

Objective

To study the reaction of metals with water under different temperature conditions.

Theory

Metals

Metals are defined as elements that naturally develop on Earth's surface. They are strong, long-lasting substances that possess positive ions and are characterised by certain physical and chemical properties. They exhibit strong thermal and electrical conductivity, malleability, ductility, high-light reflection, and often have high melting and boiling points.

Most abundant elements like iron, aluminium, calcium, potassium, and magnesium, as well as some metals like copper, gold, platinum, and silver, form in the free state and are known as metal salts. When metals react with water and undergo several chemical reactions, it is essential for industrial processes, safety measures, and environmental assessments.

Physical and Chemical Properties of Metals

Physical Properties of Metals:

- Conductivity
- Ductility
- Lustrous
- Hardness
- Malleability
- Sonorous
- Density
- Melting and Boiling Points
- Thermal Expansion

Metallic Lustre: Metals have a shining surface.

Malleability: The ability to pound a metal into thin sheets.

Ductility: Metals can be drawn into thin wires.

Hardness: Metals vary in hardness.

Conductivity: Heat and electricity are well-conducted through metals.

Melting Point: Metals have high melting points.

Chemical Properties of Metals:

- Reactivity
- Valence Electrons
- Oxide Formation
- Ionisation
- Reducing Agents
- Corrosion
- Alloy Formation

Reactivity: Metals exhibit varying degrees of reactivity with other substances.

Ionisation: Metals ionise by losing electrons, forming positive ions.

Oxidation: Metals can undergo oxidation reactions, forming metal oxides.

Redox Reactions: Metals can act as reducing agents in redox reactions, donating electrons to other substances.

Corrosion: Some metals corrode when exposed to oxygen and moisture, forming metal oxides or hydroxides.

Alloy Formation: Metals can form alloys when combined with other elements, altering their properties.

Reaction with Acids: Metals react with acids to form metal salts and hydrogen gas.

Reaction with Water: Some metals react with water to form metal hydroxides or oxides and release hydrogen gas.

PHYSICAL PROPERTIES – Comparative analysis among different metals

Metal	Hardness	Malleability	Ductility	Electrical conductivity	Density	Melting point	Boiling point
Aluminium	Soft	Yes	Yes	Good conductor	Low	660 °C	2519°C
Copper	Moderately soft	Yes	Yes	Good conductor	High	1085 °C	2562 °C
Calcium	Very soft	Yes	Yes	Poor conductor	Moderate	842 °C	1494 °C
Gold	Soft	Yes	Yes	Good conductor	High	1064 °C	2857 °C
Iron	Moderately hard	Yes	Yes	Good conductor	High	1538 °C	2862 °C

Magnesium	Soft	Yes	Yes	Good conductor	Low	650 °C	1090 °C
Platinum	Moderately hard	Yes	Yes	Good conductor	High	1769 °C	3827 °C
Potassium	Extremely soft	Yes	Yes	Good conductor	High	63.5 °C	759 °C
Silver	Soft	Yes	Yes	Good conductor	High	961 °C	2162 °C
Sodium	Soft	Yes	Yes	Good conductor	Low	97.7 °C	883 °C
Zinc	Moderately hard	Yes	Yes	Good conductor	Moderate	419.5°C	907 °C

CHEMICAL PROPERTIES – Comparative analysis among different metals

Electrons

The chemical properties of metals are based on the reactions with substances like air and water, and generally, metals possess 1, 2, or 3 electrons on the outer shell, which reacts with water and air.

Chemical Bonding

Metals have a specific bonding called metallic bonding that helps with delocalisation, which leads to electrical and heat conductivity.

METALS REACT WITH WATER

Have you ever wondered what happens when metals meet water?! Let's explore how metals react with water, varying in temperature based on the water's temperature, including cold, hot, and steam, for fascinating scientific discoveries. While many metals remain unreactive, alkali metals exhibit vigorous reactions with water.

Metal + Water → Metal oxide + Hydrogen

Metal oxide + Water → Metal hydroxide

Cold water reactions

Sodium, potassium, and calcium readily react with cold water to produce hydroxides.

Hot water reactions

Magnesium does not react with cold water but reacts with hot water to produce hydroxide.

Steam reactions

Zinc and aluminium react only with steam, to produce oxides. Iron's reaction with cold water is very slow and can take days. However, iron oxide is formed when steam and iron combine.

