17

HYDROGEN AND S-BLOCK ELEMENTS

HYDROGEN

- Hydrogen is the first element of the periodic table. Hydrogen has the simplest atomic structure and consists of a nucleus containing one proton with a charge +1 and one orbital electron. The electronic structure may be written as $1s^1$.

History and Occurrence of Hydrogen

- ***Turquet de Mayerne*** (1655) and ***Boyle*** (1672) collected an inflammable gas by reacting iron with sulphuric acid. A century later Cavendish investigated the properties of this gas and called it 'inflammable air', but it was Lavoisier who called it by its present name, hydrogen.
- Hydrogen occurs in the free state in some volcanic gases and in the outer atmosphere of the sun; other stars are composed almost entirely of hydrogen

Position in the Periodic Table

- **Hydrogen** is a nonmetal and is placed above group in the **periodic table** because it has *ns¹* electron configuration like the alkali metals.

Isotopes of hydrogen

- **Isotopes of hydrogen :** Three isotopes of Hydrogen

(i) Protium ($_1H^1$)
(ii) Deuterium
($_1H^2$) or $_1D^2$
(iii) Tritium ($_1H^3$) or $_1T^3$

Properties of Dihydrogen

- The H-H bond dissociation enthalpy is highest for a single bond dissociation enthalpy between two toms of any element. It is relatively inert at room temperature due to the high H-H bond enthalpy.

Preparation of Dihydrogen

(i) Laboratory preparation:

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

(ii) Commercial preparation: By electrolysis of acidified water.

(iii) High purity dihydrogen is obtained by electrolyzing warm aqueous barium hydroxide.

Uses of Dihydrogen

- **Hydrogen is used:**

1. for conversion of coal into synthetic petroleum.

2. In the manufacture of bulk organic chemicals, particularly methanol.

3. as primary fuel for heavy rockets.

4. for filling balloons.

COMPOUNDS OF HYDROGEN

Water

- **Hard water (H_2O):** Hard water contains calcium and magnesium salts in the form of hydrogencarbonate, chloride and sulphate. Hard water does not give lathers with soap.
- **Soft water:** Water free from soluble salts of calcium and magnesium is soft water.
- **Types of Hardness:** ***Temporary hardness*** is due to presence of calcium or magnesium hydrogen carbonate in water.
- Temporary hardness can be removed by : **(i)** Boiling

(ii) Clark's Method

- **Permanent hardness:** Such hardness is due to presence of calcium or magnesium chlorides and sulphates.
- **Permanent hardness can be removed by :**

(i) Calgon's method

(ii) Ion exchange method.

- **Demineralised or Deionised water:** Water free from all soluble mineral salts is known as demineralised water.

Heavy water and its applications

- Water containing deuterium in place of ordinary hydrogen (protium) is termed as heavy water (D_2O).

Uses: 1. Heavy water is used as a moderator in nuclear reactors. In this process the high speed neutrons are passed through heavy water in order to slow down their speed.

2. It is used in the study of mechanism of chemical reactions involving hydrogen.

- Colour of oxidising flame (except Be and Mg). Be and Mg do not show flame colouration because they have small size and very high ionisation enthalpy.
- **Reducing character:** Due to large negative electrode potentials alkaliλ metals are stronger reducing agent than alkaline earth metal.

17.3.1.4 Chemical Properties

- **Reactivity towards air:**

$4Li + O_2 \longrightarrow 2Li_2O$ (Lithium oxide)

$2Na + O_2 \longrightarrow Na_2O_2$ (Sodium peroxide)

$M + O_2 \longrightarrow MO_2$ (M = K, Rb, Cs metal superoxide)

Alkaline earth metals being smaller in size do not from superoxides.

- **Reactivity towards H_2O:**

$2M + 2H_2O \longrightarrow 2MOH + H_2$

(Alkali metal)

$M + 2H_2O \longrightarrow M(OH)_2 + H_2$

(Alkaline earth metals)

- **Reactivity towards Hydrogen:**

$2M + H_2 \longrightarrow 2MH$

(M = Li, Na, K, Rb, Cs)

$M + H_2 \longrightarrow MH_2$

(M = Mg, Ca, Sr, Ba)

$2BeCl_2 + LiAlH_4 \longrightarrow 2BeH_2 + LiCl + AlCl_3$.

