

Chemical Reactions and Equations

INTRODUCTION

WE KNOW :

- **Change** in nature can be classified into either **physical** or **chemical**.
- **Physical changes** are temporary in nature. The material undergoes change in its shape, size etc, but does not undergo **any change** in its nature.
- **Chemical changes** are permanent in nature. The substance present before the change does not exist by the end of the change and **new substance** is formed.

Let me give a few situations and you need to tell me if changes that occur, is **physical** or **chemical**?



Paper is torn,



Water is converting ice

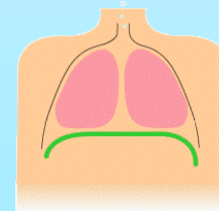
Physical changes?

Situations

Chemical changes?



Paper is burnt



Respiration

Now tell me , which among these are

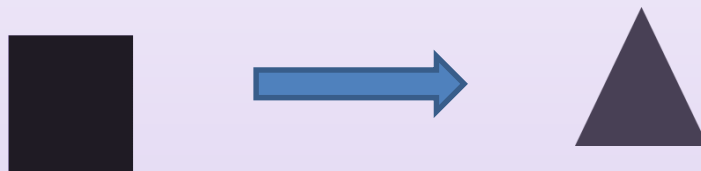
Chemical changes?

Physical changes? and which are

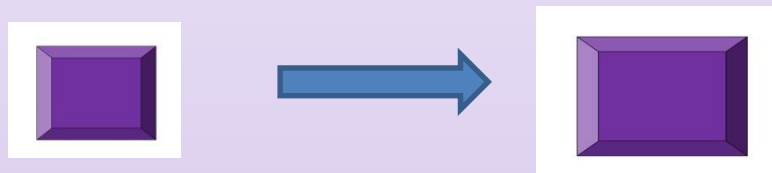
To differentiate we first need to know what physical and chemical changes need.

Physical change is a process in which a substance experiences a change in its physical properties like

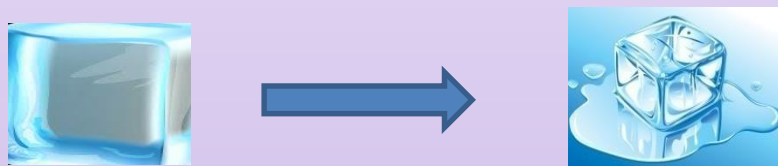
Shape



Size



Appearance or state



Thus there is no change in internal structure or molecular composition in physical changes whereas in chemical changes a new compound is formed where atoms of one or more substances are rearranged or combined like paper is burnt to get ash and in respiration O_2 get converted to CO_2 .

That means whenever a chemical change occurs we say that a chemical reaction takes place and this is **what we study in details.**

- **Chemical reaction:** It is a process in which one form of chemical substances is transformed to another form with new properties.

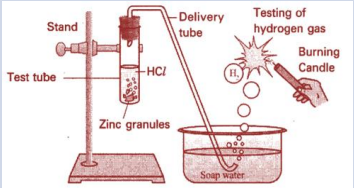
We observe many changes in **our everyday life**, for example:

- **Iron getting rusted**, Fermentation of grapes,
- **Digestion in our body**,
- Milk is left at room temperature during summers,
- Water is added to quicklime,
- **Crackers are burnt.**

We can say that any of the following observations helps us to determine whether a **chemical reaction** has **taken place or not.**

- Change in state
- **Change in colour**
- Evolution of a gas
- **Change in temperature**

You may perhaps be wondering as to what is actually meant by a chemical reaction. How do we come to know that a **chemical reaction** has taken place? Let us perform **some activities** to find the answer to these questions.

ACTIVITY	OBSERVATION	LEARNING
	Change in state- Formation of water	Physical change
	Change in colour- Rusting of iron	Chemical change
	Evolution of a gas-Evolution of hydrogen gas in the reaction of dilute hydrochloric acid and zinc granules.	Chemical change
	Change in temperature- change in colour while cooking	Chemical change

