for Predicting Selective Discharge of Cations

- *Positive ions from the metal lowest in the reactivity series are discharged at the cathode in preference to any other ions present in the solution*
- *Ions of less reactive metals e.g. Cu^{2+}, Au^{+}, Ag^{+} are preferentially discharged*
- *Otherwise, H^{+} ions from water will be discharged/reduced to form H_2 gas.*
  - *$2H^{+}(aq) + 2e \rightarrow H_2(g)$*
- *Ions of very reactive metals (Na^{+}, K^{+}, Ca^{2+}) **cannot** be discharged in the presence of water*

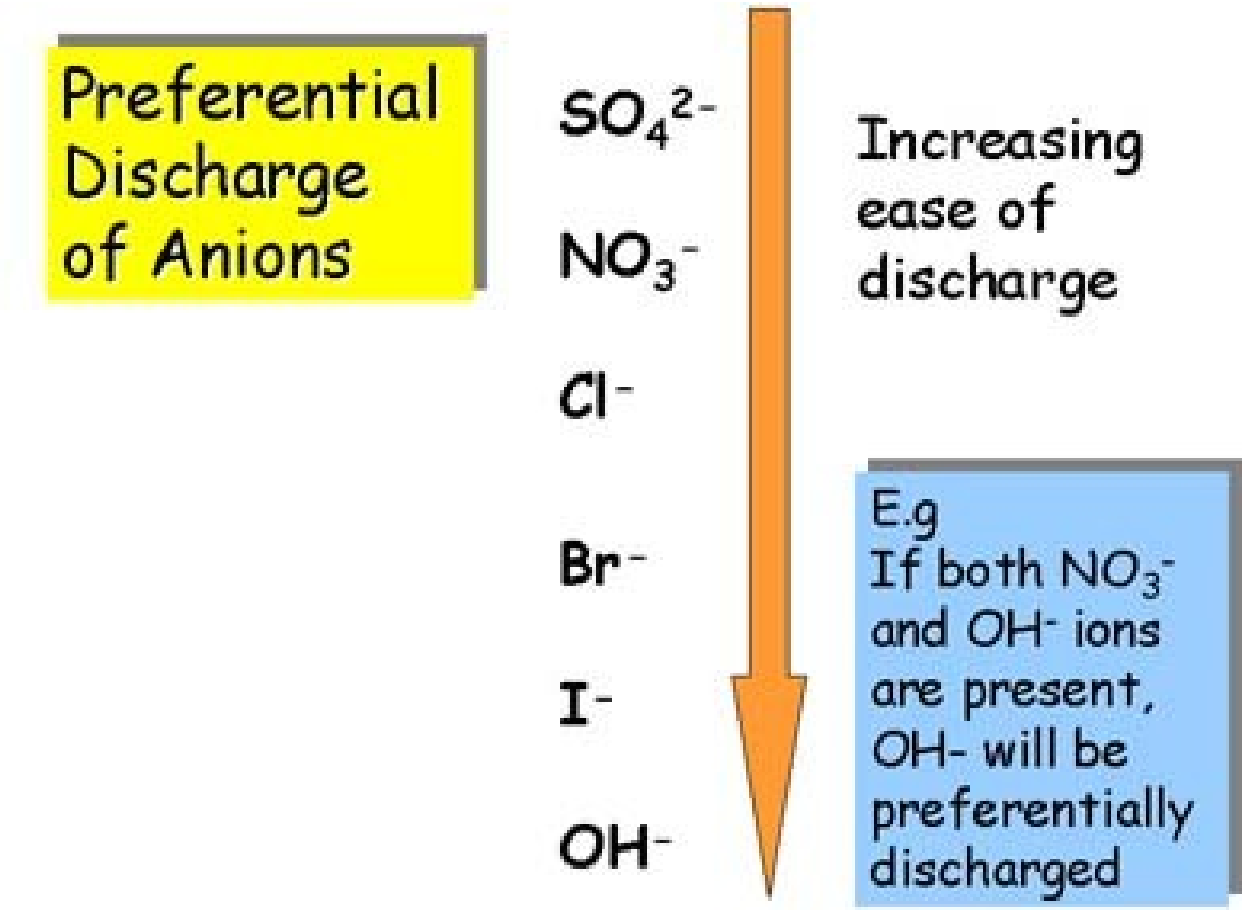
Rules for Predicting Selective Discharge of Cations



