

Metals and Non- Metals

Concepts

(i) Classification of elements (ii) Physical properties of metals (iii) Chemical properties of metals (iv) Physical properties of non-metals (v) Chemical properties of non-metals

Classification of elements

Today, some 117 chemical elements are known but only 103 out of them are well characterized in terms of their properties. The systematic classification of these 103 elements reveals that 90 elements are solids, 2 are liquids and 11 are gases. Further, 79 of them are metals, 17 are non-metals and 7 are metalloids. Metals differ from non-metals in many respects. In fact, metals and non-metals are two extremes as regards their properties.

Metals occupy the bulk of the periodic table, while non-metallic elements can only be found on the right-hand-side of the Periodic Table. A diagonal line, drawn from boron (B) to polonium (Po), separates the metals from the nonmetals. Most elements on this line are metalloids, sometimes called semiconductors. This is because these elements exhibit electrical properties intermediate to both, conductors and insulators. Elements to the lower left of this division - line are called metals, while elements to the upper right of the division - line are called non-metals.

On the basis of their general physical and chemical properties, every element in the periodic table can be termed either a metal or a nonmetal. (A few elements with intermediate properties are referred to as metalloids).

Physical properties of metals

Metals show following general physical properties.

- 1) Physical state** - Metals are solids at room temperature e.g. sodium, aluminium, potassium, magnesium. There are exception to this. Mercury and gallium are metals but they are in liquid state at room temperature.
- 2) Luster** – Metals have a shining surface called luster when freshly prepared. They have a quality of reflecting light from their surface and they can be polished e.g. metals like gold, silver, copper show this property.

- 3) **Malleability** - Metals can be beaten into thin sheets. This property is called malleability. Due to this property, metals can be rolled into sheets e.g. aluminium, copper, zinc can be beaten into sheets.
- 4) **Ductility** - Metals can be drawn into thin wires. This property is called ductility. For example, 100 grams of silver can be drawn into a thin wire about 200 meters long.
- 5) **Hardness** – Metals are generally hard e.g. iron, cobalt, nickel. There are few exceptions to this. Sodium and potassium are soft and they can be cut with a knife.
- 6) **Conduction** – Generally, metals are good conductors of heat and electricity because they have free electrons. Silver and copper are the two best conductors. Relatively, lead and bismuth are poor conductors of heat and electricity.
- 7) **Density** - Metals generally have high density and they are heavy. Iridium and osmium have the highest densities while lithium has the lowest density.
- 8) **Melting and boiling point** – Metals usually have high melting point and boiling point. For example, iron, cobalt and nickel have high melting and boiling point. Tungsten has the highest melting point. There are some exceptions to this. For example, most of the alkali metals have low melting and boiling point.
- 9) **Tensile strength** – Most of the metals possess high tensile strength i.e. tenacity. For example, iron, titanium, some alloys have high tensile strength. However, elements like sodium, potassium and mercury do not possess tenacity.

Activity 1 - Collect some samples of metal pieces of iron, copper, aluminium and magnesium. Clean them with sand paper. Look at their appearance. They have a shiny appearance. This shows that metals, in general, have shining appearance when freshly prepared or rubbed.

Activity 2 - Take small pieces of zinc, copper and lead metals which are about 2 to 3 inches in length and about 0.5 to 1 cm thick. Keep each metal piece on a block of iron and hammer it hard 5 to 6 times from the top. What do you observe? The metal samples are flattened. This shows that metals are malleable.

Activity 3 - Collect some metals in the form of wire. For example, aluminium, magnesium, tin, copper, lead are available in the form of wires. This shows that metals are ductile i.e. they can be drawn in the form of wires.

Activity 4 - Take a rod of aluminium or copper about 6 to 8 inches in length. Heat one end of this rod for about 2 to 3 minutes. You feel that the other end of the rod has become hot. This shows that metals are good conductors of heat.

Chemical properties of metals

Metals show following general chemical properties.

- 1) **Electron configuration** – Metals usually have 1 to 3 electrons in the outermost shell of their atom. For example, sodium, magnesium and aluminium have 1, 2 and 3 electrons respectively in the outermost shell of their atom.
- 2) **Valency** - Metal atoms can lose 1 to 3 electrons in their outermost shell and show valencies 1 to 3.
- 3) **Electrochemical nature** - Metal atoms have tendency to lose electrons and form cations. This tendency is called the electropositive nature. Metals generally have moderate to high electropositive nature. For example, Na, Mg and Al have high electropositive character while Zn, Cd, Sn and Pb have moderate electropositive nature.
- 4) **Electronegativity** - Metals generally have low electronegativity i.e. tendency to attract electrons in the state of molecule. For example, metals like Ca, Mg, Al, Zn have low electronegativity.
- 5) **Formation of oxides** – Metals form oxides which are generally ionic and basic in nature. If this basic oxide dissolves in water, it forms an alkali. For example, oxides of Na, K and Ca viz. Na_2O , K_2O and CaO are highly basic in nature and when dissolved in water, they form alkalies NaOH , KOH and Ca(OH)_2 . The oxides react with acids to form salts. Oxides of metals like Pb, Zn, Al and Sn viz. PbO_2 , ZnO , Al_2O_3 and SnO_2 are moderately basic and they react with acids as well as alkalies to form salt. So such oxides are called amphoteric oxides. The oxides Sb_2O_3 and Cr_2O_3 are exceptions and they are acidic in nature.
- 6) **Reducing agent** - All metals act as reducing agents. Strongly electropositive metals like Mg, Al and Cr act as strong reducing agents while moderately electropositive elements like Zn, Cd and Sn act as moderate reducing agents.
- 7) **Reaction with water** - Strongly electropositive metals like Na and K react even with cold water to produce their hydroxides and they evolve hydrogen gas. The heat evolved is not sufficient for the hydrogen to catch fire. Metals like Mg do not react with cold water. They react only with hot water to form hydroxide evolving hydrogen. The elements less electropositive than Na, K and Mg like Al, Fe and Zn do not react with cold or hot water. These hot metals react only with steam to form their oxides and hydrogen. However, metals like Cu, Ag and Au which are below hydrogen in the activity series do not react with water at all.
- 8) **Reaction with acids** - Highly reactive metals like Na, Mg and K react with dilute mineral acids like HCl or H_2SO_4 to form salt and hydrogen gas. These reactions are displacement reactions. If nitric acid is used, the hydrogen evolved gets oxidized to

water and hence no hydrogen gas is evolved. Metals like Cu, Ag and Au which are below hydrogen in the reactivity series do not react with dilute mineral acids and do not evolve H_2 .

