SYNOPSIS

(INORGANIC CHEMISTRY)

Introduction

There are about one hundred twenty known elements. These elements range from highly reactive metals of the s-block to noble metals like gold, silver and platinum in the d-block. The highly reactive non-metals are in the top right corner of the periodic table which also include noble gases in group 18. Inorganic chemistry is the study of properties of these about 120 elements and their numerous compounds.

The compounds of these elements vary from ionic solids such as NaCl, MgO to covalent compounds such as silica, Silicon carbide and metallic compounds.

To understand inorganic chemistry and to make study of inorganic chemistry simple, enlightening and easy to grasp, the students should have a strong understanding of the electronic configuration, periodic trends in atomic and ionic size, ionization enthalpy, electron gain enthalpy, chemical bonding and hybridization, the concept of oxidation states and balancing of redox reactions. The student should also have a comprehensive knowledge of acid-base concepts.

Inorganic chemistry is essential to the manufacture and important of modern materials such as semiconductors, optical fibers, advanced ceramic materials.

In this inorganic chemistry part, we will discuss about the following chapters in details using the basic concepts and principles of general chemistry.

1. **Hydrogen**
2. **The s-block elements (Group 1 and Group 2)**
3. **The p-block element (Group 13 and Group 14)**

Hydrogen

Hydrogen is the simplest known element. It has many unique characteristics which justify the special position for hydrogen in the periodic table.

Hydrogen is the most abundant element in the universe but is not found in the earth's atmosphere. Hydrogen is the only known element whose isotopes have the unique mass ratio of 1: 2: 3 (^1H : ^2H : ^3H) ^1H is the most abundant isotope.

H_2 (called dihydrogen) is prepared industrially by water gas shift reaction and is also the by product of electrolysis of brine solution.

Dihydrogen is a colourless, odourless, tasteless gas with high enthalpy of dissociation. H_2 also show nuclear spin isomerism and exist as ortho and para hydrogen.

Binary compounds of hydrogen are called **hydrides**. There are mainly three types of hydrides:

(i) Ionic hydrides (NaH, KH)

(ii) Covalent or molecular hydrides (NH_3, H_2O, CH_4)

(iii) Metallic or interstitial hydrides.

Dihydrogen is used in the manufacture of ammonia and in the hydrogenation of oils into fats. **Water in the most common, abundant substance.** Water occupies the major part of earth. It is colorless, mobile, volatile liquid with many unique properties. These properties are results of the extensive network of intermolecular hydrogen bonding. Thus water has a high specific heat, thermal conductivity and surface tension than most of the other liquids. That's why water plays an important role in the biosphere.

Water molecule has a bent structure. It behaves as an amphoteric substance. Water form hydrates of different types.

Temporary hardness of water is due to bicarbonates of magnesium and calcium. This can be removed by boiling.

Permanent hardness of water is due to chlorides and sulphates of magnesium and calcium.

Both temporary and permanent hardness can be removed by using (i) aluminosilicates like zeolites and (ii) Synthetic organic ion exchangers.

Hydrogen peroxide is another important compound of hydrogen. Hydrogen perioxide act as an oxidizing agent as well as reducing agent. It is prepared by the auto-oxidation of 2-ethyl anthraquinol. It has a non-planar structure. Hydrogen peroxide is used as a bleaching agent and in controlling pollution.

The s-Block Elements

In s-block elements, the filling of electron takes place in the outermost s-subshell. The general valence shell electronic configuration of s-block elements is ns^{1-2}. There are two groups in the s-block of the periodic table. Group-1 elements are called **alkali metals** with one s-electron in the valence shell. Group 2 elements are called **alkaline earth metals** with two s-electron in the valence shell. s-block metals are highly reactive and form mono or unipositive (M^+) and dipositive (M^{2+}) ions respectively.

These metal do not occur in the free state in nature. Since they are highly electropositive, they are generally extracted from their minerals using electrolytic methods.

There is a regular trend in the physical and chemical properties of the alkali metals with increasing atomic number. The atomic and ionic size increase and the ionization enthalpy decreases systematically down the group. Somewhat similar trends are also observed among the properties of the alkaline earth metals.

The alkali metals are silvery white, soft and have low melting point. They are highly reactive and react with water and with most of the non-metals. The compounds of the alkali metals are predominantly ionic.

The oxides and hydroxides of alkali metals are soluble in water and form strong alkalies. The oxosalts of alkali metals like carbonates, sulphates and nitrates are well known.

The thermal stability of the oxosalts increases down the group.

Sodium peroxide, Na_2O_2, sodium hydroxide, NaOH and sodium carbonate, Na_2CO_3 are among the important compounds of the alkali metals. Sodium hydroxide is manufactured by Castner-Kellner process and sodium carbonate by solvey process.