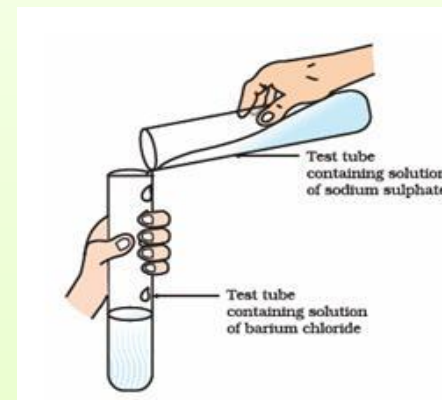
CHEMICAL REACTIONS:

EXAMPLE-1:- FORMATION OF BARIUM SULPHATE AND SODIUM CHLORIDE

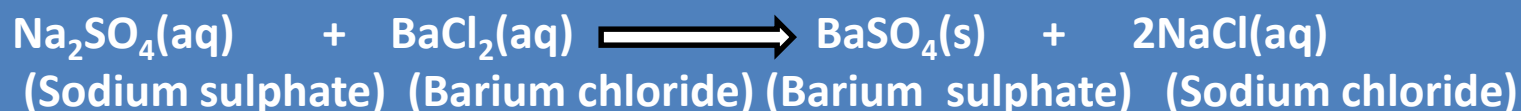
Activity:

- Take 100 ml of water in a beaker and dissolve a small quantity of Sodium Sulphate (Na_2SO_4).
- Take 100 ml of water in another beaker and dissolve a small quantity of Barium Chloride (BaCl_2).
- Add the solutions of both the beakers.

Observation: Note the changes in the colours of the solutions.



Learning Outcome: Sodium Sulphate reacts with Barium Chloride to give white precipitate, Barium Sulphate.



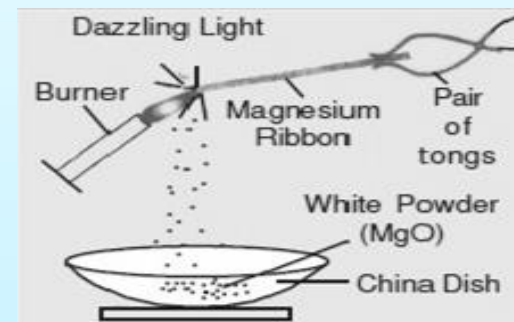
EXAMPLE-2:- BURNING OF MAGNESIUM RIBBON

Activity:

- Take a 3 cm long Magnesium ribbon
- Use a sand paper to rub and clean the ribbon
- Hold the ribbon using a pair of tongs
- Burn the ribbon using a burner

Observation:

- A dazzling white flame is produced when the Magnesium ribbon burns in Oxygen.
- A white powder is formed and collected in a China Dish.



Learning Outcome:

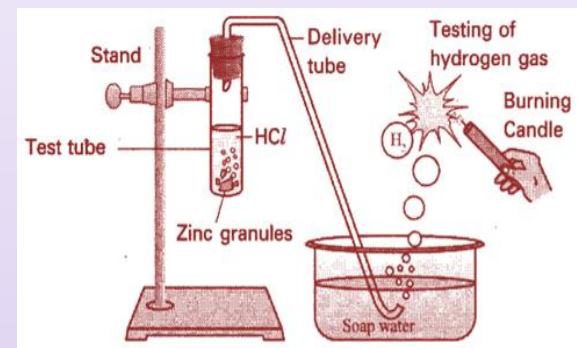
- Here, Magnesium in solid state and Oxygen in gaseous state combine.
- A single product, Magnesium powder is formed due to the reaction between Magnesium and Oxygen present in the air.



EXAMPLE-3:-FORMATION OF H₂ GAS.

Activity:

- Take a few Zinc granules in a boiling tube attach with a stand and a delivery tube which is immersed in soap solution.
- Add 5 ml of dilute hydrochloric acid into the test tube.
- Bring a burning match stick near the mouth of the soap solution.



Observation:

- The match stick is put off with a pop up sound.
- The boiling tube is warm when touched with a finger.

Learning Outcome:

- In both breaking and formation of bonds
- A change in the state and colour of the substance
- Release of heat energy with liberation of gas.



WRITING A CHEMICAL EQUATIONS

- **A chemical equation** is the simplest way of describing a chemical reaction. A chemical equation consists of reactants and products with an arrow mark indicating the **change of reactants to products**.
- **A chemical formula** describes the chemical compounds in terms of **the symbols of the constituent elements** and subscripts to represent the number of atoms of each element in the compound
- If we consider the reaction when a magnesium ribbon is burnt in oxygen, it gets converted to magnesium oxide.