9) Reaction with non-metals - Metals like Mg, Ca, Al etc. react with non-metals like H, S, Cl, Br and I under different conditions of temperature to form their respective salts. However, all metals are not equally reactive so they require different conditions to react with non-metals.

Activity 5 - Take a magnesium ribbon. Burn it in air. It forms magnesium oxide. Collect the ash of MgO and dissolve it in water. Put a red and blue litmus in it. The red litmus turns blue while blue litmus remains unchanged. This shows that metals form basic oxides.

Activity 6 - Take a magnesium ribbon about 1 inch in length. Roll it and put it in a test tube. Add about 2 ml dilute HCl to it. Gently heat the test tube. Hold a burning splinter near the mouth of the test tube. A pop sound is heard. The chemical reaction between magnesium metal and dilute HCl produces hydrogen gas which burns at the mouth of the test tube to form H_2O and this produces the pop sound.

Activity 7 - Take about 0.5 g of iodine crystals in a test tube. Add about 5 ml ethyl alcohol to it. Stir the solution. Record the temperature with the help of a thermometer. The solution should be dark brown. If it is not, then add little more iodine to it. When all the iodine has dissolved, slowly add about 0.5 g zinc powder to it with the help of a spatula. Stir the solution. The temperature will rise, indicating an exothermic reaction. Add zinc powder till the brown colour of the solution has gone. Filter the solution to remove the excess of zinc. Transfer the clear solution to a shallow dish. Allow the solvent to evaporate. This process can be speeded by placing the shallow dish on a beaker containing hot water. Zinc iodide is formed and it is left behind as a white solid. This shows that a metal reacts with a non-metal to form a salt.

Physical properties of non-metals

Non-metals show properties opposite to that of metals. Non-metals show following general physical properties

- 1) Physical state** – Non-metals can exist in solid or liquid or gaseous state at room temperature. . For example, carbon, sulphur, phosphorus, iodine are in solid state, bromine is in liquid state while oxygen, nitrogen, chlorine are in gaseous state at room temperature.
- 2) Luster** – Non-metals do not have luster. They do not reflect light from their surface. (exception – diamond and iodine) Non-metals have dull appearance. For example, sulphur, phosphorus and carbon show this property.

- 3) **Malleability** - Non-metals are non-malleable. If solids, they are brittle i.e. they break or shatter on hammering. For example, coal, sulphur, phosphorus are brittle.
- 4) **Ductility** – Non-metals can not be drawn into thin wires. So they are not ductile.
- 5) **Hardness** – Non-metals are usually not hard. They are soft. For example, coal, sulphur and phosphorus are soft. Diamond is exception to this. It is the hardest substance known.
- 6) **Conduction** - Non- metals are usually poor conductors of heat and electricity. However, carbon in the form of gas carbon and graphite is exception to this. These forms of carbon are good conductors of electricity.
- 7) **Density** – Non- metals which are gases have low density. Solid non-metals have low to moderate density. They are medium light. For example, sulphur, phosphorus and boron have densities 1.82, 2.07 and 2.34 respectively. . However, diamond has high density which is about 3.5.
- 8) **Melting and boiling point** – Non-metals usually have low melting and boiling points. For example, phosphorus, sulphur, and iodine have melting points 44° , 115° and 114° C respectively and boiling points 280° , 445° and 184° C respectively. . However, carbon, silicon and boron possess very high melting and boiling points.
- 9) **Tensile strength** – Non-metals have low tensile strength i.e. they have no tenacity.

Activity 8 – Collect some samples of carbon (coal), sulphur and red phosphorus. Look at their appearance. They are powdery in nature. Many solid non-metals are powdery in appearance. By weight, they are light. They have low density.

Chemical properties of non - metals

Non – metals show following general chemical properties

- 1) **Electron configuration** – Non -metals usually have 4 to 8 electrons in their outermost shell. For example, C, N, O, F and Ne have 4, 5, 6, 7 and 8 electrons in their outermost shell.
- 2) **Valency** - Non - metals can gain or share 1 to 4 electrons in their outermost shell and show valencies 1 to 4 . Sometimes, they show valency 5 to 7. For example, P shows valency 5 in P_2O_5 , S shows valency 6 in SO_3 and Cl shows valency 7 in $HClO_4$,
- 3) **Electrochemical nature** - Non – metal atoms have tendency to gain electrons and form anions or share electrons with other non-metals to form covalent bonds. Non - metals generally have moderate to high electronegative nature. For example, Cl, O and N have high electronegative nature while Si, P, S and I have moderate

electronegative nature.