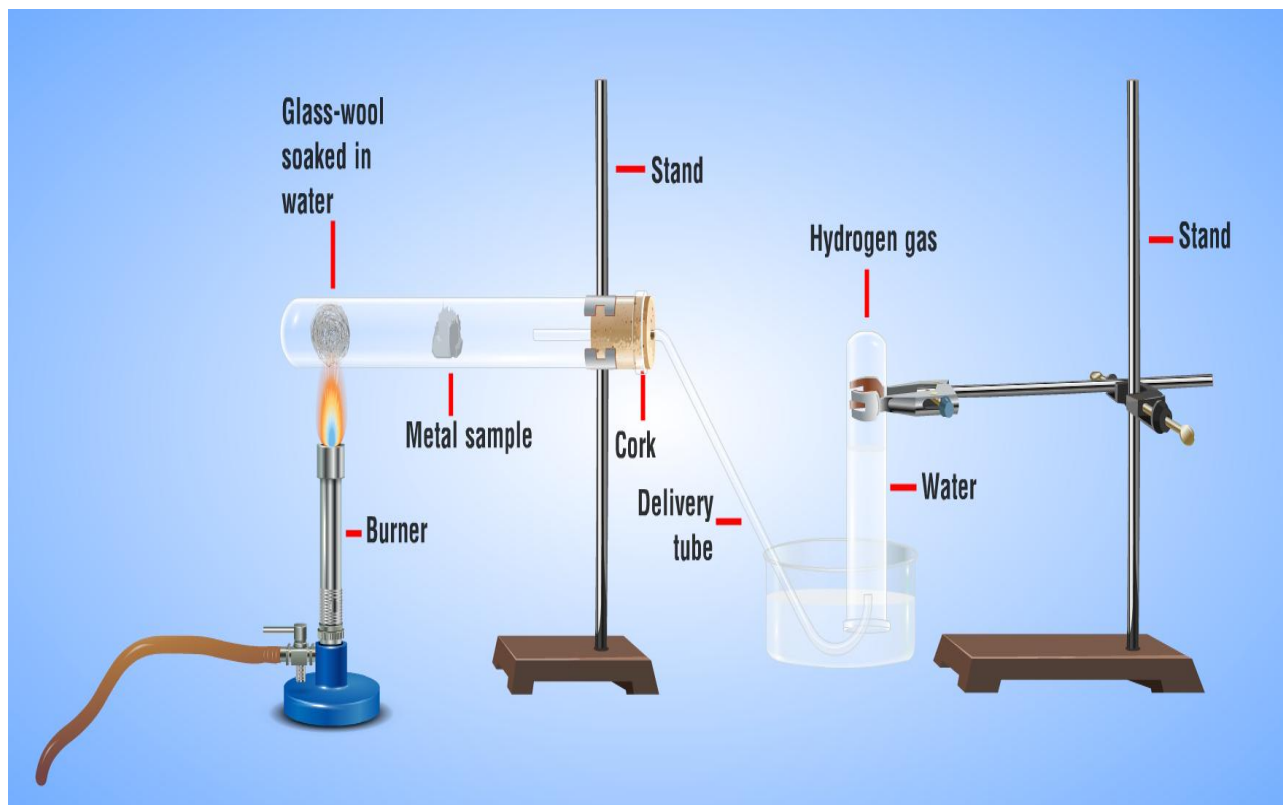
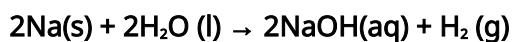


Fig.1 Apparatus demonstrates how metals react with steam

The generated oxides are transferred and captured as air bubbles by using another test tube, and the produced hydrogen gas is stored on the top of the test tube.

Reaction of Sodium with water

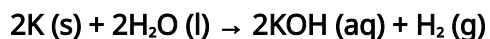
The reaction between sodium and water is highly vigorous. Hydrogen and sodium hydroxide are formed when sodium and water react. There is a strong exothermic reaction. The reaction mixture catches fire because the reaction is producing so much heat.



Note: Due to its strong reactivity, sodium is kept under kerosene when being stored to prevent it from reacting with any possible atmospheric moisture. This is done to avoid any accidental fire.

Reaction of Potassium with water

When potassium reacts with water, then potassium hydroxide and hydrogen gas are formed. Lot of heat is produced during this reaction.



Reaction of Calcium with water

When calcium reacts with water, then calcium hydroxide and hydrogen gas are produced. This too is an exothermic reaction. Calcium begins to float when hydrogen gas bubbles attach themselves to metal.