In this reaction, Magnesium (Mg) and oxygen (O₂) are **reactants** and Magnesium oxide (MgO) is the **product**.

Word equation: Magnesium + Oxygen $\longrightarrow$ Magnesium oxide

Replacing the word equation with chemical formulae of the reactants and products, we have,

Chemical equation: $2 \text{Mg(s)} + \text{O}_2 \text{(g)} \longrightarrow 2 \text{MgO (s)}$
(Reactants) (Product)

Example: Zinc metal reacts with dilute HCl to yield ZnCl₂ and liberate Hydrogen gas



Example: Sodium Sulphate reacts with barium Chloride to give white precipitate, Barium sulphate.



Chemical Balancing:

- **In a chemical reaction**, an atom is the smallest particle of an element accounting for its mass.
- According to the **law of conservation of mass** no energy or **no atoms can be created or destroyed**.
- That is, the mass of the reactants and the mass of the products before and after the chemical reaction **should not change**.
- It further means that the number of atoms that are present in the reactant has **to balance the number of atoms that are present in the products**
- In this way, application of the **law of conservation of mass principle** on chemical equations, gives rise to **the need for balancing chemical equations**.

How to balance the chemical equation? (**Hit and trial method**)

- **Step-1:** Represent the reactants and products of the chemical reaction using their correct formula. The unbalanced equation: $\text{Fe} + \text{H}_2\text{O} \longrightarrow \text{Fe}_3\text{O}_4 + \text{H}_2$
- **Step II:** List the number of atoms of different elements present in the unbalanced equation.

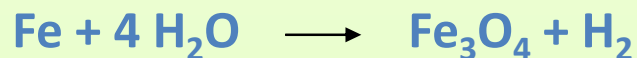
Formula unit

- **Step III:** Place suitable coefficients before the formula units for comparing and balancing the number of atoms of each elements on both sides.

(Note: The formula of reactants and products cannot be changed during the balancing of a chemical equation).

Element	Formula unit	
	LHS	RHS
Fe	1	3
H	2	2
O	1	4

So balancing oxygen atoms, put the coefficient 4 before H₂O in LHS, we get,

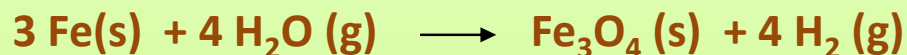


- **Step IV:** Select the next element and balance it. So balancing hydrogen put 4 before H₂ in RHS, we get, $\text{Fe} + 4 \text{H}_2\text{O} \longrightarrow \text{Fe}_3\text{O}_4 + 4\text{H}_2$

- **Step V:** Examine the above equation and pick up the third element which is not balanced. You find that only one element is left to be balanced, that is, iron. So balancing iron put 3 before Fe in LHS and we get, $3 \text{Fe} + 4 \text{H}_2\text{O} \longrightarrow \text{Fe}_3\text{O}_4 + 4\text{H}_2$

- **Step VI:** Finally, to check the correctness of the balanced equation, we count atoms of each element on both sides of the equation.

- **Step VII:** At last to make the equation more informative, write the factors like physical state of reactants and products, heat changes, gas evolved and precipitate formed to the balanced equation. That is :



Other Balancing equations:



- Sometimes the reaction conditions, such as temperature, pressure, catalyst, etc., for the reaction are indicated above and/or below the arrow in the equation. For example –

340 atm



Sunlight



PART-II

TYPES OF CHEMICAL REACTIONS: There are **four types** of chemical reactions.

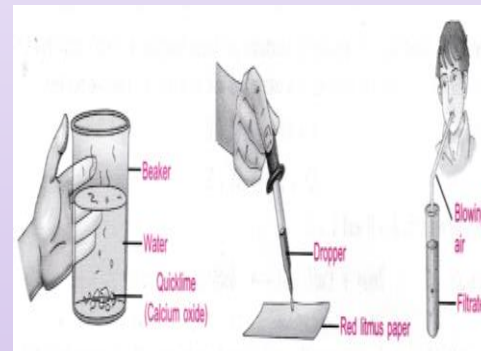
- **1. Combination Reaction:-** A reaction in which one single product is formed from two or more reactants is known as **Combination Reaction**.