- 4) **Electronegativity** - Non - metals generally have high electronegativity i.e. tendency to attract electrons in the state of molecule. For example, non - metals like F, Cl, O and N have high electronegativity.
- 5) **Formation of oxides** – Non- metals form oxides which are generally covalent and acidic in nature. If this acidic oxide dissolves in water, it forms an oxyacid. For example, oxides of Cl, P and S viz. Cl_2O_7 , P_2O_5 and SO_3 are highly acidic in nature and when dissolved in water, they form acids like HClO_4 , H_3PO_4 and H_2SO_4 . These oxides react with alkalis to form salts. Oxides of non- metals like C, H and N i.e. CO , H_2O and NO are neutral.
- 6) **Oxidizing agent** - All non - metals (except carbon) act as oxidizing agents. Strongly electronegative elements such as F, Cl and O act as strong oxidizing agents while moderately electronegative elements like sulphur, bromine and iodine act as moderate oxidizing agents. Carbon sometimes acts as a reducing agent.
- 7) **Reaction with water** - Non-metals do not react with water . Whether the water is in the form of cold water, hot water or steam, all non-metals remain unresponsive to water. The reason for this is that non-metals are electronegative and are unable to break the bond between H and O in water.
- 8) **Reaction with acids** : Most non-metals do not react with non-oxidizing acids. They are not capable of replacing hydrogen from the acids and forming a salt. For example, C, S or P do not react with dilute and concentrated HCl or dilute H_2SO_4 to give off hydrogen. Concentrated nitric acid, dilute nitric acid and concentrated sulphuric acid act as oxidizing agents and react with non – metals to form their oxides or acids. Non-metals like N, O, Si, halogens and noble gases are exception to this and they do not react with these acids. Usually solid non-metals react with these oxidizing acids.

$$\begin{array}{l} \text{C} + 4 \text{HNO}_3 \rightarrow \text{CO}_2 + 4 \text{NO}_2 + 2\text{H}_2\text{O} \quad ; \quad 3\text{C} + 4 \text{HNO}_3 \rightarrow 3\text{CO}_2 + 4 \text{NO} + 2 \text{H}_2\text{O} \\ \text{Conc.} \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \text{Dilute} \end{array}$$

$$\begin{array}{l} \text{C} + 2 \text{H}_2\text{SO}_4 \rightarrow \text{CO}_2 + 2 \text{H}_2\text{O} + \text{SO}_2 \quad ; \quad \text{S} + 2 \text{H}_2\text{SO}_4 \rightarrow 3 \text{SO}_2 + 2 \text{H}_2\text{O} \\ \text{Conc.} \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \text{Conc.} \end{array}$$

$$\begin{array}{l} 2 \text{P} + 5 \text{H}_2\text{SO}_4 \rightarrow 2 \text{H}_3\text{PO}_4 + 2 \text{H}_2\text{O} + \text{SO}_2 \\ \text{Conc.} \end{array}$$
- 9) **Reaction with metals** - Metals like Mg, Ca, Al etc. react with non-metals like H, S, Cl, Br and I on heating to form their respective salts. However, all non - metals are not equally reactive so they require different conditions like high temperature to react with metals.
- 10) **Reaction with non-metals** – Non-metals can react with each other. For example,

carbon can react with non-metals like H, O, Cl at different temperatures to form the corresponding compounds like CH_4 , CO_2 and CCl_4 . Non – metals react with each other under different conditions.

Test your understanding

- 1) Are copper, aluminium and lead ductile ? why ?
- 2) Give an example of metal which
 - a) is liquid at room temperature
 - b) can be cut easily with a knife
 - c) is the best conductor of heat
 - d) is comparatively a poor conductor of heat
- 3) Sodium metal is kept immersed in kerosene oil. Why ?
- 4) Select the elements which will act as (i) oxidizing agent (ii) reducing agent
K, Cr, C, Cl, Al, S, H, Br
- 5) Name an element which is a non-metal but has metallic luster.

Concepts

(i) Comparison of metals and non-metals (ii) Uses of metals (iii) Uses of non-metals

Comparison of metals and non-metals

No.	Metals	Non - metals
1)	Metals are solids at room temperature (Exceptions – Hg, Ga)	Non – metals may be solids, liquids or gases at room temperature.
2)	Metals have luster. They reflect light from polished or freshly cut surface.	Non-metals do not have luster. (Exceptions – Diamond and Iodine)
3)	Metals generally have high density.	Non-metals generally have low density.
4)	They are good conductors of heat and electricity.	They are usually bad conductors of heat and electricity. (exception – carbon in the form of gas carbon and graphite)
5)	Metals are malleable and ductile. They can be beaten into sheets and drawn into wires.	Non-metals are not malleable and ductile. They are brittle when solid. They can be crushed into powder.
6)	They have a three dimensional crystal structure with metallic bonds	They have different types of structures with covalent and van-der-Walls' bonds
7)	Metals are generally hard.	Non- metals are generally soft (Exception: Diamond)
8)	Metals usually have high tensile strength	Non- metals usually have low tensile strength
9)	Metals generally have 1 to 3 electrons in their outermost shell of the atom	Non-metals generally have 4 to 8 electrons in outermost shell of their atoms
10)	They show valency 1 to 4	They show valency 1 to 7
11)	They are electropositive in nature.	They are electronegative in nature.
12)	They generally form basic oxides.	They generally form acidic oxides.
13)	They act as reducing agents.	They act as oxidizing agents.
14)	Only active metals react with cold or hot water.	Non-metals usually do not react with cold and hot water.
15)	Only active metals react with non-oxidizing acids to form hydrogen gas	Solid non-metals react with oxidizing acids to form their oxides or oxyacids
16)	They react with non-metals under different conditions to form salts	They react with metals as well as non-metals under different conditions to form salts

Uses of metals

Metals find number of applications. Some of them are given below.

