Electricity and Chemistry

Saturday, October 10, 2020 3:56 PM

5.1:
Electricity and Chemistry

Electrolysis is defined as the decomposition of ionic compounds in molten or aqueous solution using electricity.

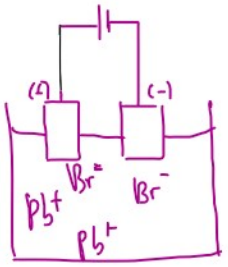
Take note that electrodes can either be reactive or unreactive. Unreactive electrodes are carbon and platinum. They are called inert. Platinum is a lot more unreactive but is very pricey. If electrode is reactive, different products will be produced

This is a **redox reaction** as reduction occurs in cathode and oxidation occurs in anode.

A mnemonic to memorize which is (+) and (-)

CNAPEL

Cathode negative, anode positive.
A general idea to understand how electrolysis works is by imagining what occurs during the process. Take an example of the electrolysis of molten lead bromide.



Since it is in molten state and it is an ionic compound, lead and bromine will split to form lead ions and bromide ions. Right now, we can see as seen from the diagram that the left side electrode is positively charged and the right side electrode is negatively charged . Hence, left side is anode and right is cathode.

With that being said, positive ions will be attracted to the cathode and negative ions will be attracted to the anode. Simply said, opposite charges attract.

Cathode(-)
$Pb^{2+}_{(aq)} + 2\bar{e} \rightarrow Pb_{(s)}$
$\bar{e}$ is gained
"Reduction"

Anode(+)
$2Br^{-}_{(aq)} \rightarrow Br_{2(g)} + 2\bar{e}$
$\bar{e}$ is lost
"Oxidation"

OILRIG

Oxidation is loss and reduction is gain

Other examples you must know:
1) Electrolysis of concentrated and dilute hydrochloric acid
2) Concentrated sodium chloride
3) Dilute sulfuric acid
4) Copper sulfate using inert and copper electrodes

A general principle to remember is that hydrogen and metal ions will form at cathode whereas non-metals(except hydrogen) will form in anode but **exceptions are there** in terms of whether hydrogen or metal ion will be displaced.

A common rule is as follows:
1) Hydrogen will always be displaced unless a metal ion less reactive than hydrogen is present
2) If halide solution is concentrated, halide gas will form. **Except for this, oxygen will always be displaced**

Electrolysis of dilute hydrochloric acid

Here, take note that it is no longer molten but a solution. Hence, water is inside it. In this solution, water will also ionize along side HCl.

$HCl \rightarrow H^+ + Cl^-$
$H_2O \rightarrow H^+ + OH^-$
Hence, at cathode, we have:

(-) $2H^+_{(aq)} + 2\bar{e} \rightarrow H_{2(g)}$

At anode:

(+) $4OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 4e$

must memorise

If the solution becomes **concentrated**, there will be no change in cathode but in anode, **instead of oxygen gas, chlorine will be discharged.**

In the electrolysis of sodium chloride (concentrated), the exact same products will be formed in relation with concentrated HCl.

Electrolysis of dilute sulfuric acid:

Ions present

$H_2SO_{4(aq)} \rightarrow 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

$H_2O \rightarrow H^+ + OH^-$

(-) $2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$

(+) $4OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 4e^-$

As the reaction progressed, the concentration of sulfuric acid increases as water is used up.

Electrolysis of copper sulfate with inert electrodes:

Ions present

$CuSO_{4(aq)} \rightarrow Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$

$H_2O \rightarrow H^+ + OH^-$

(-) $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$

(+) $4OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 4e^-$

Copper will wrap the cathode or may also fall to the bottom.
Oxygen gas will bubble of

Solution gradually loses its blue colour

If copper electrodes are used:

(-) $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$

(+) $Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + 2e^-$

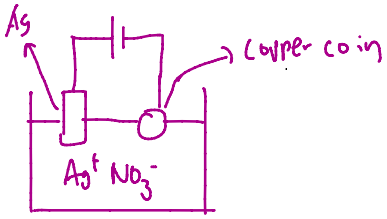
The rate at which copper ions reduce to form copper and copper oxidize to form copper ions is equal, hence, blue solution does not fade in color.

Electroplating: It is a process where metals are being coated with a different type of metal

General principle:

1) Object to be plated will be at the cathode
2) Electrolyte must that of be the metal in anode

An example would be plating a copper coin with silver



This is possible as the copper cathode, which is negative, will attract the positively charged silver ions. Silver will be deposited onto the copper coin. On the other hand, silver anode will release silver ions to the electrolyte. Hence, after a period of time, cathode will gain in mass whereas anode will lose its mass.

Primary usage:

1) To prevent corrosion
2) To improve the look of an object

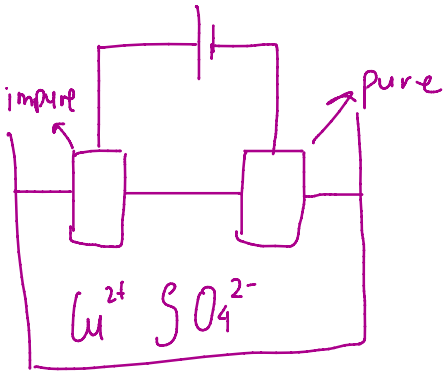
In essence, copper are used for cables as they are ductile and conduct electricity well whereas ceramics and plastics are used for food containers and cooking handles as they are insulators. Aluminum are used for planes due to it being lightweight and steel is used to make cable core for strength.