The chemistry of the alkaline earth metals is very much like that of the alkali metals. However, some differences arise because of the decreased atomic is size and ionic size and increased charge on the cation formed by alkaline earth metals.

The oxides and hydroxides of group 2 are also strongly basic but less basic than oxides and hydroxides of group 1.

Similarly the oxosalts of the alkaline earth metals are relatively less soluble and thermally less stable than these of the alkali metals.

The first element in each of these groups, lithium in group 1 and beryllium in group 2 shows similarition to the second member of the next group. Such similarities are termed as the **diagonal relationship** in the period table.

Important compound of calcium are calcium oxide (lime or quick lime), calcium hydroxide (slaked lime), calcium carbonate (lime stone), calcium sulphate (Gypsum and plaster of paris).

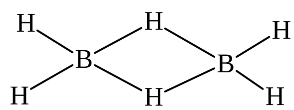
Sodium, potassium, magnesium and calcium and also biologically important.

The p-Block Elements (Group 13 and Group 14)

In p-block elements, the filling of electron takes place in the outermost p-subshell. The general valence shell electronic configuration is ns^2np^{1-6}. There are six groups in the p-block of the periodic table. Each group in the p-block of the periodic table is headed by a non-metal. Non-metals in contrast to metals have high ionization enthalpies and high electronegativities and mainly form covalent bonds by sharing of electrons.

The first member of each group in the p-block differs in many respects from the other members of the group on account of its small size, higher electronegativity and ability to form strong $p\pi$–$p\pi$ multiple bonds. Boron in group 13 is a typical non-metals. The availability of only 3 valence electrons ($2s^2\ 2p^1$) for covalent bond formation using four orbitals ($2s$, $2p_x$, $2p_y$, $2p_z$) leads to so called **electron deficient boron compounds.** Therefore boron compounds are good electron acceptors and are called Lewis acids.

Boron halides are Lewis acids, boron form an extensive series of covalent molecules compounds with hydrogen known as **Boranes**. The important hydride of boron is **diborane, B_2H_6**. Diborane contain 4 termonal normal $2e^-$ – 2c covalent bonds and two $2e^-$ – 3c bridging bonds called **multicentre bonds.**



The important compounds of boron with oxygen are boric acid, H_3BO_3 and borax $Na_2B_4O, 10H_2O$.

Boric acid, H_3BO_3 is not a protonic acid but a weak mono basic acid (Lewis acid) and accepts electron pair form OH^- ion of water

$$H_3BO_3 + H_2O \rightleftharpoons B(OH)_4^- + H^+$$

The group oxidation state of group 13 elements is +3. The stability of +3 oxidation state decreases down the group. With heavier elements +1 oxidation state gets progressively stabilized on going down the group. This is the result of the **inert pair effect.**

In group 14, carbon is a typical non-metal forming covalent bonds using all its four valence electrons ($2s^2\ 2p^2$). It shows the property of catenation, ability to form bond with itself. The tendency to catenate decreases down the group as atomic size increases.

$$C >> Si > Ge \simeq Sn > Pb$$

Carbon in group 14 also has a unique property to complete its octet via $p\pi$–$p\pi$ bond formation with itself ($C = C$, $C \equiv C$) or with oxygen $C = O$ and nitrogen ($C \equiv N$)

Carbon also shows an **allotropy**. There are three important allotropes of carbon: diamond, graphite and fullerenes.

The members of the carbon family (group 14) mainly exhibit +4 and +2 oxidation states, stability of +2 oxidation state increases down the group.

The compound in +4 oxidation states are generally covalent in nature. Lead in +2 state is stable whereas in +4 oxidation state it is a strong oxidizing agent. Carbon also exhibits negative oxidation state of –4 in CH_4.

Carbon forms two important oxides: CO and CO_2. Carbon monoxide is neutral whereas CO_2 is acidic in nature. The structure of CO is $:\overset{-}{C}\equiv\overset{+}{O}:$ whereas CO_2 is linear with C sp hybridised.

$:\ddot{O}=C=\ddot{O}:$

Carbon monoxide having one lone pair of electrons on C forms metal carbonyls. It is deadly poisonous due to higher stability of its hemoglobin complex as compared to that of oxyhaemoglobin complex. Caron dioxide as such is not toxic. In case of halides, CCl_4 is inert towards water whereas $SiCl_4$ gets hydrolysed very easily by water due to the availability of empty d-atomic orbitals.

Also, due to large size, silcon cannot complete its octet via $p\pi$–$p\pi$ bond formation like carbon in CO_2. Hence, SiO_2 is a network solid with very high melting point.

Silicon also form organosilicon polymers called **Silicones** (R_2SiO). Silicones are insulator, soft and water repellents.

Silicon exists in the earth crust as silicate minerals, some of the examples are feldspar, zeoliles, mica and asbestos.

The two important man-made silicates are glass and cement.