- 1) Zinc metal is used for galvanizing iron , in anti corrosion material, in medicinal fields and in alloys.
- 2) Iron is used as a construction material in bridges, houses, ships etc. Iron, in the form of steel is used for making domestic utensils.
- 3) Tin is used for soldering, for preparing foils, for metal coatings to prevent chemical action and corrosion, for panel lighting etc.
- 4) Lead is used in making water pipes, in pigments, batteries, in alloys etc.
- 5) Titanium finds extensive use in aircraft industries
- 6) Pure metals, which display zero resistance to electrical currents, are called superconductors. Hg, Nb are examples of superconductors. They become superconductors below a critical temperature of 4.2 K and 9.2 K respectively. Superconductors have many applications in research and industry.
- 7) Almost all metals including Zr, Ti find wide applications in atomic and space programmes and experiments.
- 8) Mercury is used in thermometers.
- 9) Silver, gold and platinum are precious metals and they are used in making ornaments.
- 10) Radioactive metals like uranium and plutonium are used in nuclear power plants to produce atomic energy via nuclear fission.

Uses of non - metals

Non - metals find number of applications. Some of them are given below.

- 1) Sulphur is used in making compounds like sulpha drugs, sulphuric acid, in matches, in gun powder , for vulcanization of rubber etc.
- 2) Boron, in the form of compound borax, is used in making skin ointments.
- 3) Phosphorus is used in making crackers.
- 4) Oxygen is used for respiration.
- 5) Chlorine, in the form of bleaching powder, is used for purification of water.
- 6) Carbon is used as a fuel, as electrodes (graphite), as a reducing agent in metallurgy.
- 7) Oxygen, hydrogen and nitrogen are used by all living things, they are the 'building blocks' of life.
- 8) Iodine is used to prevent thyroid problems.
- 9) Bromine is used in the preparation of dyes.
- 10) Some compounds of fluorine (such as sodium fluoride, stannous fluoride) are added to toothpastes to prevent dental decays or formation of cavities.

Test your understanding

- 1) Give any three differences between metals and non-metals based on their –
(i) physical properties (ii) chemical properties
- 2) You are given a hammer, a battery, a bulb, wires and a switch. How could you use them to distinguish between metals and non-metals ?
- 3) An element reacts with oxygen to form oxide which dissolves in dilute sulphuric acid. The oxide also dissolves in water and the solution turns red litmus blue. Is the element a metal or a non – metal ? Explain your answer.
- 4) Name the elements which are used in (i) gun powder (ii) match stick
- 5) Name one element which is a metal but shows at least one property of a non-metal and one element which is a non-metal but shows at least one property of a metal.
- 6) Which of the following statements is / are not true ?
 - a) Metals usually have 1 to 3 electrons in their outermost shell.
 - b) Non – metals gain valency electrons easily.
 - c) Metals form oxides which are basic in nature.
 - d) Non-metals are good reducing agents.

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Concept

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| (i) Reactivity series of metals
(iii) Applications of reactivity series | (ii) Reactivity series of non-metals |
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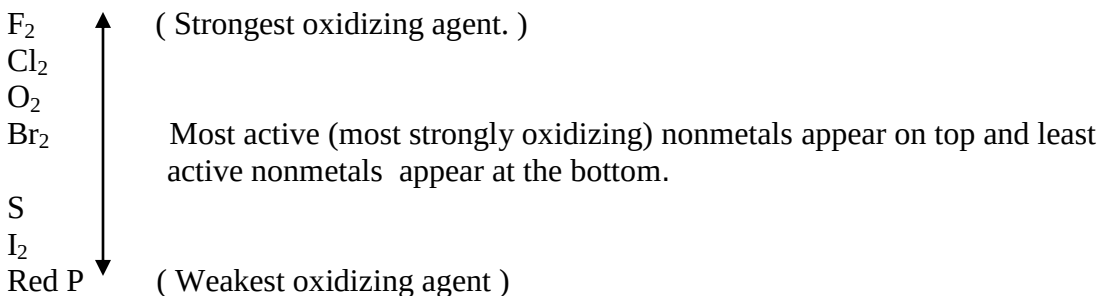
Reactivity series of metals

A series of metallic elements arranged in the increasing or decreasing order of their reactivity is called a reactivity series of metals.

Although most metals are usually electropositive in nature and lose electrons in a chemical reaction they do not react with the same vigour or speed. Metals display different reactions towards different substances. The greater the ease with which an element loses its electrons and acquires a positive charge, the greater is its reactivity. Further, the greater the number of shells and lesser the number of valence electrons, the greater is the reactivity of the metal. The activity series of metals, arranges all metals in order of their decreasing chemical activity. As we go down the activity series from potassium to gold the ease with which a metal loses electrons and forms positive ions in solutions, decreases.

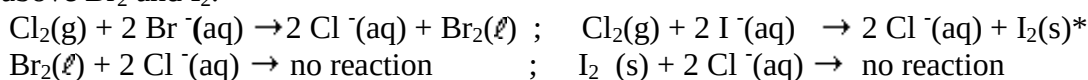
The most active metal, potassium, is at the top of the list and the least reactive metal, gold, is at the bottom of the list. Although hydrogen is a non-metal it is included in the activity series due to the fact that it behaves like a metal in most chemical reactions i.e., the hydrogen ion has a positive charge $[H^+]$ like other metals.

Activity series can be devised for non-metals as well. Since non-metallic elements tend to accept electrons in redox reactions, the non-metal activity series is arranged so that the most powerful oxidizing agents are considered most active (whereas in the metal series, the most powerful reducing agents are the most active).



Reactivity series of non-metals

The series predicts that Cl₂ will displace Br⁻ and I⁻ from solution because Cl₂ appears above Br₂ and I₂.



*The liberated iodine dissolves in water to form yellow solution.

