CHEMISTRY

METALS AND 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 non-metals. 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 non-metal. (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.

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. Foe 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_2O3 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.

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 44^0, 115^0 and 114^0C respectively and boiling points 280^0, 445^0 and 184^0C 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.

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 alkalies 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.

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.

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.