General form of this type of reaction is $A + B_2 \longrightarrow AB_2$

Exmple-1: FORMATION OF CALCIUM HYDROXIDE

Activity:

- Take some quick lime (calcium oxide) in a beaker and pour 10 ml of water over quicklime slowly into the beaker
- Stir it with a clean glass rod and **touch** the outer surface of beaker during the reaction
- Put a **red litmus paper** into the beaker after the reaction
- Filter the mixture of beaker and take about 5 ml of filtrate in a test tube and blow air through the liquid.



Observation:

- A new substance is formed with a hissing sound.
- Outer surface of beaker is hot.
- Red litmus paper turns **blue**
- On passing CO₂ through the clear filtrate, it turns milky.

Learning Outcome:

- Water reacts with quicklime to form a **new substance**.
- As heat is evolved, the reaction between water and quicklime is **exothermic**.
- The new substance formed the reaction between water and quicklime is **basic** in nature. $\text{CaO(s)} + \text{H}_2\text{O(l)} \longrightarrow \text{Ca(OH)}_2\text{(aq)} + \text{Heat}$
- The new substance formed is calcium hydroxide.

Other examples with respective equation:

- Burning of coal: $\text{C(s)} + \text{O}_2\text{(g)} \longrightarrow \text{CO}_2\text{(g)} + \text{heat}$
- Formation of water from H₂(g) and O₂(g):



We also observed that a large amount of heat is evolved. This makes the reaction **mixture warm**. Reactions in which heat is released along with the formation of products are called exothermic chemical reactions.

Other examples of exothermic reactions are –

- (i) Burning of natural gas



- (ii) **Do you know that respiration is an exothermic process?**

We all know that we need energy to stay alive. We get this energy from the food we eat. **During digestion, food is broken down into simpler substances.** For example, rice, potatoes and bread contain carbohydrates. These carbohydrates are broken down to form glucose. This glucose combines with oxygen in the cells of our body and provides energy.



- (iii) The decomposition of vegetable matter into compost is also an example of an **exothermic reaction.**
- **2. Decomposition Reaction**

If a single reactant breaks down to give a simpler products then it is called a **decomposition reaction**

General form of this type of reaction is $\text{AB} \longrightarrow \text{A} + \text{B}$

HEATING OF CALCIUM CARBONATE

Activity:

- Take calcium carbonate or lime stone in a test tube
- Place a delivery tube with a cork on the tube
- Heat the boiling tube using burner
- Put a **match stick near the open end** of the delivery tube or pass it through lime water.

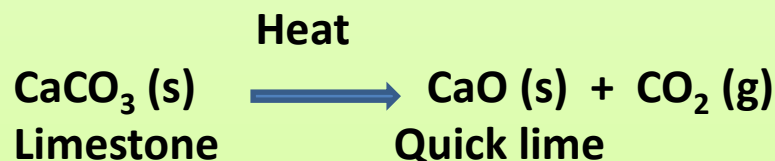


Observation:

- A gas evolves from the test tube and passes all along the delivery tube
- The gas puts off the burning match stick
- A **white precipitate** is formed.

Learning Outcome:

- Calcium carbonate decomposes and it is thermal decomposition
- It is an **endothermic reaction**.
- The gas coming out of the boiling tube **which puts off the burning match stick**, is carbon dioxide as again it formed white precipitate (CaCO_3) with lime water.



HEATING OF FERROUS SULPHATE

Activity:

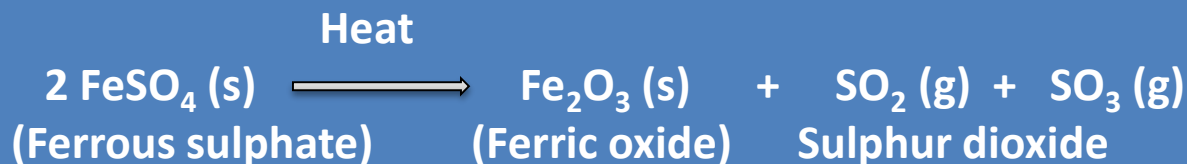
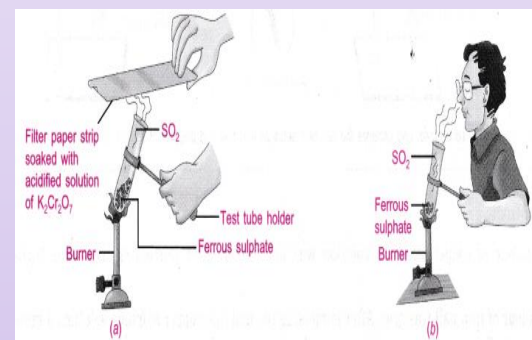
- Take about 2 gram crystal of ferrous sulphate in a boiling test tube and note the colour of the crystal and heat.
- Bring a moist blue litmus paper in contact with the evolved gas.
- Soak a strip of filter paper in acidified solution of potassium dichromate and bring it in contact with the gas.