Applications of reactivity series

- 1) One can understand the relative strength of reducing and oxidizing agent from the position of the elements in the series. For example, the elements like K, Na, Zn etc. which are placed high in the series can easily lose electrons and act as good reducing agents. The elements which are below hydrogen in this series like Cu, Ag, Au can not lose electrons easily. So they can not act as reducing agents. Instead, their cations act as good oxidizing agents.
- 2) Looking at the reactivity series, one can understand the spontaneity of the reaction. One metal can displace another metal from its salt solution. This can happen only if the first element is in the higher position in the series as compared to the second element which is displaced from its salt solution. For example, Zn can displace Fe from FeSO₄ solution but Cu can not displace Fe from FeSO₄ solution because Zn is above Fe while Cu is below Fe in the reactivity series. Similarly, for the anions – Cl⁻ can displace Br⁻ from its salt solution (KBr) but I⁻ can not displace Br⁻ from its salt solution (KBr).
- 3) One can make a choice of suitable electrodes for setting up of an electrolytic or electrochemical cell. One can choose an electrode with +ve electrode potential (higher in position in the reactivity series) and an electrode with –ve electrode potential (lower in position in the reactivity series) , combine them and set up the cell. For example a combination of Zn half cell and Cu half cell sets up a Daniel cell.

- 4) If one knows the standard electrode potential of two electrodes, then he can find out the standard E.M.F. of the cell. For example, the standard oxidation potential of Zn half cell is + 0.76 V and that of Cu half cell is – 0.34 V. So the E.M.F. of Daniel cell is $(0.76) - (-0.34) = 1.10$ V.
- 5) If a solution contains two or more cations, one can predict which cation will be discharged first at the cathode during electrolysis. For example, if the solution contains equal concentration of Na^+ and H^+ ions, then according to rule, the ion which is lower in position in the reactivity series is discharged first at the cathode. So, in this case, H^+ will be discharged in preference to Na^+ ions in electrolysis.
- 6) If a solution contains two or more anions, one can predict which anion will be discharged first at the anode during electrolysis. For example, if a solution contains equal concentration of Cl^- and OH^- ions, then as per rule, the ion which does not contain oxygen is discharged first in preference to the ion which contains oxygen. So, in this case, Cl^- will be discharged in preference to OH^- ions in electrolysis. The series of anions in the decreasing order of reactivity is given below.
- $$\text{SO}_4^{2-} \quad \text{NO}_3^- \quad \text{OH}^- \quad \text{Cl}^- \quad \text{Br}^- \quad \text{S}^{2-} \quad \text{I}^-$$

Activity 9 - Take two test tubes. In one test tube take 10 ml 10% copper sulphate solution. The solution is blue in colour. Put one iron nail in it. In another test tube, take 10 ml 10% ferrous sulphate solution. The solution is faint green in colour. Put a granule of zinc metal in it. Wait for about an hour. In the first test tube, you see a reddish brown deposit of copper on iron nail. The blue colour of the solution has become pale blue. In the second test tube, you see some bubbles and after some time, the solution has become almost colourless. In the first test tube, Fe displaces Cu from its salt solution because Fe is more reactive than Cu (Fe is above Cu in the reactivity series). The liberated Cu is deposited on iron nail. In the second test tube, Zn displaces Fe from its salt solution because Zn is more reactive than Fe (Zn is above Fe in the reactivity series). The granule of Zn becomes thinner while little reddish brown Fe appears in the test tube.

Activity 10 - Take 10 ml of 10 % KI solution in a test tube. It is colourless. Prepare chlorine gas by the conventional method ($\text{MnO}_2 + \text{Conc. HCl}$) and pass it through the KI solution. Yellowish brown precipitate of iodine settles at the bottom of the test tube. The upper clear solution becomes pale yellow indicating that little iodine has dissolved in the solution. Chlorine being more reactive than iodine, it displaces iodine from its salt solution.

Test your understanding

- 1) You are given samples of three metals – sodium, magnesium and copper. Suggest any two activities to arrange them in the order of decreasing reactivity.
- 2) Which of the following pairs will give displacement reaction ?
 - a) NaCl solution and copper metal
 - b) MgCl_2 solution and aluminium metal
 - c) FeSO_4 solution and silver metal
 - d) AgNO_3 solution and copper metal

- 3) Food cans are coated with tin and not with zinc because –
 a) zinc is costlier than tin b) zinc has higher melting point than tin
 c) zinc is more reactive than tin d) zinc is less reactive than tin
- 4) Metal X displaces metal Y. Metal Z does not react with X or Y. Which order of decreasing reactivity is correct ?
 a) X Y Z b) Y Z X c) X Z Y d) Z Y X
- 5) A dilute aqueous solution containing NaCl and MgCl_2 is subjected to electrolysis. The product obtained at the anode will be –
 a) O_2 b) H_2 c) Cl_2 d) H_2O

Concepts

(i) Noble metals (ii) Properties of noble metals (iii) Uses of noble metals
 (iv) Purity of gold

Noble metals

In a chemical language, noble means inactive.

The metals which are inactive are called noble metals.

The noble metals are - ruthenium, rhodium, palladium, silver, osmium, iridium, platinum, gold, mercury and rhenium

Properties of noble metals

- 1) Noble metals are resistant to corrosion and oxidation in moist air.
- 2) Noble metals are not affected by air, water, acids, heat etc.
- 3) Ordinarily, they do not take part in chemical reactions. Hence they are called noble metals.
- 4) They tend to be precious, often due to their rarity in the Earth's crust.

Noble metals should not be confused with precious metals (although many noble metals are precious). Usually, rhodium, palladium, silver, platinum, gold and

indium are known as the precious metals. Chemically, the precious metals are less reactive than most elements. Precious metals have luster, they are softer or more ductile and they have higher melting points than many metals. They are very expensive. Gold, silver, and platinum are both noble and precious metals.

Uses of noble metals

- 1) Some of the precious metals like Ag, Au and Pt are used for making coins, ornaments and jewelry. They are considered as bullion metals.
- 2) Ruthenium is used in strengthening alloys of Pd and Pt.
- 3) Rhodium is used in electroplating platinum and white gold to provide them with reflective surfaces.
- 4) Palladium is used in jewelry, dentistry, blood sugar testing strips, watch making, spark plugs for aircrafts and surgical instruments.
- 5) Indium has many industrial uses because of its hardness, high resistance to corrosion and high melting point. It is widely used in spark plugs, electrodes and catalysis.
- 6) Silver is used in medicines due to its antibacterial properties.
- 7) Platinum is used as a catalyst and in making electrodes.