Refining metals:

This has a very similar concept to that of electroplating.

Here, the major difference is that cathode has thin strip of pure metal whereas anode has the impure metal. Electrolyte will be a solution containing that metal and must be soluble.

Take an example when copper is refined.



Quite simply, as we already know, anode will undergo oxidation. Hence, the copper atoms in the impure copper will undergo oxidation to form copper ions. This copper ion is then attracted to the cathode which then reduces it to form copper atoms. **The electrons move through the circuit but ions move in the electrolyte.**

Hence, anode will gradually decrease in size and cathode will gradually increase in size.

Simple cell

Simple cell is often confusing for students as the signs are flipped for the electrodes. Here, cathode is (+) and anode is (-). That is the huge difference one must remember.

The primary concept is how when two metal electrodes of different reactivity, if submerged in a solution, whether acid, alkaline or salt solution, will produce electricity.

The more reactive metal will oxidize as it has greater tendency to lose electrons. Hence, it will be the anode. On the other hand, the less reactive metal will be cathode.

The magnitude of electricity produced depends on how far away are the metals from each other. The further, the more electricity is produced.

The reactivity series is given :

P Please
Na Stop
Ca Calling
Mg Me
Al A
C Cute
Zn zebra

Li Lute
Zn Zebra
Fe Instead

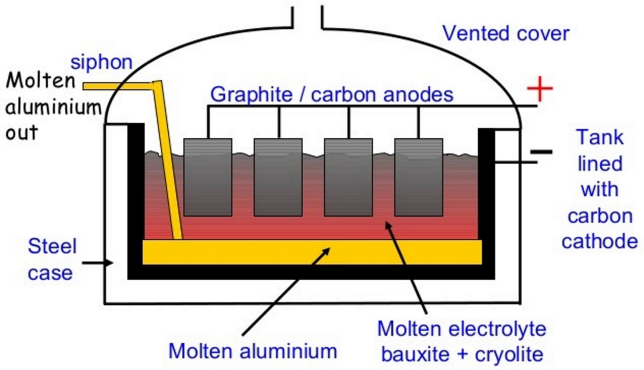
Tn Try
Pb Learning
H How
Cu Copper

Ag Saves
Au Gold

11

Extraction of Aluminum:

Extraction of aluminium: overall



http://smarteduhub74.blogspot.com/2017/01/aluminium-extraction-notes.html

Aluminum is extracted from an ore called Bauxite. It has very high melting point. Before anything, it is first purified in order to obtain Alumina, which is aluminum oxide. It is then mixed with cyolite to lower its melting point. Afterwards, it is melted in order for it to be able to carry electricity.

Initially, melting point is at 2070 degrees Celsius but is lowered up to 915 degrees Celsius

Products at each electrode are:

(-) $Al^{3+}_{(aq)} + 3\bar{e} \rightarrow Al_{(s)}$

(+) $2O^{2-}_{(aq)} \rightarrow O_{2(g)} + 4\bar{e}$

Due to high temperature,

$C + O_2 \rightarrow CO_2$

Electrodes must be replaced after

Overall reaction

$2Al^{3+} + 6O^{2-} \rightarrow 4Al + 3O_2$

more info in Redox Chapter

Sometime

Electrolysis of Brine:

Brine is concentrated sodium chloride. The electrolysis of brine produces by products which are crucial for the manufacturing industry.

Ions present:

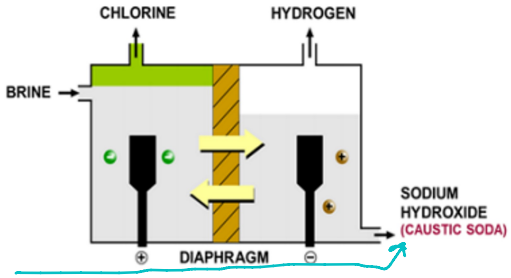
$NaCl_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$

$H_2O \rightarrow H^+ + OH^-$

(+) $2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$

(-) $2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$

Notice that as H^+ and Cl^- is used up. NaOH remains



Anode is made up of titanium and cathode is made up of steel. Membrane in the center only allows ions to move through it due to difference in liquid pressure.

Material	Usage
Hydrogen gas	Fuel cells and raw material for the production of ammonia
NaOH	Soaps and water treatment
Chlorine gas	disinfectant

General tips during exams:

1) Read carefully whether the solution is concentrated or not
2) If it is molten, the discharged is always the cation and anion
3) Take into account what ion is being used up and what remains. This gives clues regarding concentration and by products
4) Remember that OILRIG and CNAPEL
5) CNAPEL is opposite for simple cell. Remember that magnitude of electricity produced depends on different in reactivity
6) It is frequently asked why carbon electrode is frequently replaced in extraction for Aluminum as well as why cryolite is used
7) Industrial uses is often asked as well
8) Understand that around the circuit, **electrons move,** but in the electrolyte, **ions move.**