Observation:

- The crystals are green in colour and change to brown.
- Colourless gas with a smell of burning sulphur is evolved.
- Moist blue litmus paper turns red.
- The orange colour of strip changes to green.

Learning Outcome:

- The colour of ferrous sulphate is green
- New substances are formed. The gas coming out is acidic.
- Sulphur dioxide gas is evolved.



HEATING OF LEAD NITRATE

Activity:

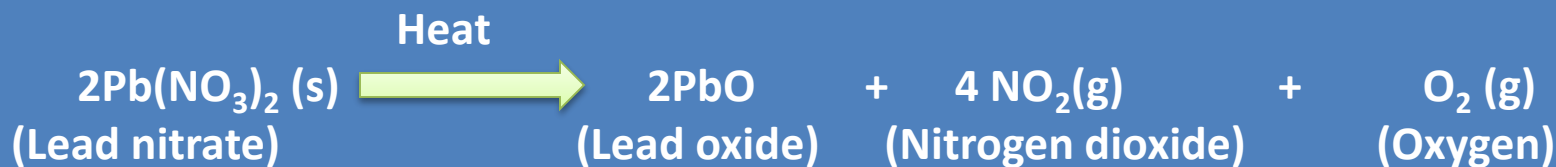
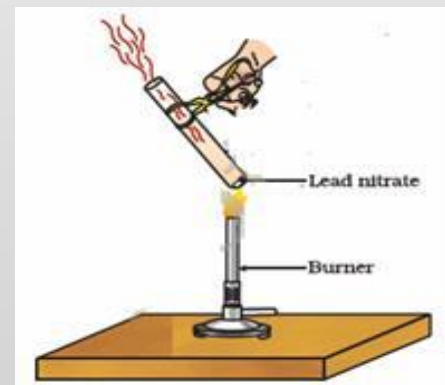
- Take about 0.5 gram of Lead Nitrate in a boiling test tube
- Heat the boiling tube containing Lead Nitrate using burner.

Observation:

- A gas evolves from the boiling tube.
- The colour of the gas is brown.
- A white precipitate is formed at the bottom of the boiling tube.

Learning Outcome:

- Lead nitrate decomposes. It is thermal decomposition and endothermic reaction.
- Lead Oxide is formed as precipitate.
- The brown colour gas coming out of the boiling tube is Nitrogen dioxide.



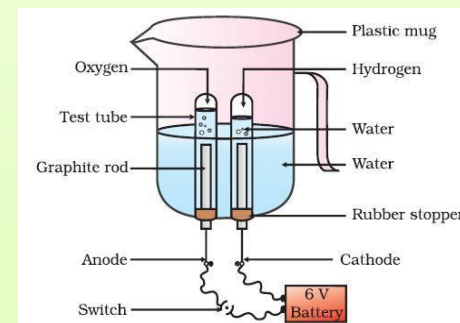
ELECTROLYSIS OF WATER

Activity:

- After drilling Insert two carbon electrodes into these holes of **mug** using two rubber stoppers and Connect the two electrodes **to a 6 V battery**.
- Immerse the electrodes in water by filling the mug with the water with few drops **of dilute sulphuric acid**.
- Invert two water filled test tubes over the electrodes and **Switch on the circuit**.
- Carefully remove the test tubes completely filled with gases.
- **Bring a burning candle** near the mouth of both the tubes to test the gases.

Observation:

- Gas bubbles appear in both the test tubes
- There is a rise in the level of water in both the **tubes to different extents**.
- The candle continues to burn in the presence of the gas coming from the first tube.
- The **candle puts off by the gas** coming from the second test tube.



