St Ninian's High School

Chemistry Department

National 5 Chemistry

Unit 3: Chemistry in Society

Electrochemistry

Summary Notes

Name _____

Learning Outcomes

After completing this topic you should be able to :

1	state that, in a battery, electricity comes from a chemical reaction
2	state that electricity passing along metal wires is a flow of electrons
3	explain the need to replace batteries in terms of the chemicals being used up in the reaction
4	state that some batteries are rechargeable, e.g. the lead-acid battery, the lithium-ion battery
5	explain that in a cell an electrolyte is needed to complete the circuit
6	state that electricity can be produced by connecting different metals together (with an electrolyte) to form a cell
7	state that the voltage between different pairs of metals varies and that this leads to the electro-chemical series
8	state that electricity can be produced in a cell by connecting two different metals in solutions of their metal ions
9	state that the purpose of an ion bridge is to complete the circuit
10	state that electricity can be produced in a cell when at least one of the half-cells does not involve metal atoms
11	explain the movement of ions in an ion bridge is to provide ions to complete the circuit
12	state that the reactions in electrochemical cells are examples of redox reactions
13	describe the reactions at the electrodes in electrochemical cells can be described using ion-electron equations
14	combine the ion-electron equations for the reactions at the electrodes to give a redox equation for the cell reaction
15	apply the terms oxidation and reduction to more complex ion-electron equations, e.g. SO_4^{2-} and SO_3^{2-}
16	rechargeable batteries and fuel cells are technologies which use redox reactions.

Batteries

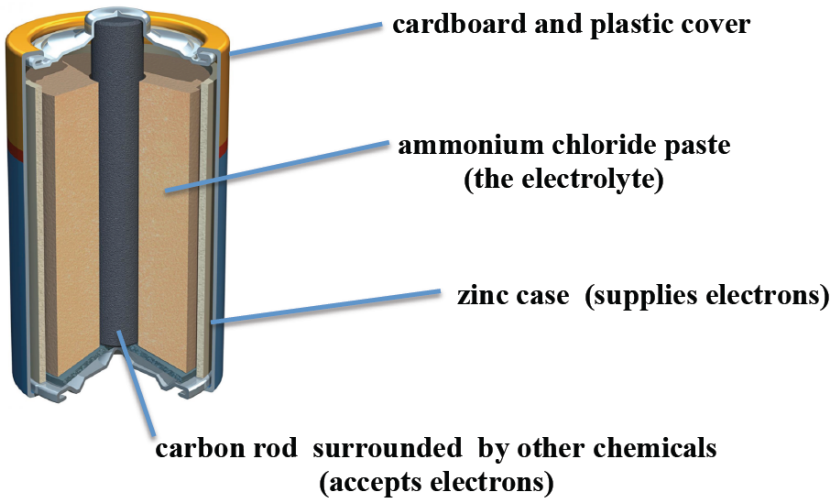
An **electrochemical cell** (or just cell for short) is able to make electricity. More than one cell joined together is technically called a battery. A simple battery consists of two different metals connected by an electrolyte (a solution which contains ions). An **electrolyte** is needed to complete the circuit.

Batteries "run out" and most eventually have to be replaced. This is because the chemicals that take part in the chemical reactions which occur in batteries are used up. In a battery, or cells, a chemical reaction occurs where the chemical energy is changed into electrical energy.

Chemical Energy ⟶ **Electrical Energy**

Dry-Cell Batteries

One of the most widely used batteries is the dry cell. It is used in remote controls, toys, torches, etc. A cut through diagram is shown below. Your teacher may show you an opened dry cell battery.



When a dry-cell battery is in use, chemical reactions result in a flow of electrons. The zinc case supplies electrons and the carbon rod accepts them. The electrolyte, which is needed to complete the circuit, is ammonium chloride paste. As the battery is used the zinc case wears away and eventually the battery needs to be replaced.

Batteries

Rechargeable Batteries

Some batteries such as the nickel-cadmium, lithium-ion and lead-acid are rechargeable and can be used again. When the battery is on charge, the chemical reactants are regenerated using electricity.

