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15. s-BLOCK ELEMENTS

HYDROGEN

1. INTRODUCTION

The most abundant element of universe (≈76%), the fifteenth most abundant in the earth, and the tenth most abundant in earth crust Hydrogen is the lightest, smallest and first element of periodic table with atomic number one.

In nature, hydrogen is found in the free as well as in the combined state.

In the atmosphere, the presence of hydrogen is found to very minute (only one part in a million by volume) owing to its high chemical reactivity. Low abundance in the atmosphere is also due to the earth's gravitational field which is too small to hold on to so light an element.

Hydrogen

Symbol: H	At. No.: 1
Placed with alkali metals as well as Halogens	At. Wt.: 1.008
Electronic configuration - $1s^1$	

2. POSITION OF HYDROGEN IN PERIODIC TABLE

Hydrogen is a unique element, it has only one electron in the 1s-orbital and no electrons in the other shell. It may donate one electron forming H^+ (like alkali metals) or may accept one electron forming H^- (like halogens). It ranges in character from being a strong Lewis base (H^-) to being a strong Lewis acid (H^+). It is this nature which makes it difficult for us to assign hydrogen its proper place in the periodic table because of its resemblance with halogens as well as with alkali metals.

2.1 Resemblance with Alkali Metals

Hydrogen resembles alkali metals in the following respects:

(a) **Electronic Configuration** - Like alkali metals, hydrogen also has one valence electron.

(b) **Electropositive Character** - Like other alkali metals, Hydrogen readily forms the Hydronium ion, which is very stable.

(c) **Reaction with Non-Metals** - Forms sulphides, oxides and halides same as alkali metals.

(d) **Reducing action** - Like alkali metals, hydrogen also acts as strong reducing agent.

E.g., $F_2 + H_2 \rightarrow 2HF$

2.2 Resemblance with Halogens

(a) **Electronic configuration:** Like halogens, hydrogen is short of one electron for stability in the outer orbit as explained below-

$H + e^- \rightarrow H^-$ $\qquad$ $F + e^- \rightarrow F^-$

(b) **Atomicity:** All halogens exist as diatomic covalent molecules F_2, Cl_2, etc. In a similar way hydrogen is a diatomic covalent molecule.

E.g. H_2, $\quad Cl_2$, $\quad Br_2$

(c) **Physical state:** Hydrogen is a gas like F_2 and Cl_2.

(d) **Ionization potential:** I.P of hydrogen is very high, same as in the case of halogens.

H	13.12 eV
F	16.8 eV
Cl	12.55 eV

(e) **Reaction with non-metals:** Both, halogens and hydrogen combine with other non-metals by forming single bonds to give compounds like CCl_4, CH_4, and $SiCl_4$.

3. SPECIAL FORMS OF HYDROGEN

3.1 Nascent Hydrogen

(a) Nascent H is hydrogen at the moment of its generation, i.e., when it is just set free in a chemical reaction.

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + \underset{\text{(Nascent hydrogen)}}{2H}$$

(b) This hydrogen is more reactive and a more powerful reducing agent than ordinary H_2. It reduces the following:

(i) Decolourizes yellow colour of $FeCl_{3(aq)}$.

$$H + \underset{\text{Yellow}}{FeCl_3} \longrightarrow \underset{\text{Colourless}}{FeCl_2} + HCl$$

(ii) Decolourizes violet colour of $KMnO_4$.

$$\underset{\text{Violet}}{2KMnO_4} + 3H_2SO_4 + 10H \longrightarrow K_2SO_4 + \underset{\text{Colourless}}{2MnSO_4} + 8H_2O$$

(iii) Turns $K_2Cr_2O_7$ solution to green.

$$\underset{\text{Orange}}{K_2Cr_2O_7} + 4H_2SO_4 + 6H \longrightarrow K_2SO_4 + \underset{\text{Green}}{Cr_2(SO_4)_3} + 7H_2O$$

No such change in colour is produced when H_2 is bubbled through the solution of $FeCl_3$, $KMnO_4$ or $K_2Cr_2O_7$.

3.2 Adsorbed Hydrogen (Occluded Hydrogen)

H_2 on bubbling at the surface of platinum black, is adsorbed there and becomes capable of bringing out many chemical changes such as reduction and hydrogenation. This type of hydrogen is named as adsorbed H_2. Similarly H_2, occluded or adsorbed on Palladium is a very strong reducing agent and combines with halogens even in the dark, precipitates Hg from $HgCl_2$.

