Some metals engage in chemical reactions vigorously, certain others react sluggishly in the same reaction.

Let us analyse the reaction of some metals with water

Reaction of metals with water

1. Take three beakers having the same quantity of water. Take pieces of sodium, magnesium and copper of same size and drop each one to each beaker. Observe the reactions.

Observation

Metal	In cold water	In hot water
Sodium	Reacts vigorously. A gas is formed	
Magnesium	No reaction	Reacts . A gas is formed
Copper	No reaction	No reaction

The gas formed in the above reactions is hydrogen.

2. Based on your observation, arrange these metals in the decreasing order of their reactivity.

Answer: Sodium > Magnesium >Copper

Reactions of Metals with Air

3. Cut a piece of sodium using a knife. Observe the freshly cut portion. Don't you see that its shining fades after sometime? Give reason:

Answer: This is due to the conversion of sodium into its compounds by reacting with oxygen, moisture and carbon dioxide in the atmosphere

4. A fresh magnesium ribbon losing its lustre when kept exposed in the air for some days. Why?

Answer: This is also due to its reaction with atmospheric air. Magnesium reacts with oxygen of air forming a black layer of magnesium oxide over it.

$$2\,Mg_{(s)} + O_{2\,(g)} \rightarrow 2MgO_{(s)}$$

Aluminium vessels diminishes as time passes by. In the case of copper vessels, it takes months for the loss of its lustre by the formation of verdigris. But the shining of gold fades even after a long time. This indicates that metals react with air at different rates.

5. (a) Which metal among magnesium, copper, gold, sodium and aluminium, loses its lustre at a faster rate?

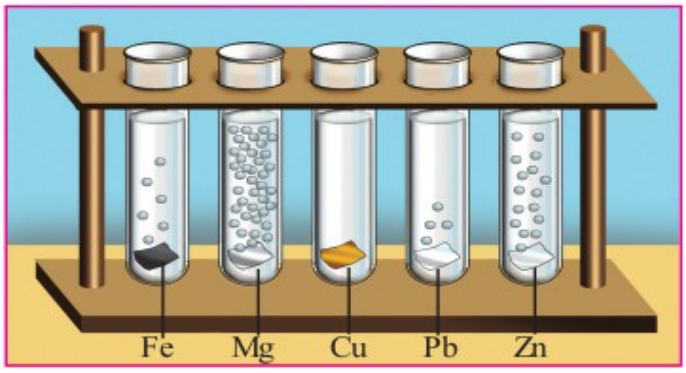
Answer: Sodium

(b) List the above metals in the decreasing order of their reactivity with air and thereby losing lustre.

Answer: Sodium > Magnesium > Aluminium> Copper > Gold

Reaction of Metals with Acids

The image given below shows the reaction of some metals with dilute HCl



This indicates that metals react with dilute HCl at different rates.

6. What is reactivity series?

The series obtained by arranging the metals in the decreasing order of their reactivity is known as the reactivity series.

Note that hydrogen is also included in this series for the sake of comparison of chemical reactivity.

Potassium	K
Sodium	Na
Calcium	Ca
Magnesium	Mg
Aluminium	Al
Zinc	Zn
Iron	Fe
Nickel	Ni
Tin	Sn
Lead	Pb
Hydrogen	H
Copper	Cu
Silver	Ag
Gold	Au

React with dil HCl and displace hydrogen

Do not displace hydrogen from dil. HCl

Reactivity series and displacement reactions

7.Prepare some $CuSO_4$ solution in a beaker and dip a Zn rod in it. Observe the changes after sometime and write down the observations.