Purity of gold

The purity of gold is expressed in carats, often abbreviated as 'ct' or 'K' in the USA and some other countries. Pure gold has a purity of 24 carats.

As a measure of purity, one carat is 24 times the purity by mass of gold :

$$X = 24 \text{ Mg} / \text{Mm}$$

Where

X is the carat rating of the material,

Mg is the mass of pure gold or platinum in the material and

Mm is the total mass of the material.

Therefore 24-carat gold is fine (99.9% Au w/w), 18-carat gold is 75% gold, 12-carat gold is 50% gold, and so forth.

Various other purities exist that are measured relative to 24 carats. These are summarized in the table below

The relationship between gold content (by weight , its carating and hallmark rating for standard gold alloys

Purity	Gold content (wt %)	Fineness
24 carat gold	99 +	990
22 carat gold	91.6	916
18 carat gold	75	750
14 carat gold	58.5	585
9 carat gold	37.5	375

An alternative method of expressing purity is 'fineness'. This expresses the purity of gold in parts per 1000.

Gold may be alloyed with other metals such as silver, copper, zinc or silicon to produce purities less than 24 carat. Silver and copper are most commonly used alloying elements for gold. Pure gold is too soft to be able to be used for jewelry.

The metal chosen as an alloying element may influence properties such as workability and colour of the resultant gold alloy.

The purity of the gold is 'marked' onto jewelry by stamping or laser engraving. This acts as a quality control stamp. Often this is done after the alloy is tested by a qualified testing laboratory or facility. Depending on in which country the gold is produced, the carat or fineness may be stamped into the item of jewelry.

According to the International Hallmarking Convention, there is a "no negative tolerance" policy. This means that a gold alloy determined to consist of 749 parts of gold per 1000 would not qualify for a 750 quality mark.

Test your understanding

- 1) Which noble metals are found in free state in nature ?
- 2) Name the metals which are noble as well as precious.
- 3) We can make an ornament from pure silver but we can not make an ornament of pure gold. Why ?
- 4) How much % of copper will have to be added to make a 22 carat gold ornament ?

Concepts

(i) Metalloids

(ii) Properties of metalloids

(iii) Uses of metalloids

Metalloids

These elements are also called semimetals. They are located in the periodic table along the line between the metals and the non-metals.

The elements which exhibit the external characteristics of metals but behave chemically both as metals and non-metals are called metalloids.

Arsenic and antimony, for example, are hard crystalline solids that are definitely metallic in appearance. They may, however, undergo reactions that are characteristic of both metals and nonmetals. However, only when this dualistic chemical behavior is very marked and the external appearance is metallic then the elements are commonly called metalloids.

Metalloids include boron, silicon, germanium, arsenic, antimony, tellurium and polonium.

Properties of metalloids

Metalloids tend to show properties intermediate between metals and non-metals.

- 1) Metalloids can be shiny like metals. . For example, silicon possesses metallic luster but it is an inefficient conductor and is brittle.
- 2) Metalloids are insulators at room temperature. Some of them make good semiconductors. For example, silicon, germanium act as good semiconductors while boron and arsenic act as good dopants to these semiconductors.
- 3) They are ductile in nature. They can be drawn in shapes of pipe. This is the property of metals.
- 4) They have electronegativity between those of metals and non-metals.
- 5) Metalloids have ionization energy between those of metals and non-metals.
- 6) The reactivity of the metalloid depends upon the element with which it is reacting.
For example, boron acts as a non-metal when it reacts with sodium but it acts as if it is a metal when it reacts with fluorine.
- 7) Metalloids form amphoteric oxides.

Uses of metalloids

- 1) Some metalloids are used as semiconductors.
- 2) Silicon is used to make a rubbery water proof adhesive.
- 3) Tellurium is used for giving colour for vases.
- 4) Germanium and its oxide are used in highly sensitive infrared detectors and other optical devices.
- 5) Antimony is used in alloying to increase hardness and mechanical strength.

Test your understanding

- 1) Name the metalloids. Why are they so called ?
- 2) Where do you find metalloids in the periodic table ?
- 3) Name some properties of metalloids which justify their behaviour between metals and non-metals .
- 4) Give any three uses of metalloids.

Concepts

(i) Corrosion (ii) Theory of corrosion (iii) Methods to prevent corrosion

Corrosion

Corrosion can be defined as the degradation of a material due to a reaction with its environment.

Degradation implies deterioration of physical properties of the material. In other words, corrosion is the wearing away of metals due to a chemical reaction. Corrosion can also be defined as the disintegration of the material due to chemical reaction with its surrounding. Oxygen and moisture are essential for corrosion. Corrosion process is accelerated due to the presence of impurities, moist air, electrolyte, presence of SO₂ and strains in metals like dent, scratches, welding parts etc.

In the most common use of the word, this means electrochemical oxidation of metals in reaction with an oxidant such as oxygen. Formation of an oxide of iron due to oxidation of the iron atoms in solid solution is a well-known example of electrochemical corrosion, commonly known as rusting. This type of damage typically produces oxide(s) and/or salt(s) of the original metal. The black coating on silver and the green coating on copper are the examples of corrosion. Corrosion causes damage to car bodies, bridges, iron railings, ships and to all objects made of metals.