Rules for Predicting Selective Discharge of Anions

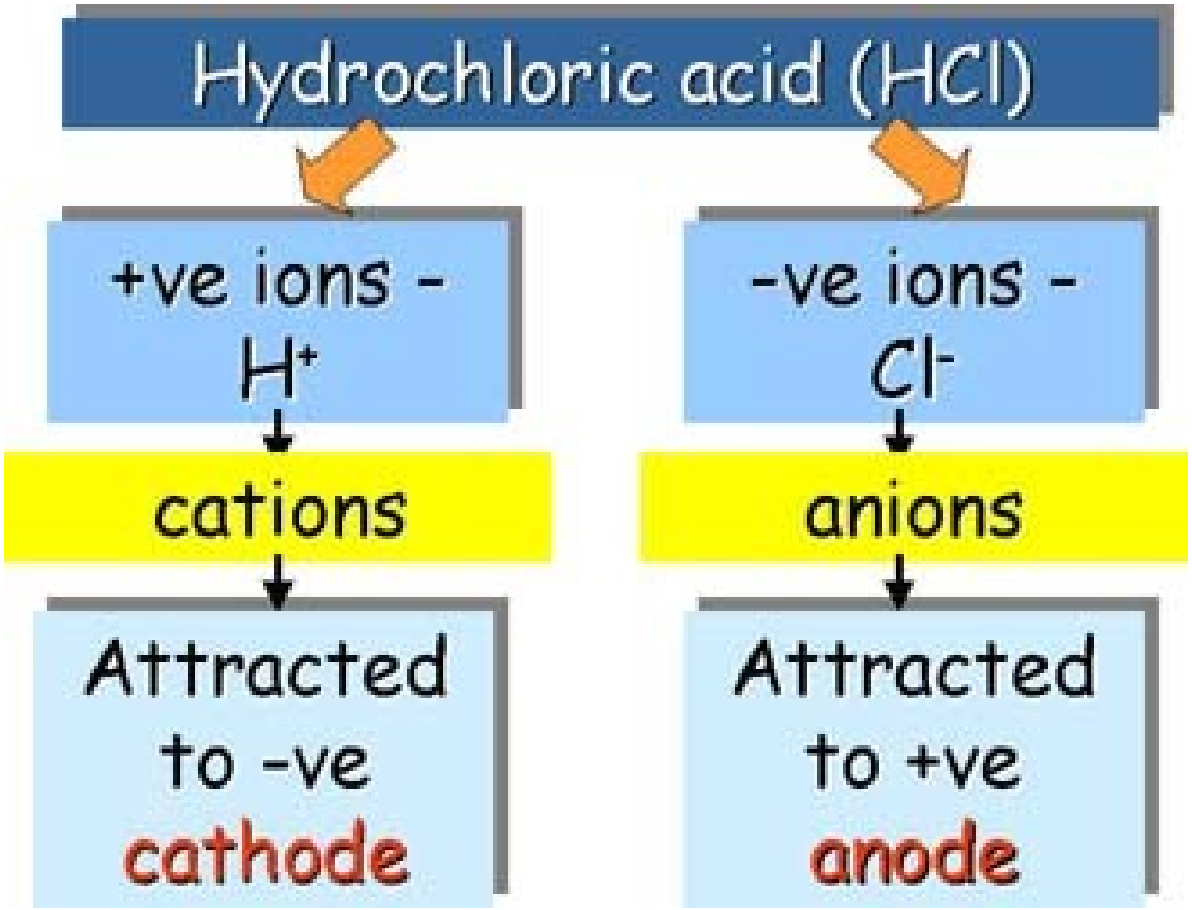
- *OH^- ions from water are preferentially discharged when the solutions are dilute, to form O_2.*
  - *$4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e$*
- *Negative ions such as Cl^-, Br^- and I^- can be preferentially discharged when their concentrations are high enough when compared to OH^-*
- *When SO_4^{2-} and NO_3^- are present in water, it is the OH^- from water which is preferentially discharged.*