3.3 Atomic Hydrogen

In 1922, Langmuir showed that H_2 placed in contact with a tungsten wire, heated by an electric arc at low pressure dissociates into atoms with an absorption of 104.0 kcal of heat per mol.

$H_2 \xrightarrow{\text{Electric Arc}} 2H, \Delta H = 104 \text{ kCal mol}^{-1}$ ($t_{1/2}$ for atomic hydrogen is 0.3 seconds only)

3.4 Ortho and Para Hydrogen

When the spins of both the protons (nucleus) in the hydrogen molecule are in the same direction then this form is known as ortho hydrogen. The molecule of hydrogen in which both the protons are spinning in opposite directions known as para hydrogen. These are nuclear isomers.

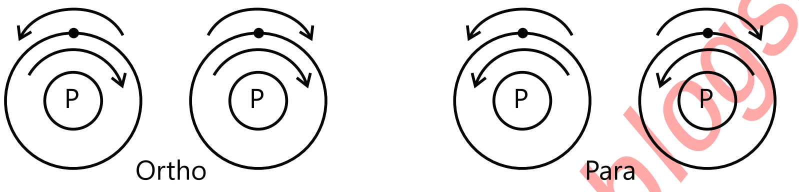


Figure 15.1: Spins for Ortho and Para Hydrogen

At normal temperature the ratio of ortho and para hydrogen is 3: 1, but as the temperature is lowered, the proportion of para hydrogen increases (at 20°C).

PLANCESS CONCEPTS

- Difference between Nascent and Atomic Hydrogen - Scientifically, nascent refers to the substance at the point at which it forms. Such as Zinc reacts with sulphuric acid, individual hydrogen atom forms but very quickly reacts with other hydrogen atom forming H_2 molecule. This is the only common situation at which atomic hydrogen exists even very fleetingly.
- Since ortho is more stable than para form at room temperature. Para readily gets converted into ortho by following reaction:

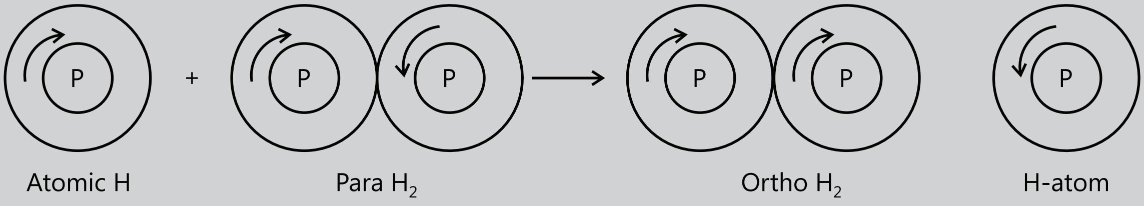


Figure 15.2: Conversion of para H_2 to ortho H_2

- Adsorbed H_2 is more reactive than normal dihydrogen.

Vaibhav Krishnan (JEE 2009, AIR 22)

4. DIHYDROGEN OR DIPROTIUM

4.1 Methods of Preparation of Dihydrogen

4.1.1 From Water

The cheapest and most widely available source of hydrogen is water. H_2 can be obtained from water using any one of the processes given below:

(a) By action of water on metals

(b) By action of water on hydrides

(c) By action of water on methane

(d) By electrolysis of water

4.1.2 From Acids

Metals which lie above hydrogen in electro-chemical series i.e. metals with positive $E°_{OP}$, do not displace H_2 from dilute mineral acid like HCl or H_2SO_4. Metals having negative $E°_{OP}$ (i.e. metals lying below hydrogen in ECS) displace H_2 from acids, e.g., Zn, Mg, Fe etc. displace H_2 from acids.

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2\uparrow$$

4.1.3 From Alkali

Certain metals like Zn, Sn, Al, Pb, Si etc. (amphoteric metals) react with boiling NaOH to liberate H_2.

$$Zn + 2NaOH \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2} + H_2\uparrow$$

$$2Al + 2NaOH + 2H_2O \longrightarrow \underset{\text{Sodium aluminate}}{2NaAlO_2} + 3H_2\uparrow$$

4.2 Manufacture of H_2 on Commercial Scale

4.2.1 By Electrolysis of Water

The water containing a small amount of an acid or alkali (about 15-20%) is electrolysed in an electrolytic cell. The anode and cathode are separated by an asbestos diaphragm. The cathode is usually made up of iron and anode usually of nickel.