Learning Outcome:

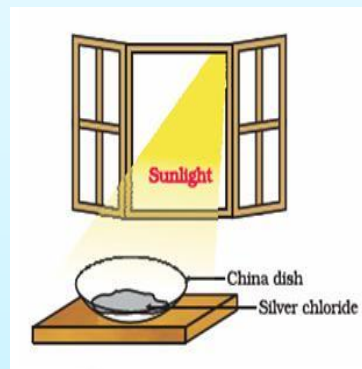
- Hydrogen is the first product which **puts off the candle flame**.
- Oxygen is the second product which **allows the candle to burn**.



SILVER BROMIDE IN SUNLIGHT

Activity:

- Take silver Chloride in a watch glass
- Observe the **colour before and after.**
- Place the watch glass under sun light for some time.



Observation: The **colour** of the chemical changes.

Learning Outcome:

- In this reaction, the compound Silver Chloride decomposes under sunlight.
- This is why, it is **called a photochemical reaction** and it is **endothermic reaction.**
- **Silver is the first product** in the form of **grey colour.**



- **Chloride is the second product** liberated in the form of gas.

Silver bromide also behaves in the same way.



The above reactions are used in **black and white photography.**

• 3. Displacement Reaction

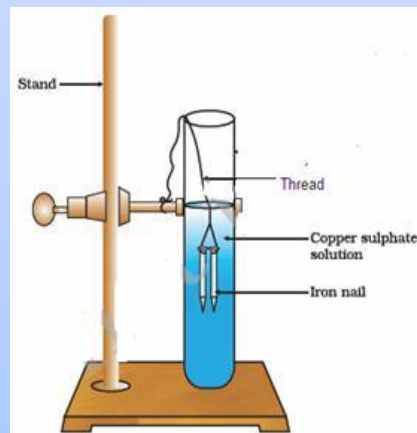
Displacement reaction is a chemical reaction in which a more reactive element displaces a less reactive element from its compound. Both metals and non-metals take part in displacement reactions. This reactivity depends on reactivity series.

Example : Reaction of iron nails with copper sulphate solution.

Activity:

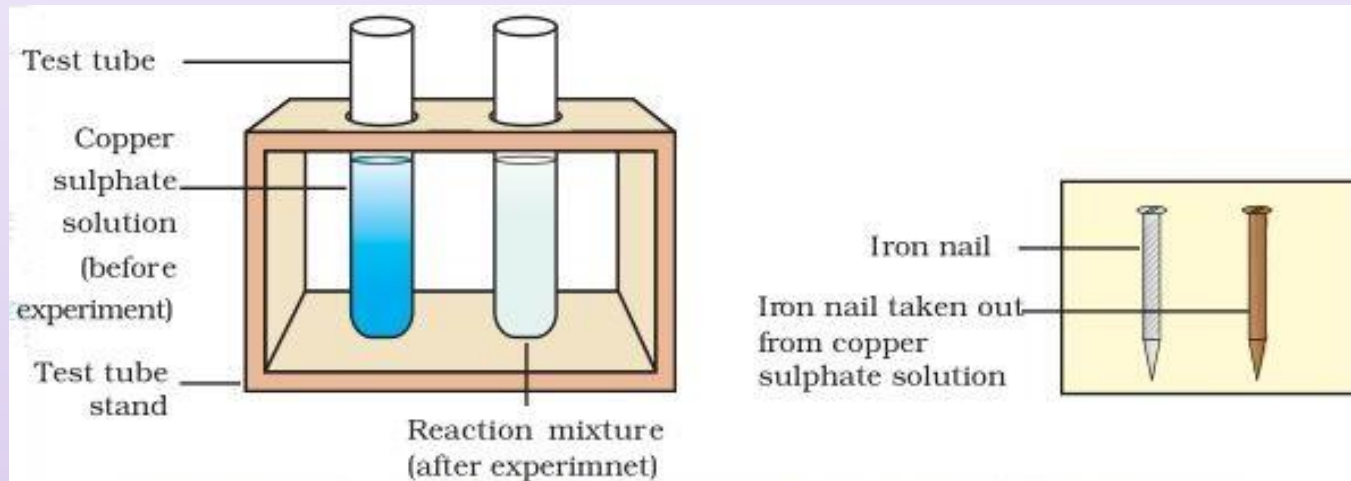
- Clean Three iron nails using sand paper.
- Take two test tubes and mark them as A and B
- Take 10 ml of copper sulphate solution in the test tubes A
- Tie two nails with the thread and dip into the solution of test tube A and keep undisturbed for 20 minutes.
- The other nail taken in test tube B as reference.
- Take the nails out from test tube A.
- Compare the colour of the iron nails and solution in test tube A