Observation	Before the experiment	After the experiment
Colour of Zinc rod	Grey	Covered with copper
Colour of $CuSO_4$ solution	Blue	**Colourless**

The blue colour of $CuSO_4$ solution is due to the presence of Cu^{2+} ions. When the Zn rod is dipped in $CuSO_4$ solution, the Cu^{2+} ions in the solution get deposited at the Zn rod as Cu atoms. The chemical reaction taking place here is given below.

$$\mathbf{Zn_{(s)} + CuSO_{4(aq)} \rightarrow ZnSO_{4\,(aq)} + Cu_{(s)}}$$

Zinc is more reactive than copper. Hence zinc will displace copper from the solution. As a result, $ZnSO_4$ and Copper are formed. The blue colour of the solution diminishes and disappears. The displaced copper gets deposited at the zinc rod.(The colour of the solution changes to the colour of the newly formed compound(solution).

$$Zn_{(s)} + CuSO_{4(aq)} \rightarrow \mathbf{ZnSO_{4\,(aq)}} + Cu_{(s)}$$

The ionic form of the above reaction is given below.

$$Zn^{0}_{(s)} + Cu^{2+}SO_4^{2-}{}_{(aq)} \rightarrow Zn^{2+}SO_4^{2-}{}_{(aq)} + Cu^{0}_{(s)}$$

Here Zinc undergoes the following reaction,

$$\mathbf{Zn^{0}_{(s)} \rightarrow Zn^{2+} + 2\,\bar{e}}$$

Each ***Zinc atom loses two electrons*** . That is , ***Zinc undergoes Oxidation .***

At the same time ,Cu^{2+} ions receive two electrons to become Cu atoms

$$\mathbf{Cu^{2+} + 2\,\bar{e} \rightarrow Cu^{0}_{(s)}}$$

Each ***Zinc Copper ion gains two electrons*** . That is , Copper ions ***undergo Reduction.***

Since oxidation and redox reactions occur simultaneously , this is a redox reaction.

8 A copper plate is immersed in $AgNO_3$ solution,

(a) Identify and record the changes.

Answer: Copper is more reactive than Silver. Hence copper will displace silver from silver nitrate solution. Silver gets deposited at the copper plate. Since copper nitrate solution is formed, the colour of the solution becomes blue.

$$Cu_{(s)} + AgNO_{3(aq)} \rightarrow Cu(NO_3)_{2\,(aq)} + Ag_{(s)}$$

(b) Write the reaction in ionic form to show that it is a redox reaction

$$Cu_{(s)} + AgNO_{3(aq)} \rightarrow Cu(NO_3)_{2\,(aq)} + Ag_{(s)}$$

$$[Cu^{0}_{(s)} \rightarrow Cu^{2+} + 2\,\bar{e}$$
$$2Ag^{+} + 2\,\bar{e} \rightarrow 2\,Ag^{0}_{(s)}]$$

$$Cu^{0}_{(s)} + 2Ag^{+} + \rightarrow Cu^{2+} + 2\,Ag^{0}_{(s)}$$

Each Copper atom loses two electrons . That is , ***Copper undergoes Oxidation .***
Each Ag^+ ***ion gains one electron*** . Hence Silver ions ***undergo Reduction.***
Since oxidation and redox reactions occur simultaneously , this is a redox reaction.

Displacement reactions

Highly reactive metals can displace less reactive metals from their salt solutions . Such reactions are called displacement reactions. **Displacement reactions are redox reactions.**

9.Certain metals and the salt solutions in which they are dipped are given below.
Identify displacement reaction occurs.

Metal/ Solution	**Mg**	**Cu**	**Zn**	**Fe**	**Ag**	**Al**
Magnesium sulphate						
Copper sulphate						
Zinc sulphate						
Ferrous sulphate						
Silver nitrate						
Aluminium nitrate						

Answer:

Metal/ Solution	**Mg**	**Cu**	**Zn**	**Fe**	**Ag**	**Al**
Magnesium sulphate	**No reaction**	**No reaction**	**No reaction**	**No reaction**	**No reaction**	**No reaction**
Copper sulphate	**Reaction occurs**	**No reaction**	**Reaction occurs**	**Reaction occurs**	**No reaction**	**Reaction occurs**
Zinc sulphate	**Reaction occurs**	**No reaction**	**No reaction**	പ്രവർത്തനമില്ല	**No reaction**	**Reaction occurs**
Ferrous sulphate	**Reaction occurs**	**No reaction**	**Reaction occurs**	പ്രവർത്തനമില്ല	**No reaction**	**Reaction occurs**
Silver nitrate	**Reaction occurs**	**Reaction occurs**	**Reaction occurs**	**Reaction occurs**	**No reaction**	**Reaction occurs**
Aluminium nitrate	**Reaction occurs**	**No reaction**	**No reaction**	**No reaction**	**No reaction**	**No reaction**

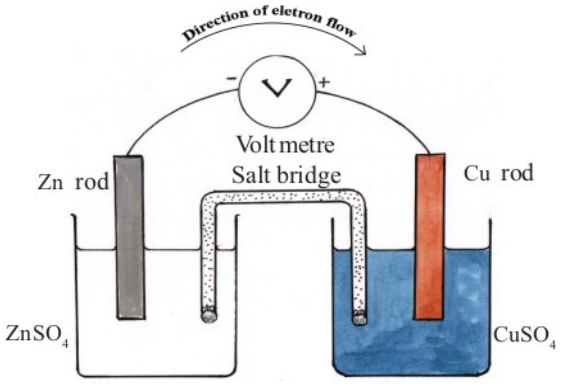
10 . Arrange the above metals in the decreasing order of their reactivity.

Answer: Mg > Al > Zn > Fe > Cu > Ag

Galvanic cell

We have learned that metals differ in their reactivity. Galvanic cell is an arrangement in which the difference in reactivity of metals is used to produce electricity.

Arrange the apparatus as shown in the picture. Take two beakers, one containing 100mL $ZnSO_4$ solution and the second containing the same amount of $CuSO_4$ solution with the same concentration.



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Connection details

Zn rod in $ZnSO_4$ solution , Cu rod in $CuSO_4$ solution.
Negative terminal of voltmeter is connected to the Zn rod and the positive terminal to the Cu rod.
Two solutions in the beakers are connected using a salt bridge
(A long filter paper moistened with KCl solution can be used instead of salt bridge).

Observation

The reading of the voltmeter changes. We can produce electricity using such arrangements.
Here electricity is produced due to chemical change.

Galvanic cell or voltaic cell is an arrangement in which chemical energy is converted into electrical energy by means of a redox reaction.

11. We have understood from the reactivity series that Zn has higher reactivity than Cu.

a. Which electrode has the ability to donate electrons in a cell constructed using these metals?

Answer: Zn

b. Which one can gain electrons?

Answer: Cu

c. Identify the chemical reaction that takes place at the Zn electrode.

(i) $Zn \rightarrow Zn^{2+} + 2\ \bar{e}$
(ii) $Zn^{2+} + 2\ \bar{e} \rightarrow Zn$

Answer: **(i) $Zn \rightarrow Zn^{2+} + 2\ \bar{e}$**

d. Which reaction takes place here? Oxidation/Reduction

Answer: Oxidation

That is, Zn loses two electrons and becomes Zn^{2+} .
An electrode at which oxidation occurs is called anode. **Anode has negative charge in this case.**
The electrons liberated from Zn rod reach the copper electrode through the external circuit . These electrons are received by copper ions in the solution changing them into copper.
a. Write the chemical equation for the reaction taking place at the Cu electrode.