At anode: OH^- ions are discharged and oxygen is evolved.

$$4OH^- \longrightarrow 2H_2O + O_2 + 4e^-$$

At cathode: H^+ ions are discharged and hydrogen is evolved.

$$2H^+ + 2e^- \longrightarrow H_2\uparrow$$

4.2.2 Bosch Process

This process is most common, and in this process, first steam is passed over hot coke at 1000°C to obtain water gas or Synthesis gas or Syn gas.

$$C_{(s)} + H_2O_{(V)} \xrightarrow{Ni/1000°C} \underbrace{CO + H_2}_{\text{Syn.gas}}$$

This process of obtaining 'Synthesis gas' from coal or coke is called "Coal gasification"

4.2.3 Lane's Process

This process involves the decomposition of steam by heated Fe (550 - 800°C). The reaction is known as **"gassing reaction".**

$3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2\uparrow ;\Delta H = -160.7kJ$

4.2.4 From Hydrocarbons

(a) Thermal Cracking: $CH_4 \xrightarrow{\text{Catalyst}/\Delta} C + 2H_2\uparrow$

(b) By partial oxidation: $\underset{\text{Natural gas}}{CH_4} + H_2O \xrightarrow{\text{Ni/1000°C}} \underbrace{CO + 3H_2\uparrow}_{\text{Syn.gas}}$

4.3 Physical Properties of Dihydrogen

(a) Colourless, odourless, tasteless gas

(b) Sparingly soluble in water due to non-polar nature

(c) Density is 0.09 gm/lit

(d) B.P is 20.4 K

(e) Pd metal can adsorb H_2 gas

4.4 Chemical Properties of Dihydrogen

(a) **Nature:** H_2 is neutral and so it does not affect litmus.

(b) **Combustion:** H_2 is highly combustible and in presence of air, it burns with pale blue flame. It does not support combustion.

$2H_2 + O_2 \longrightarrow 2H_2O_{(l)} \qquad \Delta H = -285.9\ kJmol^{-1}$

Reaction is highly exothermic and its calorific value is higher than other fuels.

(c) **Reducing action:** Dihydrogen reduces oxides of certain less electropositive metals (generally less electropositive than Zn and placed above H in ECS) like Fe, Pb, Cu etc. The product is metal, e.g.,

$Fe_2O_3 + 3H_{2(g)} \xrightarrow{\Delta} 2Fe + 3H_2O$

$CuO_{(s)} + H_{2(g)} \xrightarrow{\Delta} Cu + H_2O$

(d) **Reaction with non-metals:** With non-metals, hydrogen forms covalent hydrides, e.g., $H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$

$3H_2 + N_2 \xrightarrow{\text{750K/Fe,Mo}} 2NH_3$ (Haber's process)

(e) **Reaction with Metals**: Under suitable conditions, H_2 reacts with metals to form hydrides which are chiefly ionic. Alkali metals and alkaline earth metals (except Be) react with H_2 directly.

$2M + H_2 \rightarrow 2MH$ (M = Li, Na, K, Rb etc.)

$M + H_2 \rightarrow MH_2$ (M = Mg, Ca, Ba etc.)s

PLANCESS CONCEPTS

Hydrogen is a diatomic gas having H—H bond. H—H bond is strongest known single bond (Bond energy = 435.9 kJ mol^{-1}) between two atoms of any element.

H_2 is not very reactive at normal temperature and pressure. This lack of reactivity is due to thermodynamics, not kinetics as it is related to bond strength. Since the H—H bond energy is very high it reacts at high temperature only and in the presence of catalysts which further lower the activation energy.

Nikhil Khandelwal (JEE 2009, AIR 94)

5. HEAVY HYDROGEN OR DEUTERIUM

5.1 Preparation of Deuterium

D_2 can be absorbed from H_2 by distillation, diffusion and other chemical properties. One notable method is adsorption of H_2 on charcoal leaving out D_2.

5.2 Physical Properties

(a) It is colourless, odourless, tasteless, water insoluble, diatomic gas.

(b) Its physical constants like b.pt., m.pt., triple point etc. are higher than H_2.

(c) Being heavier than H_2, it diffuses at less speed than H_2.