- **Reactivity towards Halogens:**

$2M + X_2 \longrightarrow 2MX$ (M = Li, Na, K, Rb, Cs)

$M + X_2 \longrightarrow MX_2$ (M = Mg, Ca, Sr, Ba)

$BeO + C + Cl_2 \xrightarrow{600\text{-}800\,K} BeCl_2 + CO$

Diagonal Relationship between Lithium and Magnesium

(i) Both Li and Mg are hard.

(ii) Both react with N_2 to form nitrides.

$6Li + N_2 \longrightarrow 2Li_3N$

$3Mg + N_2 \longrightarrow Mg_3N_2$

Anomalous behavior of Li and Be

- It is done to very small size, high I.E. and high polarizing power (i.e., charge/radius).

(iii) Decomposition of carbonates:

$Li_2CO_3 \longrightarrow Li_2O + CO_2$

$MgCO_3 \xrightarrow{\Delta} MgO + CO_2$

(iv) Both LiCl and $MgCl_2$ are deliquescent. They form hydrates salts $LiCl.2H_2O$ and $MgCl_2.6H_2O$.

(v) Decomposition of netrates:

$4LiNO_3 \xrightarrow{\Delta} 2Li_2O + 4NO_2 + O_2$

$2Mg(NO_3)_2 \xrightarrow{\Delta} 2MgO + 4NO_2 + O_2$

Sodium Hydroxide

- **Manufacturing of causing soda (NaOH):** Castner-Kellnerc

Cathode : $Na^+ + e^- \xrightarrow{Hg} Na\text{-}Hg$

Anode : $Cl^- \longrightarrow e^- + \frac{1}{2}Cl_2$

$2Na\text{-}Hg + 2H_2O \longrightarrow 2NaOH + 2Hg + H_2$

Sodium Carbonate

- **Manufacturing of washing soda ($Na_2CO_3.10H_2O$) :**
- **Solvay process :**

$$NH_3(g) + CO_2(g) + H_2O\ (l) \longrightarrow NH_4HCO_3\ (aq)$$
$$NH_4HCO_3\ (aq) + NaCl\ (aq) \longrightarrow NaHCO_3(s) + NH_4Cl\ (aq)$$
$$2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + H_2O(l) + CO_2(g)$$
$$2NH_4Cl\ (aq) + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O + 2NH_3$$

Sodium hydrogen carbonate

- This can be obtained by passing carbon dioxide through a cold concentrated solution of the corresponding carbonate, ***e.g.***

$$(Na^+)_2CO_3^{2-}(aq) + CO_2(g) + H_2O(1) \longrightarrow 2Na^+HCO_3^-(s)$$

Calcium oxide (CaO)

- **Manufacture of CaO:** CaO (quick lime) is manufactured in enormous quantities (126 million tonnes in 1988) by roasting $CaCO_3$ in lime Kiln.

$$CaCO_3 \xrightarrow{heat} CaO + CO_2$$

CaCO3 Calcium Carbonate

- $CaCO_3$ occurs in two different crystalline forms, calcite and aragonite. Both forms occur naturally as minerals. Calcite is the more stable: each Ca^{2+} is surrounded by six oxygen atoms from $CO3^{2-}$ ions.

Uses of Lime:

1. In steel making to remove phosphates and silicates as slag.

2. By mixing with SiO_2 and alumina or clay to make cement.

Diagonal relationship (similarities) between Be and Al:

i. Both are passive to acids due to formation of oxide layer.

ii. Hydroxides of both dissolve in alkali to form $[Be(OH)_4]^{2-}$ and $[Al(OH)4]^{-}$.

iii. Chloride of both has bridged structure.

iv. Both have tendency of form complexes of BeF_4^{2-}, AlF_6^{3-}.