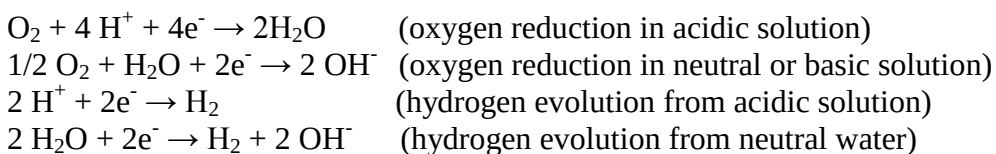
Theory of corrosion

Electrochemical corrosion involves two half-cell reactions; an oxidation reaction at the **anode** and a reduction reaction at the **cathode**. For iron corroding in water with a near neutral pH, these half cell reactions can be represented as:

Anode reaction: $2\text{Fe} \Rightarrow 2\text{Fe}^{2+} + 4\text{e}^-$ **Cathode reaction:** $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \Rightarrow 4\text{OH}^-$

The anodic reaction releases electrons, while the cathodic reaction consumes electrons. In general, there are three common cathodic reactions - oxygen reduction (fast), hydrogen evolution from neutral water (slow), and hydrogen evolution from acid (fast).

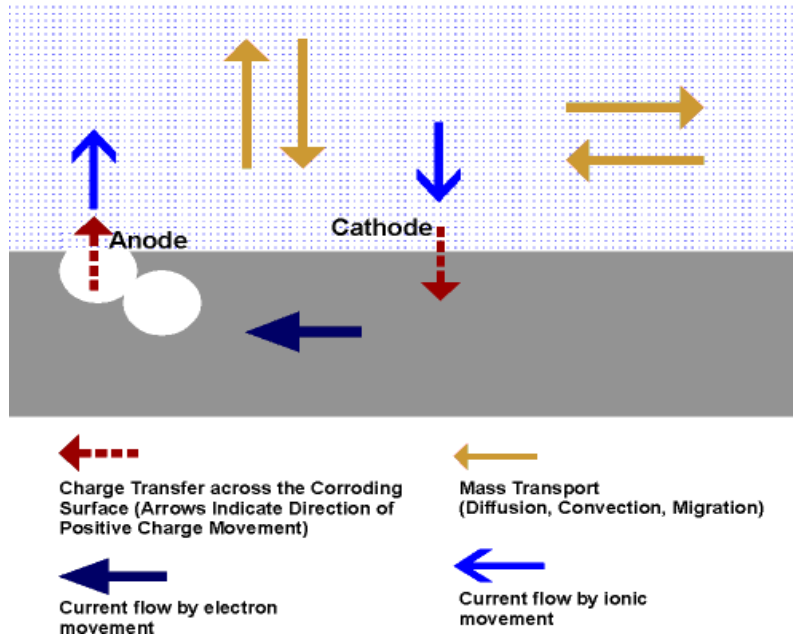
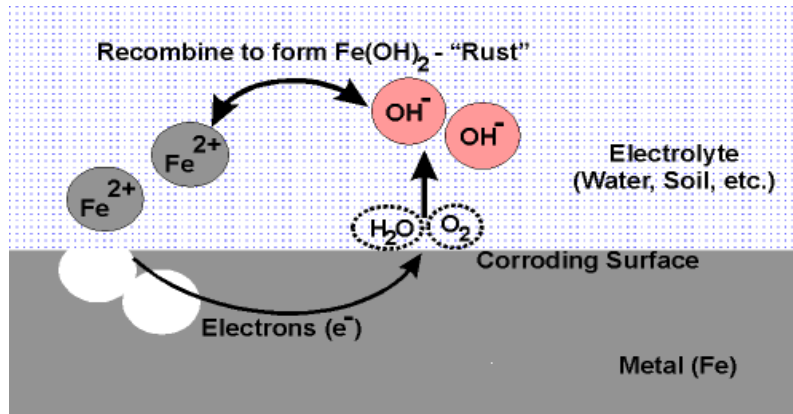
Cathodic reactions:



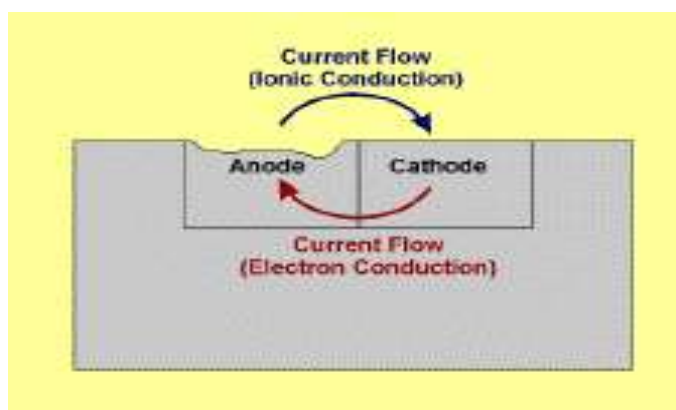
Anodic reaction: $M \rightarrow M^{n+} + ne^{-}$

M stands for a metal and n stands for the number of electrons that an atom of the metal will easily release. i.e. for iron : $Fe \rightarrow Fe^{2+} + 2e^{-}$

There are obviously different anodic and cathodic reactions for different alloys exposed to various environments. These half cell reactions are thought to occur (at least initially) at microscopic anodes and cathodes covering a corroding surface. Macroscopic anodes and cathodes can develop as corrosion damage progresses with time.



Schematic representation of electrochemical corrosion process
(aqueous corrosion of iron under near neutral pH conditions)



Schematic representation of current flow (conventional current direction) in a simple corrosion cell

Activity 11 - Take three test tubes and place clean iron nails in each of them. Label the test tubes as A, B and C. Pour some water in test tube A and cork it. Pour boiled distilled water in test tube B, add about 1 ml pine oil and cork it. The oil will float on water and prevent the air from dissolving in the water. Put few crystals of anhydrous calcium chloride in test tube C and cork it. Anhydrous calcium chloride will absorb moisture, if any, from the air. Leave these test tubes for two days and then make observation.