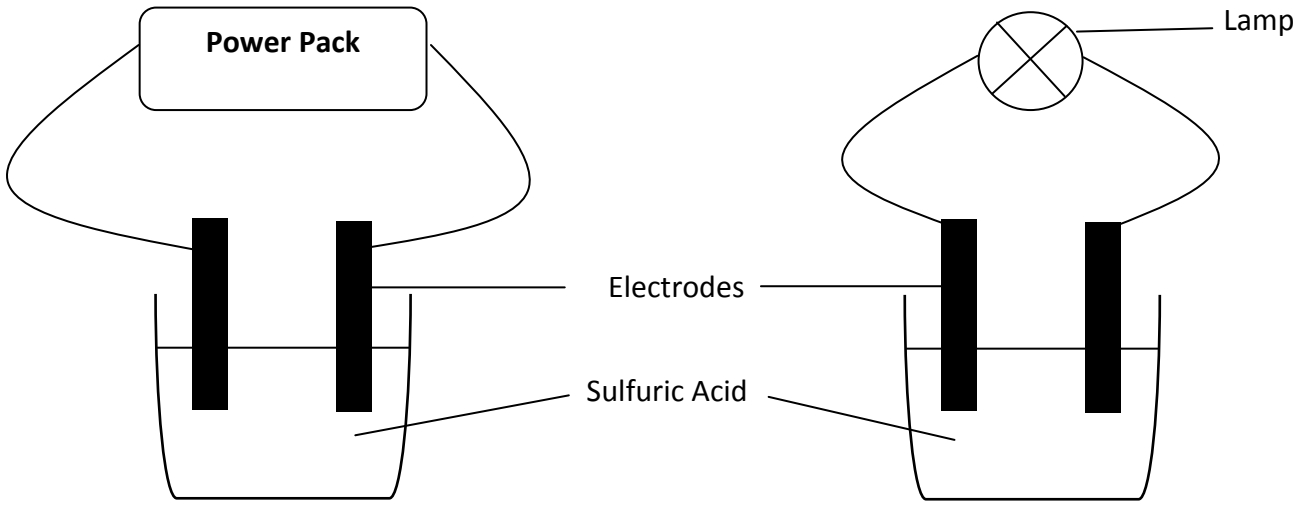
using a battery (making electricity)

CHEMICAL REACTANTS ⇄ **CHEMICAL PRODUCTS**

recharging a battery (using electricity)

Lead-Acid Battery

Lead-acid batteries are most commonly found in cars, it charges while the engine is running. The following demonstration in the class shows that lead-acid batteries can store charge.

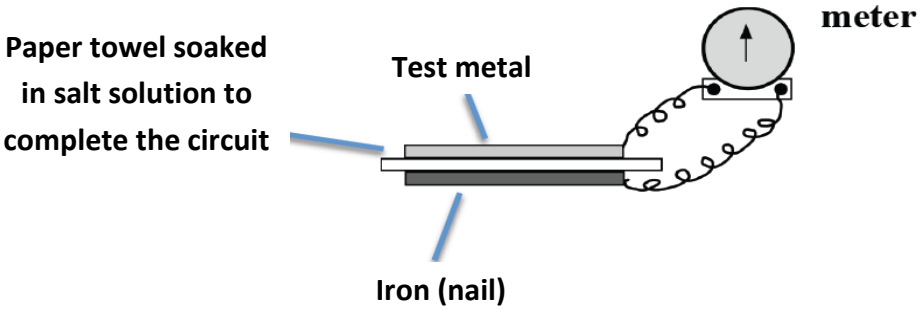


The lithium ion battery is another type of rechargeable battery found in mobile phones. During charging electrical energy is changed into chemical energy.

Electrochemical Cells

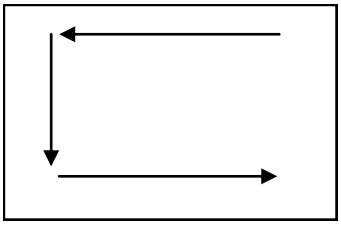
If two different metals are linked together in a certain way a flow of electrons (electricity) can be produced. A simple electrochemical cell will consist of two different metals connected through an electrolyte and external wires. Electrons flow through the wires between the two metals and ions flow through the electrolyte completing the circuit. The direction of electron flow depends on the metals used.