- **Solution in liquid ammonia:** The fresh solution of alkali metals and alkaline earth metals (except Be and Mg) is deep blue, paramagnetic and highly reducing due to presence of ammoniated electrons.
- Solubility of alkaline earth metal hydroxide in water :
  $Li_2CO_3 < Na_2CO_3 < K_2CO_3 < RbCO_3 < Cs_2\ CO_3$
- Solubility of alkaline earth metl carbonates in water.
  $BaCO_3 < SrCO_3 < CaCO_3 < MgCO_3 < BeCO_3$
- Solubility of alkaline earth metal sulphates in water :
  $BaSO_4 < SrSO_4 < CaSO_4 < MgSO_4 < BeSO_4$
- Thermal stability of alkali metal carbonates:
  $Li_2CO_3 < Na_2CO_3 < K_2CO_3 < Rb_2CO_3 < Cs_2CO_3$
- Thermal stability of alkaline earth metal carbonates :
  $BeCO_3 < MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3$
- **Biological Role of Mg^{2+} and Ca^{2+}**
- Mg^{2+} ions are concentrated in animal cells, and Ca^{2+} are concentrated in the body fluids outside the cell.
- They are also essential for the transmission of impulses along nerve fibres. Mg^{2+} is important in chlorophyll, in the green parts of plants.
- Ca^{2+} is important in bones and teeth as apatite $Ca_3(PO_4)_2$, and the enamel on teeth as fluoroapatite $[3(Ca_3(PO_4)_2)\bullet CaF_2]$.
- Ca^{2+} ions are important in blood clotting, and to maintain the regular beating of the heart.

Check Yourself

1. CsOH is

(A) Strongly basic

(B) Weakly basic

(C) Slightly acidic

(D) Amphoteric.

2. Solvay's process is used for the manufacture of:

(A) NaOH (B) (Na_2CO_3. $10H_2O$)
(C) K_2CO_3 (D) Na_2O_2

3. Alkali metals give a ________________when dissolved in liquid ammonia

(A) Deep blue solution

(B) Colourless

(C) Red colour

(D) None of the Above

4. What are Oxo-Acids?

(A) Acid containing Oxygen

(B) Acid containing Sulphur

(C) Acid containing Carbon

(D) None of the Above

5. In curing cement plasters, water is sprinkled from time to time. This helps in

(A) Converting sand into silicic acid

(B) Keeping it cool

(C) Developing interlocking needle like crystals of hydrated silicates

(D) Hydrating sand and gravel mixed with cement.

Stretch Yourself

1. Give reason the compounds of alkaline earth metals are less ionic than alkali metals.

2. How is Calcium Hydroxide (Slaked lime), $Ca(OH)_2$ Prepared?

3. Which elements of s- block are largely found in biological fluids & what is its importance?

4. Name the most power full reducing agent & give reason for it.

5. Why Solvay process cannot be extended for the manufacture of potassium carbonate?

Test Yourself

Question: Arrange the first group elements in the decreasing order of Hydration Enthalpy.

Answer: Li^+, Na^+, K^+, Rb^+, Cs^+

Answers

Check Yourself

Answer: 1(A); 2(B); 3(A); 4(A); 5(C)

Stretch Yourself

1. That is because Alkaline earth metals have smaller sizes of cation and more valence electrons.

2. Calcium hydroxide, $Ca(OH)_2$, colorless crystal or white powder. It is prepared by reacting calcium oxide (lime) with water; a process called slaking, and is also known as hydrated lime or slaked lime. When heated above 580°C it dehydrates, forming the oxide.

3. The Na^+, K^+, Mg^{2+}, and Ca^{2+} ions are important components of intracellular and extracellular fluids. Both Na^+ and Ca^{2+} are found primarily in extracellular fluids, such as blood plasma, whereas K^+ and Mg^{2+} are found primarily in intracellular fluids.

4. Due to the smallest standard reduction potential, lithium is the strongest reduction agent. It decreases another substance when something is oxidized, becoming a reduction agent. Lithium is, therefore, the most powerful reducing agent.

5. Ammonium hydrogen carbonate does not react with potassium chloride.