Answer: $Cu^{2+} + 2\,\bar{e} \rightarrow Cu$

b. Which reaction takes place here? Oxidation/Reduction

Answer: Reduction

That is, Cu gains two electrons and becomes Cu .
An electrode at which reduction occurs is called cathode. **Cathode has positive charge in this case.**

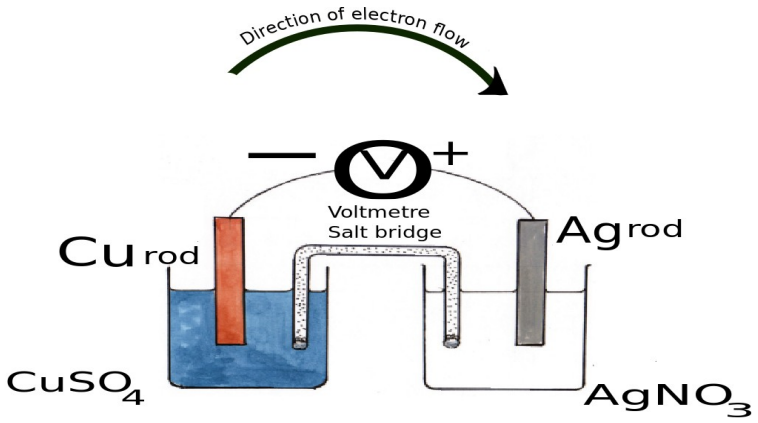
Normally highly reactive metals donate electrons

*The electrode at which **oxidation** occurs is the **anode** and that at which **reduction** occurs is the **cathode. Anode** attains **negative** charge and **cathode** gets **positive** charge.*

The combined form of these reactions can be written as

$$Zn_{(s)} \rightarrow Zn^{2+} + 2\,\bar{e}$$
$$Cu^{2+} + 2\,\bar{e} \rightarrow Cu_{(s)}$$
$$Zn_{(s)} + Cu^{2+} \rightarrow Zn^{2+} + Cu_{(s)}$$

Since oxidation and reduction occur at the same time, it is a redox reaction.
The transfer of electrons produced by this redox reaction causes the flow of electric current in the cell. The direction of electron flow is from anode to cathode.
12. Construct a galvanic cell using silver and copper electrodes.



Anode	Cu	Cu is more reactive than Ag
Cathode	Ag	
Reaction at anode	**$Cu \rightarrow Cu^{2+} + 2\bar{e}$**	2 Ag^{+}ions receive the two electrons
Reaction at cathode	**$Ag^{+} + \bar{e} \rightarrow Ag$**	

13. How many cells can be constructed using Zn , Cu and Ag ?
Find the cathode and anode of the cell.

Answer:

Cell	*Anode*	*Cathode*
Zn – Cu	Zn	Cu
Zn – Ag	Zn	Ag
Ag - Cu	Cu	Ag

Electrolytic cells

Electrolysis of water is a chemical reaction employing electrical energy. We have learned about this chemical reaction in lower classes.

The process of chemical change taking place in an *electrolyte* by passing electricity is known as electrolysis.

Electrolytes are substances which conduct electricity in molten states or in aqueous solutions and undergo chemical change.

Acids, alkalis and salts are electrolytes in their molten state or in aqueous solution.

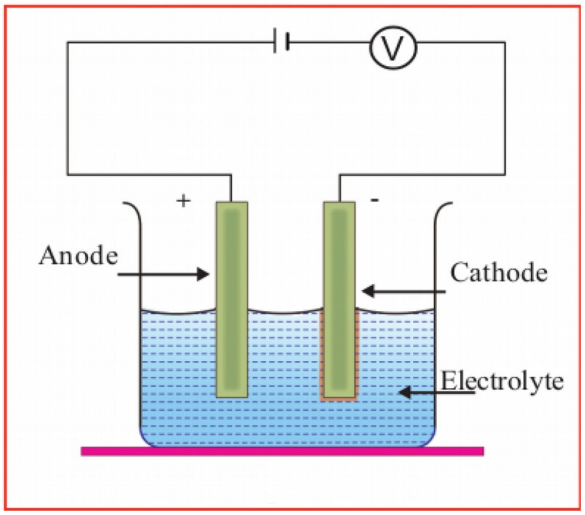
In molten state or in aqueous solution, ions of the electrolytes can move freely. These ions are responsible for the conduction of electricity by the electrolytes.