potassium	most reactive	K
sodium		Na
calcium		Ca
magnesium		Mg
aluminium		Al
carbon		C
zinc		Zn
iron		Fe
tin		Sn
lead		Pb
hydrogen		H
copper		Cu
silver		Ag
gold		Au
platinum	least reactive	Pt



Observation:

- The nail taken from the test tube A turns brownish
- The colour of the copper sulphate solution fades from being blue in colour initially.



Learning Outcome:

- Here, the element iron in solid state reacts with the compound copper sulphate in aqueous state and gives aqueous iron sulphate and solid copper.
- The element iron being a more active element displaces copper from its place in copper sulphate reactant and forms the product iron sulphate.



- Other examples:
- $$\text{Zn(s)} + \text{CuSO}_4\text{(aq)} \longrightarrow \text{ZnSO}_4\text{(aq)} + \text{Cu(s)}$$

(Copper sulphate) (Zinc sulphate)
- $$\text{Pb(s)} + \text{CuCl}_2\text{(aq)} \longrightarrow \text{PbCl}_2\text{(aq)} + \text{Cu(s)}$$

(Copper chloride) (Lead chloride)
- With the help of reactivity series find out where displacement reaction occurs or not?

METAL	MgSO ₄	ZnSO ₄	FeSO ₄	CuSO ₄
Mg				
Zn				
Fe				
Cu				

X = No Reaction

Yes = Displacement reaction

• 4. Double Displacement Reaction

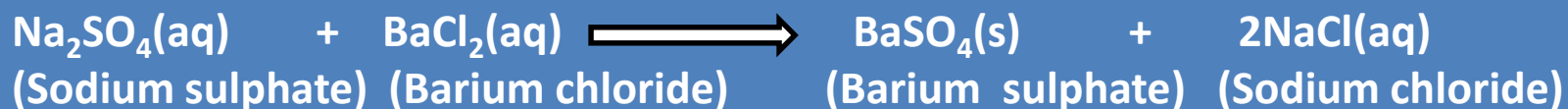
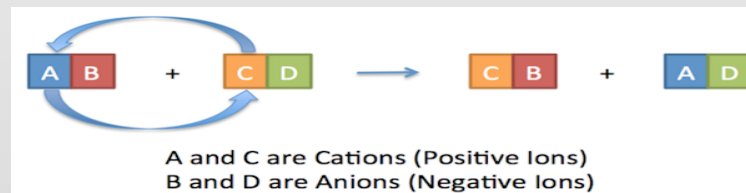
Double displacement reactions may be defined as the chemical reactions in which one component each of both the reacting molecules is **exchanged to form the products**. During this reaction, the **cations and anions of two different** compounds switch places, forming two entirely different compounds.

Activity:

- Take 100 ml of water in a beaker and dissolve a small quantity of Sodium Sulphate (Na_2SO_4).
- Take 100 ml of water in another beaker and dissolve a small quantity of Barium Chloride (BaCl_2).
- Add the solutions of both the beakers.

Observation: Note the changes in the colours of the solutions.

Learning Outcome: Sodium Sulphate reacts with Barium Chloride to give **white precipitate**, Barium Sulphate.

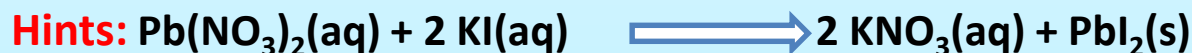


In this reaction, You will observe that a **white substance**, which is insoluble in water, is formed. This insoluble substance formed is known as a precipitate. Any reaction that produces a precipitate can be **called a precipitation reaction**.