Iron nail in test tube A rusts. This nail is exposed to both air and water. The nail in test tube B does not rust. It is exposed to only water. Iron nail in test tube C does not rust. It is exposed to only dry air. This shows that water and air (or oxygen) both are essential to cause corrosion.

Methods to prevent corrosion

From the above theory it should be apparent that there are four fundamental components in an electrochemical corrosion cell.

(i) An anode. (ii) A cathode (iii) A conducting environment for ionic movement (electrolyte). (iv) An electrical connection between the anode and cathode for the flow of electron current.

If any of the above components is missing or disabled, the electrochemical corrosion process will stop. Clearly, these elements are thus fundamentally important for corrosion control.

Corrosion can be controlled by preventing the material from its exposure to moisture and any acid. Latest methods to control corrosion is insulating the corrosive material with some non-corrosive agents, painting the materials, using anti-corrosion additives etc. It can be prevented also by galvanization. Some of the methods to prevent corrosion are as follows.

- 1) **Painting** - The material is coated with anti corrosion paint. This prevents contact between the metal and oxygen.
- 2) **Coating with plastic, oil, grease** – The material is coated with olive oil or grease or some plastic polymer. This prevents the contact between the metal and oxygen.
- 3) **Coating with more active metal** – Galvanizing iron with zinc. Zinc is more reactive than iron. So zinc reacts with environment first and protects iron.
- 4) **Tinning (Coating with less active metal)** – Iron and copper are coated with tin. Tin is not so easily acted upon by air or water, as iron and copper are. Tin, a less active metal, provides mechanical cover to other metals like iron and copper and protects them from rusting.

Activity 12 - Take two plates of iron about 1 cm thick and 2 inch long and 2 inch broad. Clean them. Keep one plate exposed to atmosphere for one week. Apply grease from all sides to the second plate. Keep the second plate along side the first plate for one week. Observe both the plates after one week. You will find little rust accumulated on the first plate. Remove grease from the second plate. You will find that the second plate does not have any rust. You have protected the second plate from rusting by applying coating of grease. The second plate could not come in contact with oxygen and water due to the coating of grease hence it did not rust.

Test your understanding

- 1) What is corrosion? What are the essential conditions for corrosion to occur?
- 2) Give the chemical reactions taking place in rusting of iron.
- 3) Which of the following methods is useful in preventing iron vessels of grain storage from rusting?

a) applying grease	b) applying paint
c) applying a coating of zinc	d) a, b, c all
- 4) Answer the following :
 - (i) Ships are frequently painted
 - (ii) In humid atmosphere, copper vessels get a green layer.

Concepts

(i) Alloys (ii) Properties of alloys (iii) Uses of alloys

Alloys

An alloy is a homogeneous mixture of two or more metals (or a metal and non-metal) mixed in a definite proportion in their molten state. Alloy is a solid solution of two or more elements in which one is a metal.

Usually, the properties of an alloy are different than the properties of its components. Alloy formation is usually done for following reasons.

- (i) To increase the hardness, tensile strength and conductance of the material.
- (ii) To alter / change the melting point of the material.
- (iii) To modify the physical properties like appearance, colour, casting ability, machinability etc. of the components.

The alloy of mercury with another metal is called an amalgam. An amalgam is in the form of semi-solid paste.

Properties of alloys

- (i) Alloys are solid mixtures which behave like a single metal. For example, brass is an alloy of copper and zinc which looks like a single metal.
- (ii) Alloys usually show properties which are in between the properties of the constituents. For example, the melting point of zinc is 420°C , that of copper is 1085°C while the melting point of their alloy, brass, ranges between 900 and 940°C . Some alloys have melting point lesser than the melting point of their constituents. Such alloys are called **fusible alloys**. For example, solder is a fusible alloy. It has melting point of 180°C which is lower than the melting point of its constituents Pb (327°C) and Sn (232°C).
- (iii) Certain non-metals also form alloys. For example, the alloy of carbon and iron is called steel.

Uses / Applications of alloys

- (i) Silver, tin and zinc amalgams are used in dentistry to fill up the cavities in the teeth.
- (ii) Aluminium alloys are extensively used in the production of automotive engine parts.
- (iii) Copper alloys are used in electrical equipment.
- (iv) Nickel alloys have good corrosion resistance hence they are used in aircraft gas turbines, nuclear power systems etc.

- (v) Steel is used in building ships, bridges, houses, machines, automobile parts , domestic utensils etc.
- (vi) Titanium alloys are used in space crafts, jet engines and aeroplanes.

Some alloys , their composition and uses are given below.

Alloy	Composition	Uses
1) Brass	Zn(35%), Cu(65%)	In musical instruments
2) Bronze	Cu(87.5%), Sn(12.5%)	Boat hardware, Screws
3) Stainless steel	Fe(70%), Cr(20%), Ni (10%)	In chemical plants, Machine parts
4) Alnico	Al(12%), Ni(15%), Co(6%), Ti(1%), Cu(6%), Fe(60%)	In preparing magnets
5) Duralium	Al(95%), Mn(4%), Mg(1%)	For making airships, aeroplanes

Test your understanding

1) Match the following :

Metal / Alloy

- A. Aluminium
- B. Zinc
- C. Brass
- D. Iron
- E. Brass

Use

- a. Making of steel
- b. Electrical fittings
- c. Galvanizing
- d. Radiation shield
- e. Aeroplane wings

2) Give the composition of following alloys :

- a) Bronze b) Solder c) Brass d) Steel

3) What is the purpose of preparing an alloy ?

4) Are the properties of alloy the same as that of its components ?

References / Figures / Diagrams

- 1) <http://www.corrosion-club.com/basictheory.htm>
- 2) <http://www.tutorvista.com/content/science/science-ii/metals-non-metals/reconcept-series-metals.php>