It was Michael Faraday who gave a scientific explanation for electrolysis for the first time. Electrodes are substances which pass electricity to the electrolytes. During electrolysis one electrode is connected to positive terminal of a battery and the other to the negative terminal. The electrode which is connected to the positive terminal of the battery is the anode. The electrode which is connected to the negative terminal is the cathode.

Electrode at which oxidation takes place is anode and electrode at which reduction take place is cathode. In an electrolytic cell oxidation takes place at the positive electrode and reduction takes place at the negative electrode.

14. Compare and contrast electrochemical cells and electrolytic cells.
Answer:

Electro**chemical** cells	Electro**lytic** cells.
Chemical energy is converted into electrical energy	Electrical energy is used to bring about a chemical change.
Anode is negative	Anode is positive
Cathode is positive	Cathode is negative
Oxidation occurs at anode	Oxidation occurs at anode
Reduction occurs at cathode	Reduction occurs at cathode



15. a.To which electrodes are the positive ions attracted during electrolysis?
Answer: During electrolysis, *positive ions are attracted towards negative electrode*(Cathode)
b.To which electrodes are the negative ions attracted during electrolysis?
Answer: During electrolysis, *negative ions attracted towards positive electrode*(Anode)
c.What changes happen to the ions which are attracted to cathode?
Answer: Positive ions are attracted to cathode. They receive electrons to become atoms or molecules . (Positive ions get reduced at cathode)
d.What changes happen to the ions which are attracted to anode?
Answer: Negative ions are attracted to anode. They donate electrons to become atoms or molecules . (Negative ions get oxidised at anode).

The positive ions which are attracted towards the negative electrode are called cations and negative ions which move towards the anode are called anions.

1. Electrolysis of molten sodium chloride

Sodium chloride in solid state is not an electrical conductor because its ions have no freedom of movement. But electricity flows through molten sodium chloride. When sodium chloride melts, the positively charged sodium ions (Na^+) and the negatively charged chloride ions (Cl^-) are free to move.

$$NaCl \rightarrow Na^+ + Cl^-$$

- Which ion is attracted to the positive electrode (anode)?
  Cl^-
- What is the chemical reaction taking place there?
  $2Cl^- \rightarrow Cl_2 + 2\bar{e}$
- Which is the gas liberated at the anode?
  Cl_2
- Which is the ion attracted to the negative electrode (cathode)?
  Na^+
- Write the change happening to it?
  $Na^+ + \bar{e} \rightarrow Na$
- Which is the metal deposited at the cathode?
  Na

2. Electrolysis of sodium chloride solution

Ions present	Na^+, Cl^-, H_3O^+, OH^- and H_2O
Ions attracted to negative electrode (Cathode)	Na^+,H_3O^+
Reaction at Cathode	$2H_2O + 2\bar{e} \rightarrow \mathbf{H_2} + 2OH^-$
Substance / gas liberated at cathode	Hydrogen
At cathode, reduction *occurs.* ***H_2O has a greater tendency to get reduced ,compared to Na^+ and H_3O^+.*** *Hence hydrogen is liberated at cathode.*	

Ions attracted to positive electrode(Anode)	Cl^-, OH^-
Reaction at Anode	$2Cl^- \rightarrow Cl_2 + 2\bar{e}$
Substance / gas liberated at cathode	Chlorine
At anode, oxidation *occurs.* ***Cl^- has a greater tendency to get oxidised as compared to OH^-.*** *Hence chlorine is liberated at cathode.*	

Electrodes	Chemical change	Products
Anode	$2Cl^- \rightarrow Cl_2 + 2e^-$	Chlorine gas
Cathode	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	Hydrogen gas

As a result of electrolysis of sodium chloride solution, ***chlorine is obtained at the anode, hydrogen is obtained at the cathode and* NaOH *is obtained in the solution.***

Practical utility of electrolysis

1.Production of metals

Metals like ***Potassium, calcium, sodium and aluminium*** are produced by the electrolysis of their compounds.