The Electrochemical Series



Electrons flow from the metal higher in the electrochemical series to the metal below. The size of the voltage produced depends on the relative positions of the two metals. The bigger the gap between the two metals in the electrochemical series the larger the voltage. (See data booklet page 10.)

Direction of electron flow on the electrochemical series.



Redox Equations for Cells

The electrochemical series (ECS) places metals in order of their ability to lose electrons to form ions. Metals higher in the ECS are more likely to lose electrons than metals lower down, e.g. magnesium is more likely to lose electrons than copper.

$Mg(s)$	$\longrightarrow$	$Mg^{2+}(aq)$	+	$2e^-$	**More likely**
$Cu(s)$		$Cu^{2+}(aq)$	+	$2e^-$	**Less likely**

When these two metals are attached in an electrochemical cell electrons will flow from magnesium to copper. This means the magnesium atoms are oxidised and the copper ions reduced, in other words a redox reaction occurs. Electrons must be cancelled in a redox equation.

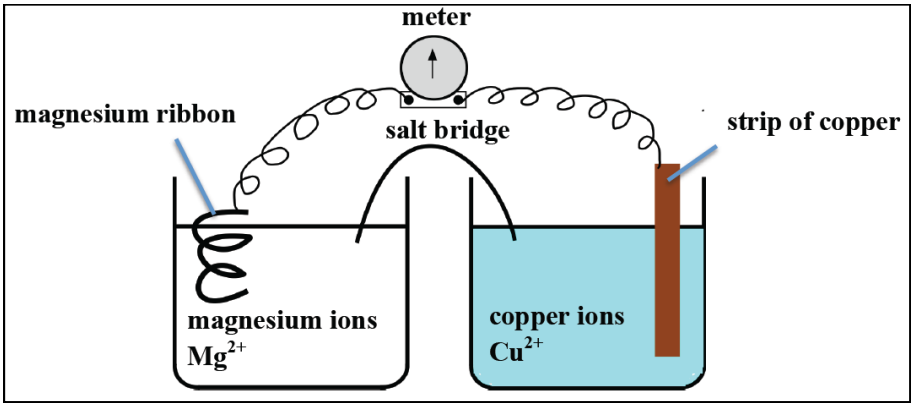
Oxidation: ~~$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^-$~~

Reduction: ~~$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$~~

Electrochemical Cells

Half Cells

Metals ionise more efficiently when they are dipped into a solution already containing their own ions. A half cell can be produced where the two metals are placed in a solution of their own ions and linked with a salt bridge (ion bridge) to complete the circuit. The two metals are attached through wires, electrons flow through the wires and ions through the salt bridge.