Rules for Predicting Selective Discharge of Anions



Electrolysis of Concentrated Hydrochloric Acid

Carbon rods as electrodes



At the cathode

- *H^+ ions gain electrons from the electrodes to become hydrogen gas molecules*
- *Gas produced extinguishes a lighted splint with a 'pop' sound*
- *Electrode Reaction at the Cathode:*
  - *$2H^+(aq) + 2e \rightarrow H_2(g)$*

At the anode

- *Cl^- ions lose electrons to the electrode to become chlorine gas molecules*
- *Gas turns moist blue litmus paper red and then bleached it*
- *Electrode Reaction at the Anode:*
  - *$2Cl^-(aq) \rightarrow Cl_2(g) + 2e$*
- *Overall equation:*
  - *$2HCl(aq) \rightarrow Cl_2(g) + H_2(g)$*

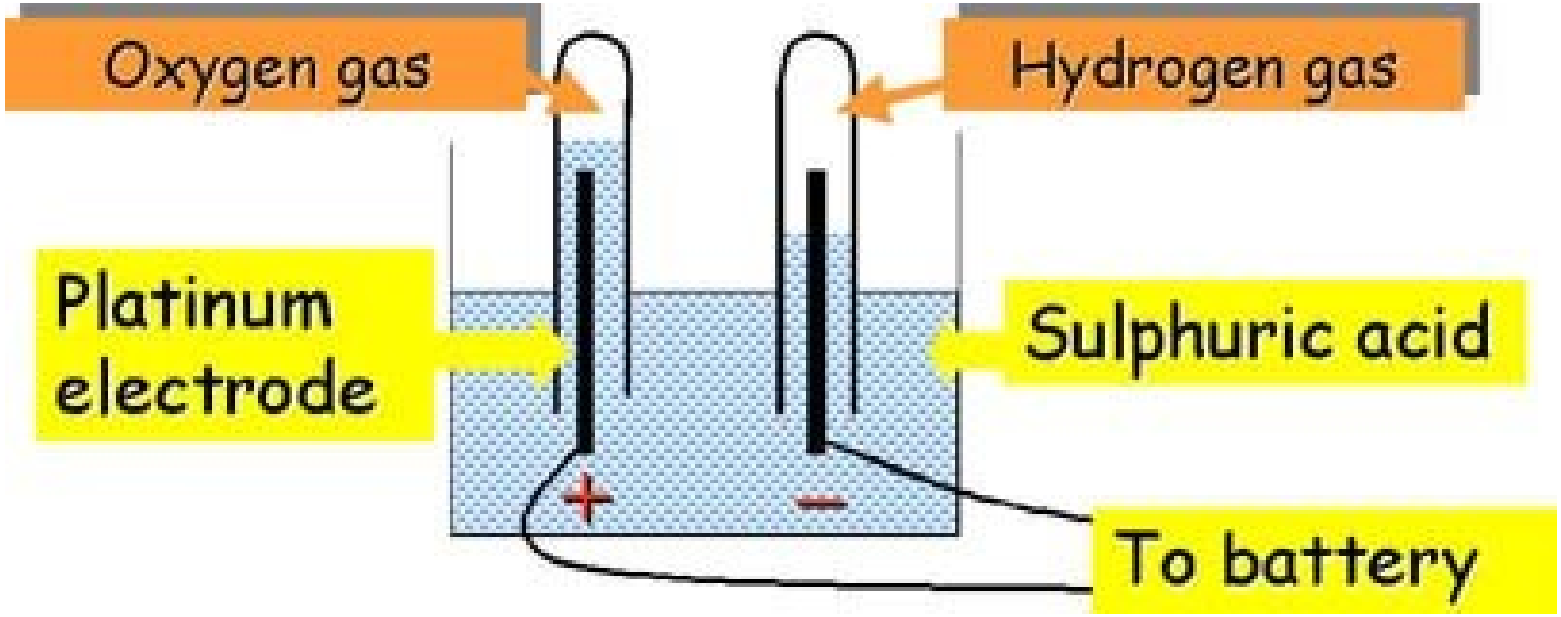
Electrolysis of other concentrated aqueous solutions with carbon electrodes