2.Production of non-metals

Electrolysis can be utilised for the bulk production of non metals.

Hydrogen,oxygen,chlorine etc. are some of the non-metals produced by this method.

3.Production of compounds

Electrolysis can be employed to produce compounds like ***sodium hydroxide, potassium hydroxide*** etc.

4.Refining of Metals

Metals such as copper, gold etc. are refined by electrolysis.

Electroplating

The process of obtaining a coating of one metal over another metal using electrolysis is known as electro plating.

This thin coating is helpful for improving the appearance of the metal and also in preventing metallic corrosion.

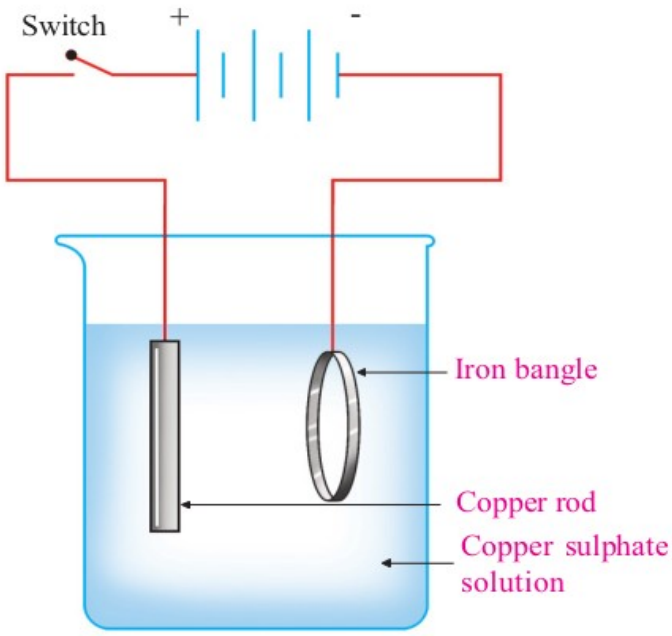
Clean the article to be coated and connect it to the negative terminal of the battery.

The metal to be plated is connected to the positive terminal of the battery.

A salt solution of the metal to be coated is taken as the electrolyte.

Electroplating of some metals			
Metal to be plated	**At positive terminal**	**At negative terminal**	**Electrolyte**
Copper	Copper	The article	Copper sulphate solution
Silver	Silver	The article	Silver nitrate solution **or** sodium cyanide + silver cyanide solution
Gold	Gold	The article	Sodium cyanide + gold cyanide solution

Copper plating on iron bangle



When electricity is passed through the Cu^{2+} ions of the solution, they are attracted to the *negative electrode (iron bangle) or to the cathode.*

● What happens to Cu^{2+} ions at the cathode?

Cu^{2+} ions receive electrons to become Cu atoms(Reduction)

$$Cu^{2+} + 2\bar{e} \rightarrow Cu$$

Cu^{2+} ions are deposited on the iron bangle as Cu atoms.

● Copper undergoes oxidation at the copper plate which is the positive electrode (anode).

$$Cu \rightarrow Cu^{2+} + 2\bar{e}$$

Since both the reactions are similar and opposite in direction , the concentration of ions in the solution remains constant during electrolysis.

Some of the examples for electroplating.

1.Gold plated jewellery.
2.Chromium plated handle bars.
3.Silver plated utensils.

Let us Assess

1.The solution of $ZnSO_4$, $FeSO_4$ and $CuSO_4$ are taken in three different test tubes. Suppose, an iron nail is kept immersed in each one.

a● In which test tube the iron nail undergoes a colour change?

b● What is the reaction taking place here?

c● Justify your answer.

2. Compare the electrolysis of molten potassium chloride and solution of potassium chloride. What are the processes taking place at the cathode and the anode?