5.3 Chemical Properties

D_2 resembles with H_2, in its chemical properties, but reacts at a slower rate than H_2, because it's bond strength is greater than that of H_2. There is marked isotope effect as mol. wt. of D_2 is twice to H_2. Also, its adsorption on the surface of metals is also slower than H_2.

6. WATER

6.1 Structure of Water

Molecule of water is V-shaped and its structure is given below: In water, the central oxygen atom is sp^3 hybridised. Out of four sp^3 hybrid orbitals, two form σ bond with s-orbital of H-atom while rest two are occupied by lone pairs of electrons. Due to lp-bp repulsion, the H—O—H bond angle is contracted to 104.5°. O—H bond length is 95.7pm. Due to its V-shaped structure, H_2O is a polar molecule ($\mu = 1.84$ D).

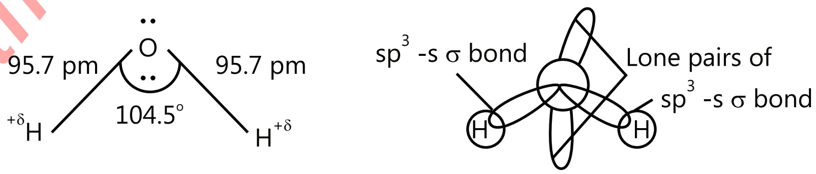


Figure 15.4: Water Molecule

6.2 Structure of Ice

In ice, each oxygen atom is bonded to 4 other oxygen atoms by hydrogen bonds as shown in Fig. This gives ice, an open framework. When ice melts, some hydrogen bonds are broken. The 'bridges' and the open framework collapse, causing water molecules to fall into the empty spaces.

This close packing of molecules allows the liquid to occupy a smaller volume than the ice, and the density increases.

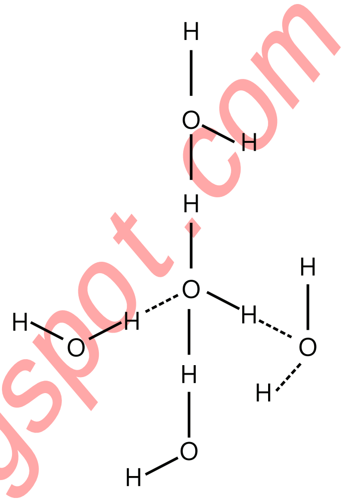


Figure 15.3: Structure of Ice

6.3 Physical Properties of Water

Pure water is a colourless, odourless and tasteless liquid. It gives a bluish tinge in thick layers. Water has an abnormally high freezing point, boiling point, heat of vaporization, heat of fusion. Water has a high specific heat, surface tension and thermal conductivity than most other liquids. These properties are responsible for water to play a vital role in life processes. These unique properties of water are due to the presence of hydrogen bonding.

6.4 Chemical Properties of Water

(a) Acid-Base Nature: Water acts as both an acid and a base, and is said to be amphoteric. Water acts as a base towards acids stronger than itself and as an acid in the presence of a base stronger than itself, as shown below:

$$\underset{\text{Base}}{H_2O_{(l)}} + \underset{\text{Acid}}{HCl_{(aq.)}} \rightleftharpoons \underset{\text{Acid}}{H_3O^+_{aq}} + \underset{\text{Base}}{Cl^-_{aq.}}$$

$$\underset{\text{Acid}}{H_2O_{(l)}} + \underset{\text{Base}}{NH_{3(aq.)}} \rightleftharpoons \underset{\text{Acid}}{NH_4^+{}_{(aq.)}} + \underset{\text{Base}}{OH^-_{(aq.)}}$$

(b) Oxidation and Reduction: Water acts both as an oxidizing as well as a reducing agent.

e.g. $2Na + H_2O \longrightarrow 2NaOH + H_2$

$2NaH + H_2O \longrightarrow 2NaOH + H_2$

(c) Hydrolytic Reaction: Compounds like calcium hydride, aluminium nitride, calcium phosphide, calcium carbide, silicon halide etc. undergo hydrolysis with water.

$CaH_2 + 2H_2O \longrightarrow Ca(OH)_2 + 2H_2$

$AlN + 3H_2O \longrightarrow Al(OH)_3 + NH_3$

(d) Hydrate Formation: Water reacts with certain metal salts to form hydrates. In hydrated salts water may remain in 5 types:

(i) Co-ordinated water, (ii) Hydrogen bonded water, (iii) Lattice water, (iv) Zeolitic water, (v) Clathrate water.