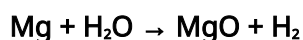


Reaction of Magnesium with water

Magnesium does not react with cold water. When it reacts with hot water, hydrogen gas and magnesium hydroxide are formed. It also starts floating due to the bubbles of hydrogen gas sticking to its surface.

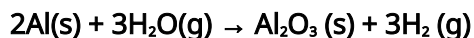


The reaction quickens when magnesium is exposed to steam. Magnesium oxide and hydrogen gas are formed, in this reaction.



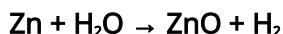
Reaction of Aluminium with water

Aluminium does not react with cold or hot water. However, hydrogen gas and aluminium oxide are formed when steam is passed over aluminium.



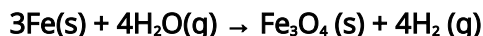
Reaction of Zinc with water

Neither hot nor cold water will react with zinc. When steam is passed over zinc metal, zinc oxide and hydrogen gas are formed.



Reaction of Iron with water

Iron and cold water react too slowly. Rust is the result of iron reacting with atmospheric moisture (iron oxide). However, this response is extremely slow. Hydrogen gas and iron oxide are formed when steam is passed over iron.



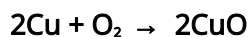
METALS REACT WITH AIR

All metals are combined with oxygen to produce metal oxides.



Example:

When copper is heated and combined with oxygen, copper (II) oxide is produced, and is generally called black oxide.

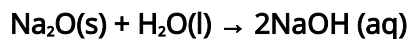


(Copper) (Copper (II) oxide)

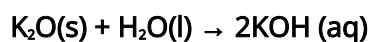
Most metal oxides are insoluble in water, but some of the metal oxides are dissolved in water to produce alkalis.

Example:

For example, Sodium oxide and potassium oxide dissolve in water to produce alkalis of sodium hydroxide and potassium hydroxide.



(Sodium oxide) (Sodium hydroxide)



(Potassium oxide) (Potassium hydroxide)

OTHER CHEMICAL PROPERTIES OF METALS

Metals	Ionization	Corrosion	Redox reaction	Alloy formation	Oxidation
Aluminium	Loses electrons readily	Resists corrosion due to the protective oxide layer	Primarily acts as a reducing agent	Forms alloys with copper and magnesium	Forms a protective oxide layer $\text{Al} + \text{O}_2 \rightarrow \text{Al}_2\text{O}_3$
Calcium	Loses electrons readily	Can corrode in moist environments	Primarily acts as a reducing agent	Forms alloys with magnesium	Forms oxides $\text{Ca} + \text{O}_2 \rightarrow \text{CaO}$
Iron	Loses electrons readily	Rusts in the presence of oxygen and moisture	It is a dual-purpose agent that can reduce and oxidize.	Forms alloys with carbon and chromium	Forms oxides $\text{Fe} + \text{O}_2 \rightarrow \text{FeO, Fe}_2\text{O}_3$
Magnesium	Loses electrons readily	Can corrode in moist environments	Primarily acts as a reducing agent	Forms alloys with aluminium	Forms oxides $\text{Mg} + \text{O}_2 \rightarrow \text{MgO}$
Potassium	Loses electron very easily	Can react with air and moisture	Primarily acts as a reducing agent	Forms alloys with sodium	Forms oxides $\text{K} + \text{O}_2 \rightarrow \text{K}_2\text{O}$

Non-Reactive Metals

At any temperature, lead, copper, silver, and gold do not react with water.

Safety Considerations:

- Metal-water reactions can release a lot of heat (exothermic) and produce flammable gases.
- Proper handling techniques, such as wearing safety goggles and gloves, are essential when conducting these experiments.
- Ensure proper ventilation in the laboratory to prevent the accumulation of flammable gases.
- Use appropriate protective measures, such as fume hoods or safety shields, to minimise the risk of exposure to hazardous substances.
- Always have a fire extinguisher and emergency eyewash station readily available in case of accidents.
- Follow safety protocols and guidelines provided by instructors or supervisors when conducting experiments involving metal-water reactions.
- Immediately report any accidents or spills to the instructor or supervisor for prompt action.

Learning Outcomes

- Students understand the term "Metal" and their physical and chemical properties.
- Students understand the reactions of different metals with water under various conditions.
- Students are better able to perform the experiment in the real lab after experiencing it in the virtual lab.