C6: Electrolysis: Knowledge Organiser: Chemistry Specification Higher

Process of Electrolysis

When an ionic compound is dissolved in water or melted, the ions are free to move about. This means that the liquid ionic compounds and solutions are able to conduct electricity. These melted ionic compounds and solutions containing the ionic compounds are called electrolytes. Passing an electric current through electrolytes causes the ions to move to the electrodes. Positively charged ions move to the negative electrode, and negatively charged ions move to the positive electrode. The negative electrode is called the cathode and the positive electrode is called the anode. Ions are discharged at the electrodes producing elements. This process is called electrolysis.

Electrolysis of Molten Ionic Compounds

When a ionic compound is melted we say it is molten. When a simple ionic compound is electrolysed in the molten state using inert electrodes, the metal is produced at the cathode and the non-metal is produced at the anode. For example if molten lead bromide were to be electrolysed, lead would form at the cathode and bromine would form at the anode. If molten zinc chloride were to be electrolysed, zinc would form at the cathode and chlorine would form at the anode.

Oxidation and Reduction

Oxidation is the loss of electrons while reduction is the gain of electrons. This can be remembered using the phrase **OIL RIG**. **O**xidation **I**s **L**oss, **R**eduction **I**s **G**ain.

During electrolysis, at the cathode (negative electrode), positively charged ions gain electrons and so the reactions are reductions. At the anode (positive electrode), negatively charged ions lose electrons and so the reactions are oxidations.

Using Electrolysis to Extract Metals

Metals can be extracted from molten compounds using electrolysis. Electrolysis is used if the metal is too reactive to be extracted by reduction with carbon or if the metal reacts with carbon. Large amounts of energy are used in the extraction process to melt the compounds and to produce the electrical current. This means the process is expensive.

Extracting Aluminium Using Electrolysis

Aluminium is extracted from the ore bauxite using electrolysis. Bauxite contains the compounds aluminium oxide which has the formula Al_2O_3. Aluminium oxide has a high melting point and so is mixed with cryolite to lower it. The aluminium oxide mixture is then melted so that the ions are free to move. The Al^{3+} ions are attracted to the cathode while the O^{2-} ions are attracted to the anode.

At the cathode the Al^{3+} ions gain 3 electrons and become aluminium atoms. The positive aluminium ions are attracted to the negative charge of the cathode. When the ions form atoms they then sink to the bottom of the electrolysis tank. As the ions have gained electrons they have been reduced. What happens at the negative electrode can be represented with the following half equation:

$$Al^{3+} + 3e^- \rightarrow Al$$

At the anode the O^{2-} lose two electrons. The negative ions are attracted to the positive charge of the anode. The oxygen atoms then bond together to form oxygen molecules O_2. As the ions have lost electrons they have been oxidised. What happens at the positive electrode can be represented with the following half equation:

$$O^{2-} \rightarrow O_2 + 4e^-$$

Overall:

Aluminium Oxide → Aluminium + Oxygen

$$Al_2O_3 \rightarrow Al + O_2$$

The anode needs to be replaced because the carbon it contains reacts with the oxygen made to make carbon dioxide.

Aqueous Solutions

An aqueous solution is one in which a substance is dissolved in water. When ionic compounds dissolve in the water there will be ions from the compounds as well as hydrogen ions (H^+) and hydroxide ions (OH^-) from the water.

$$H_2O\ (l) \rightleftharpoons H^+\ (aq) + OH^-\ (aq)$$

Electrolysis of Aqueous Solutions

The ions discharged when an aqueous solution is electrolysed using inert electrodes depend on the relative reactivity of the elements involved. In a solution containing a dissolved ionic compound there will be positive and negative ions from this compound as well as positive hydrogen ions and negative hydroxide ions from the water.

At the cathode hydrogen is produced if the metal in the solution is more reactive than hydrogen. If the metal is less reactive than hydrogen then a solid layer of pure metal will be produced instead.

At the positive electrode (anode), if halide ions are present in the solution then molecules of halogens will form. For example if the solution contains Cl^- ions then chlorine molecules will form at the anode while if F^- ions are present then fluorine molecules will form at the anode instead. If there are no halide ions in the solution then oxygen gas will be formed instead. This is because OH^- ions are attracted to positive electrode and are discharged making oxygen.

Half Equations

Half equations show the reactions at the electrodes.

For example when hydrogen forms at the cathode:

$$2H+ + 2e^- \rightarrow H_2$$

And when oxygen forms at the anode:

$$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$$