6.5 Soft and Hard Water

A sample of water which easily produces lather with soap is known as "Soft Water" while "hard water" doesn't produce lather with soap easily.

The soluble Ca^{+2}, Mg^{+2} or Fe^{+2} ions react with soap to give Ca or Mg soap which being insoluble in water get precipitated.

$MgCl_2 + 2C_{17}H_{35}COONa \longrightarrow (C_{17}H_{35}COO)_2Mg \downarrow + 2NaCl$

$CaCl_2 + 2C_{17}H_{35}COONa \longrightarrow 2NaCl + (C_{17}H_{35}COO)_2Ca \downarrow$

Hardness of Water and Removal

(a) Temporary hardness: It is due to the dissolution of bicarbonates of Ca and Mg in water. It can be removed by boiling.

$$Ca(HCO_3)_2 \xrightarrow{\text{Boiling}} CaCO_3 + H_2O + CO_2$$

$$Mg(HCO_3)_2 \xrightarrow{\text{Boiling}} MgCO_3 + H_2O + CO_2$$

It can also be done by adding lime

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 + 2H_2O$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow CaCO_3 + MgCO_3 + 2H_2O$$

(b) Permanent Hardness and its Removal: Permanent hardness happen due to the dissolution of chloride and sulphates of Ca, Mg, Fe. It cannot be removed by boiling of water.

It can be removed by following

(i) **Adding washing soda:** $CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2NaCl$

(ii) **Permutit Method:** Permutit is an artificial zeolite. It is sodium alumino orthosilicates i.e. $Na2Al_2Si_2O_8$. The hardness causing ions are retained by the bed and Na^+ ions from bed, form soluble salt like $NaHCO_3$. To recharge the bed after complete exhaustion, it is treated with NaCl solution which regenerates the zeolite bed. This process removes both types of temporary and permanent hardness.

$$Na_2Z + Ca(HCO_3)_2 \downarrow \longrightarrow CaZ \downarrow + 2NaHCO_3$$

$$CaZ\ (\text{or } MgZ) + 2NaCl \xrightarrow{(\text{or } MgHCO_3)} Na_2Z + CaCl_2\ (\text{or } MgCl_2)$$

(iii) **Calgon Process:** Calgon which is also known as Grahm's salt is the trade name of sodium hexametaphosphate $(NaPO_3)_6$. The Ca^{+2} and Mg^{+2} ions dissolved in hard water react with calgon to produce complex anions, which are very inactive and don't produce a ppt. with soap.

$$Na_2[Na_4(PO_3)_6] + 2CaCl_2 \longrightarrow Na_2[Ca_2(PO_3)_6] + 4NaCl$$

(iv) **By Ion Exchange Resin:** Resins are giant organic molecules attached with acidic or basic groups. Cation exchange resin contain –COOH or $–SO_3H$ groups. These remove cations like Na^+, Ca^{+2}, Mg^{+2}, Fe^{+2} etc by exchange with H^+. Anion exchange resins contain $–NH_2$ group they are represented by $RNH_3^+\ OH^-$. These resins remove negative ions such as Cl^-, SO_4^{-2}, NO_3^- etc.

(c) Degree of Hardness: Degree of hardness is usually expressed in parts per million (ppm) and thus may be defined as the number of parts by weight of $CaCO_3$ (equivalent to calcium and magnesium salt) present in a million (10^6) parts by weight of water.

1 ppm = 1 part of $CaCO_3$ in 10^6 parts of water.

6.6 Heavy Water

Heavy water is extensively used as a moderator in nuclear reactors and in exchange reactions for the study of reaction mechanisms. It can be prepared by exhaustive electrolysis of water or as a by-product in some fertilizer industries.

It is used for the preparation of other deuterium compounds, for example:

$$CaC_2 + 2D_2O \longrightarrow C_2D_2 + Ca(OD)_2$$

$$SO_3 + D_2O \longrightarrow D_2SO_4$$

$$Al_4C_3 + 12D_2O \longrightarrow 3CD_4 + 4Al(OD)_3$$

PLANCESS CONCEPTS

The dissociation constant of D_2O is less than H_2O because O-D bond is stronger than O-H bond so it takes more energy to break O-D bond owing to more atomic mass of D than H which stabilises the bond by reducing the vibration of bonds.