3. You are given a solution of $AgNO_3$ a solution of $MgSO_4$,a Ag rod and a Mg ribbon. How can you arrange a Galvanic cell using these? Write down the reactions taking place at the cathode and the anode.

Answers

1.

a. In $CuSO_4$

b. Displacement

c. Iron is more reactive than the metal in salt solution (Cu)

2.Electrolysis Molten potassium chloride

Potassium chloride in solid state is not an electrical conductor because its ions have no freedom of movement. But electricity flows through molten potassium chloride. When potassium chloride melts, the positively charged potassium ions (K^+) and the negatively charged chloride ions (Cl^-) are free to move.

$$KCl \rightarrow K^+ + Cl^-$$

● Which ion is attracted to the positive electrode (anode)?

Cl^-

● What is the chemical reaction taking place there?

$2Cl^- \rightarrow Cl_2 + 2\bar{e}$

● Which is the gas liberated at the anode?

Cl_2

● Which is the ion attracted to the negative electrode (cathode)?

K^+

● Write the change happening to it?

$K^+ + \bar{e} \rightarrow K$

● Which is the metal deposited at the cathode?

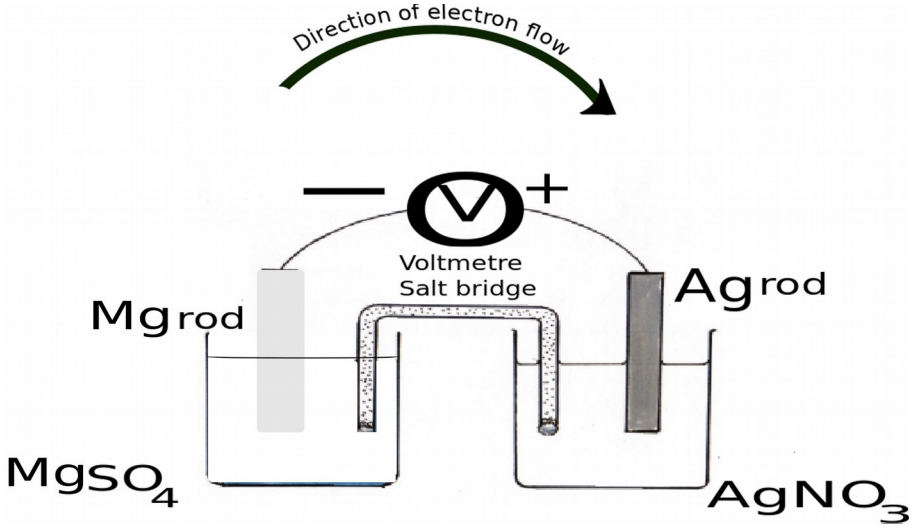
K

Electrolysis of potassium chloride solution

Ions present	K^+, Cl^-, H_3O^+, OH^- and H_2O
Ions attracted to negative electrode (Cathode)	K^+,H_3O^+
Reaction at Cathode	$2H_2O + 2\bar{e} \rightarrow \mathbf{H_2} + 2OH^-$
Substance / gas liberated at cathode	Hydrogen
At cathode, reduction *occurs.* ***H_2O has a greater tendency to get reduced,compared to K^+ and H_3O^+.*** *Hence hydrogen is liberated at cathode.*	

Ions attracted to positive electrode(Anode)	Cl^-, OH^-
Reaction at Anode	$2Cl^- \rightarrow Cl_2 + 2\bar{e}$
Substance / gas liberated at cathode	Chlorine
At anode, oxidation *occurs.* ***Cl^- has a greater tendency to get oxidised as compared to OH^-.*** *Hence chlorine is liberated at cathode.*	

3.



Anode	Mg
Cathode	Ag
Reaction at anode	**$Mg \rightarrow Mg^{2+} + 2\bar{e}$**
Reaction at cathode	**$2Ag^+ + 2\bar{e} \rightarrow 2Ag$**