- **Concentrated sodium chloride solution**
- Product at cathode
  - Hydrogen
  - $2H^+ + 2e \rightarrow H_2$
- Product at anode
  - Chlorine
  - $2Cl^- \rightarrow Cl_2 + 2e$

- **Concentrated zinc sulphate solution**
- Product at cathode
  - Zinc
  - $Zn^{2+} + 2e \rightarrow Zn$
- Product at anode
  - Oxygen
  - $4OH^- \rightarrow O_2 + 2H_2O + 4e$

Electrolysis of Dilute Sulphuric Acid

Platinum rods as electrodes



At the cathode

- *H^+ ions attracted to the cathode, gain electrons and are discharged to form hydrogen gas*
- $2H^+ + 2e \rightarrow H_2$

At the anode

- *Both OH^- and SO_4^{2-} will be attracted to the anode but OH^- ions are preferentially discharged to form oxygen gas.*
- $4OH^- \rightarrow O_2 + 2H_2O + 4e$

Overall Reaction

- *$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$*
- *Sometimes known as electrolysis of acidified water*
- *Sulphuric acid increases the number of mobile ions to help conduct electricity*
- *In this process, the amount of acid remains the same, but amount of water decreases*
- *Hence the concentration of sulphuric acid increases*

Electrolysis of other diluted aqueous solutions with carbon electrodes

- **Dilute sodium chloride solution**
- Product at cathode
  - Hydrogen
  - $2H^+ + 2e \rightarrow H_2$
- Product at anode
  - Oxygen
  - $4OH^- \rightarrow O_2 + 2H_2O + 4e$

- **Dilute copper (II) sulphate solution**
- Product at cathode
  - Copper
  - $Cu^{2+} + 2e \rightarrow Cu$
- Product at anode
  - Oxygen
  - $4OH^- \rightarrow O_2 + 2H_2O + 4e$

Inert & Reactive Electrodes

- Inert Electrodes
  - Carbon
  - Platinum
- Reactive Electrodes

– take part in the reactions

  - Copper
  - Silver

Electrolysis of Copper (II) Sulphate Solution Using Copper Electrodes

- *At the cathode,*
- *Both Cu^{2+} and H^{+} ions attracted to it but Cu^{2+} preferentially discharged and deposited on the cathode as a brown deposit of solid copper.*
- *$Cu^{2+}(aq) + 2e \rightarrow Cu(s)$*

Electrolysis of Copper (II) Sulphate Solution Using Copper Electrodes

- *At the anode,both OH^- and SO_4^{2-} ions attracted to it but NEITHER are DISCHARGED*
- *Copper electrode dissolved instead*
- *$Cu(s) \rightarrow Cu^{2+}(aq) + 2e$*

Overall Reaction

- *Cathode gains copper & becomes larger*
- *Anode loses copper & become smaller*
- *Concentration & colour of copper(II) sulphate solution remain unchanged*
- *Amount of Cu^{2+} ions which are discharged to form Cu deposits on the cathode (from the solution)* **=** *Amount of Cu atoms (from the anode) which ionises and enter the solution as Cu^{2+} ions*

Factors affecting discharge of Ions

- Relative positions of the ions in the reactivity series
- Concentration of the ions in the electrolyte
- Nature of the electrode

Generally

- Metals or hydrogen are formed at the cathode
- Non-metals (other than hydrogen) are formed at the anode

Uses of Electrolysis

- Purification of metals
- Electroplating
- Extraction of metals