Magnesium-copper half cell

Oxidation: $Mg(s) \longrightarrow Mg^{2}(aq) + 2e^{-}$

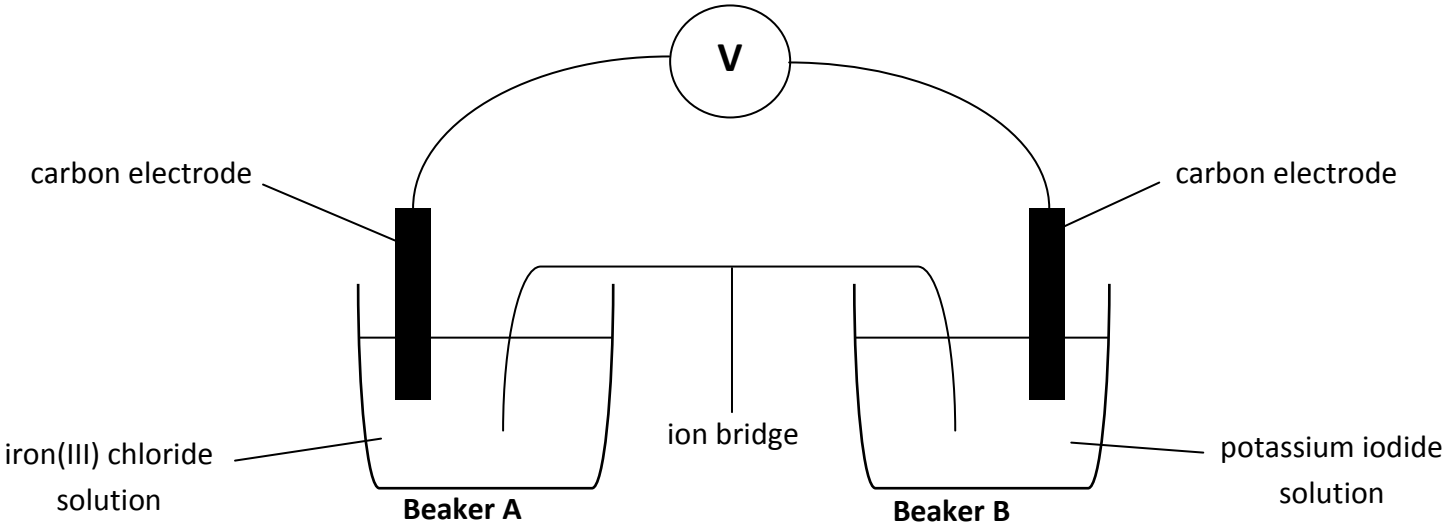
Reduction: $Cu^{2+}(aq) + 2e^{-} \longrightarrow Cu(s)$

Redox Eq: $Mg(s) + Cu^{2+}(aq) \longrightarrow Mg^{2}(aq) + Cu(s)$

Non-Metal Cells

Electrochemical cells can be produced using non-metals where carbon in the form of graphite is used as the electrodes. Electrons can be removed from one half cell (oxidation) and donated to the other half cell where reduction occurs.

The Iron(III)-Iodide Cell



Electrochemical Cells

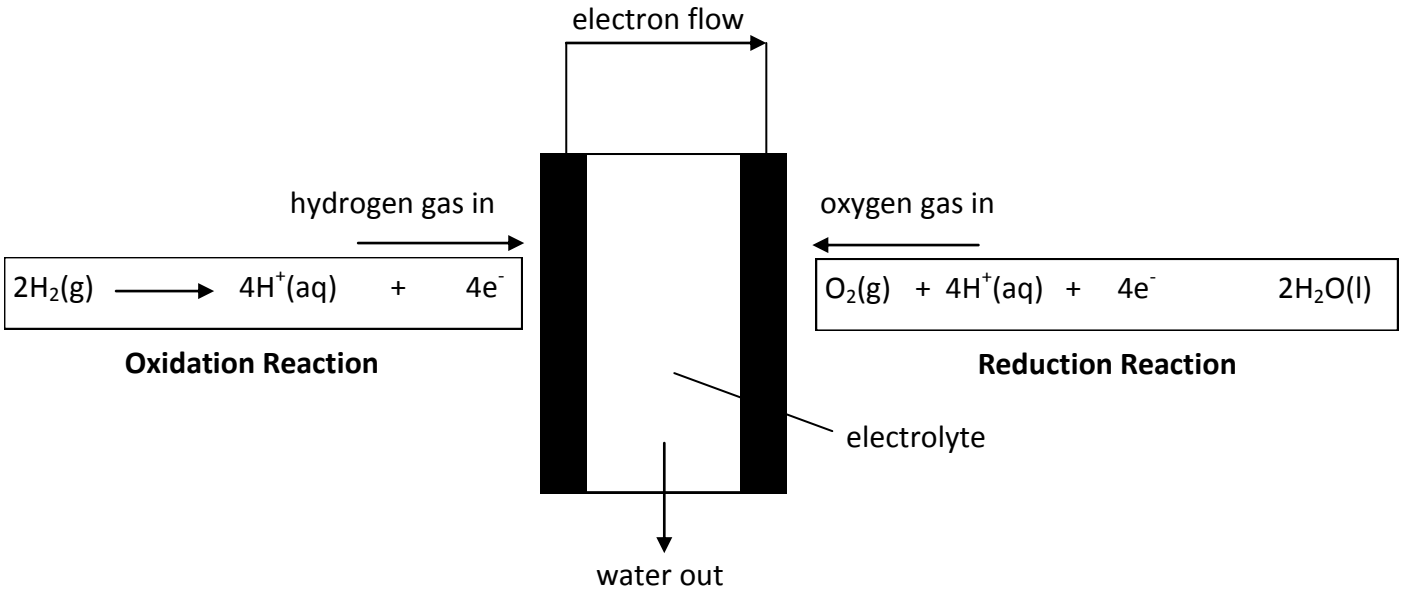
The Iron(III)-Iodide Cell Equations:

Oxidation:	$2I^-(aq)$	$\longrightarrow$		$I_2(aq)$	+	$2e^-$			
Reduction:	$Fe^{3+}(aq)$	+	e^-	$\longrightarrow$		$Fe^{2+}(aq)$		**(multiplied by 2)**	
Redox:	$2I^-(aq)$	+	$2Fe^{3+}(aq)$	$\longrightarrow$		$I_2(aq)$	+	$2Fe^{2+}(aq)$	

Fuel Cells

Rechargeable batteries have a finite life since they can only be charged up and run down a certain number of times before they need to be replaced. The lithium ion battery is a popular rechargeable battery often found in mobile phones. It is a much lighter than other types of rechargeable battery and holds charge better. However, the production of batteries whether rechargeable or not uses finite resources and causes pollution.

Fuel cells use electrochemistry to generate electricity. A fuel cell is a device that converts chemical energy from a fuel into electricity through a chemical reaction with oxygen. The hydrogen fuel cell, shown below, uses hydrogen which reacts with oxygen to produce water and release energy.



Fuel cells require a constant source of fuel and oxygen/air to maintain the chemical reaction, however fuel cells can produce electricity continuously when constantly supplied with fuel and oxygen. Fuel cells are used in remote locations such as spacecraft, remote weather stations and certain military applications like submarines. Fuel cells can also be used to power vehicles such as buses. The use of fuel cells is likely to expand in the years ahead.

Displacement Reactions - An Example of Redox

Displacement Reactions

Atoms of metals near the bottom of the electrochemical series do not lose electrons easily, so they don't form ions easily. Atoms of metals near the top of the electrochemical series lose electrons easily to form ions.

If a metal is placed in a solution containing ions of a different metal the two metals will swap places if the metal being added is higher up in the electrochemical series than the one which is in solution. When this happens a **displacement reaction** has taken place. If the metal being placed in the solution is lower down in the electrochemical series than the metal which is in solution in its ionic form, no reaction will take place.

For example if an iron nail is placed in a solution of copper(II) sulfate, the iron nail will react to form iron ions and the copper ions in the solution will turn to copper atoms producing solid copper. This happens since iron is above copper in the electrochemical series. Iron will therefore displace copper. The iron will be oxidised and the copper ions reduced therefore overall a redox reaction would take place.

Summary Statements

- ☐ In a battery the electrical energy comes from a chemical reaction. Batteries need to be replaced as the chemicals get used up.
- ☐ Electricity passing along metal wires is a flow of electrons.
- ☐ Some batteries are rechargeable, e.g. the lead-acid battery (cars), the lithium-ion battery.
- ☐ An electrolyte is needed in a cell to complete the circuit. Ions flow through the electrolyte.
- ☐ Electricity can be produced by connecting different metals together (with an electrolyte) to form a cell. The voltage between different pairs of metals varies and that this leads to the electrochemical series.
- ☐ Electricity can be produced in a cell by connecting two different metals in solutions of their metal ions. An ion bridge is used to complete the circuit since ions move across it.
- ☐ Chemical reactions in electrochemical cells are examples of redox reactions.
- ☐ Reactions at electrodes in a cell are described using ion-electron equations.
- ☐ Oxidation occurs when electrons are lost and reduction occurs when electrons are gained. (OILRIG)
- ☐ Redox equations are written by combining oxidation and reduction equations.
- ☐ The terms oxidation and reduction can be applied to more complex ion-electron equations, e.g. SO_4^{2-} and SO_3^{2-}.
- ☐ Rechargeable batteries and fuel cells are technologies which use redox reactions.
- ☐ Electricity can be produced in a cell when at least one of the half-cells does not involve metal atoms.