- **Recall Activity :**

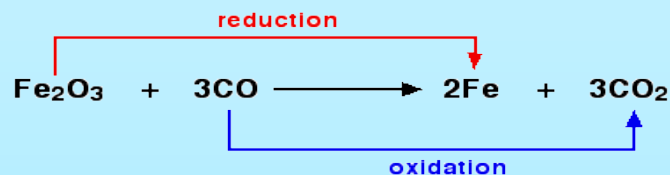
You are given test tube, the solutions of lead(II) nitrate and potassium iodide and are instructed to mix together in a test tube. Give answers by activity :

- (i) What was the colour of the precipitate formed? Can you name the compound precipitated?
- (ii) Write the balanced chemical equation for this reaction.
- (iii) Is this also a double displacement reaction?



- **5. Oxidation and Reduction (Redox Reaction)**

- The chemical reactions involving **addition of Oxygen and removal of Hydrogen** are called **Oxidation reaction**.



- The chemical reactions involving **addition of Hydrogen and removal of Oxygen** are called **Reduction reaction**.

Interestingly, Oxidation and reduction reactions occur at the same time. Hence, such reactions are **called Redox reactions**.

REACTION BETWEEN COPPER AND OXYGEN

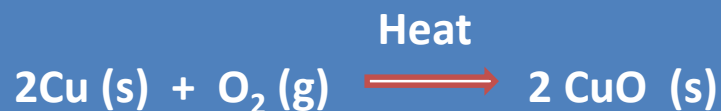
Oxidation activity:

- Take 1 gram of Copper powder in brown colour in a china dish.
- Place the dish on tripod stand with wire gauze.
- Heat the Copper powder using bunsen burner.

Oxidation observation: The colour of the Copper powder turns black from brown.

Oxidation learning:

- Here, the solid Copper powder burns in the presence of Oxygen or air.
- The product formed is the black Copper Oxide.
- The reactant Copper gained Oxygen in this reaction, and hence it is called Oxidation.

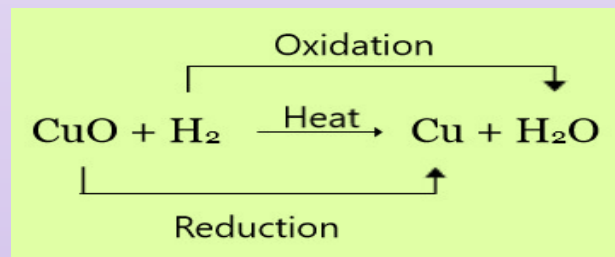


REACTION BETWEEN COPPER OXIDE AND HYDROGEN

Reduction Activity:

- Take the black Copper Oxide in a glass tube supported by two stands on its both ends.
- Put corks with nozzle in them on the two ends.
- Pass Hydrogen gas from nozzle of the first cork and allow the gas to leave from the nozzle of the cork on the other end.
- Use a bunsen burner to heat the black Copper Oxide powder in the presence of Hydrogen gas.

Reduction observation: The black colour of the Copper Powder changes to brown.



Reduction learning:

- Copper Oxide gains Hydrogen or loss Oxygen and turns into Copper again. Hence it is a reduction.
- In this reaction, Copper Oxide (CuO) is said to be reduced and Hydrogen (H₂) is oxidized.
- Together, the oxidation and reduction reactions form a Redox reaction.

Other examples:

- $\text{ZnO} + \text{C} \longrightarrow \text{Zn} + \text{CO}$
- $\text{MnO}_2 + 4 \text{HCl} \longrightarrow \text{MnCl}_2 + 2 \text{H}_2\text{O} + \text{Cl}_2$

Recall Activity: You are given Mg ribbon and you are burning in air. You observe that magnesium ribbon burnt with a dazzling flame in air (oxygen) and changed into a white substance.

- (i) What is the compound formed?
- (ii) Is magnesium being oxidized or reduced in this reaction?

THE EFFECTS OF OXIDATION REACTIONS IN EVERYDAY LIFE?

Yes, there are quite many effects. Let me enlist them here.

- **Browning of cut surfaces of fruits.**
- Formation of metal oxide on metal like iron rust, black coating on silver items, green coating on copper item (**Called Corrosion**- The process in which metals are eaten up gradually by the action of air ,moisture or chemicals on their surface.)
- **Burning of crackers**
- **Rancidity:** The spoiling of food materials due to slow oxidation is called **Rancidity**. Food materials containing oil or fat in them smell or taste foul when left uncovered for a long time.