$H_2O \rightleftharpoons H^+ + OH^-$; $K_W = 1.0 \times 10^{-14}$

$D_2O \rightleftharpoons D^+ + OD^-$; $K_W = 1.95 \times 10^{-15}$

Use of Organic resins for softening the hard water is the best method because purification can be easily done so it is used commercially.

Saurabh Gupta (JEE 2010, AIR 443)

7. HYDROGEN PEROXIDE

7.1 Preparation of H_2O_2

(a) Lab method of preparation of H_2O_2 – H_2O_2 obtained by passing a current of CO_2 through a cold pasty solution of BaO_2 in water.

$$BaO_2 + CO_2 + H_2O \longrightarrow H_2O_2 + BaCO_3$$

(b) Treating Na_2O_2 with $H_2SO_4^{-2}$

(i) $Na_2O_2 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O_2$

(ii) Also, by small amount of Na_2O_2 added to ice cold water.

(iii) $Na_2O_2 + 2H_2O \longrightarrow 2NaOH + H_2O_2$

(c) Industrial process: By electrolysis of 50% H_2SO_4 at 0°C using Pt electrode.

$$2H_2SO_4 \longrightarrow 2H^+ + 2HSO_4^-$$

At cathode: (Cu) – $2H^+ + 2e^- \longrightarrow H_2$

At anode: (Pt) – $2HSO_4^- \longrightarrow H_2S_2O_8 + 2e^-$

$H_2S_2O_8 + 2H_2O \longrightarrow H_2O_2 + 2H_2SO_4$

(d) Electrolysis of ammonium hydrogen sulphate: In the electrolysis of ammonium hydrogen sulphate, ammonium per sulphate is formed. It is separated and distilled with dil.H_2SO_4 to give 30 - 40% H_2O_2 (aqueous solution)

$NH_4HSO_4 \Leftrightarrow NH_4\,SO_4^- + H^+$

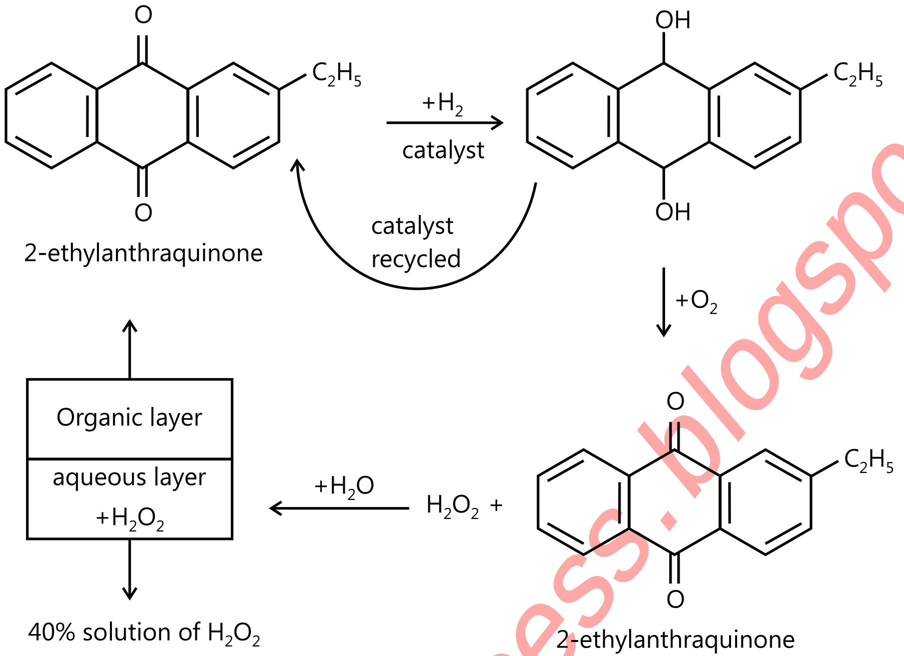
At cathode: $2H^+ + 2e^- \longrightarrow H_2$(reduction)

At anode: $2NH_4\,SO_4^- \longrightarrow (NH_4)_2S_2O_8 + 2e^-$ (oxidation)

Distillation: $(NH_4)\,S_2O_8 + 2H_2O \xrightarrow{H_2SO_4} 2NH_4HSO_4 + H_2O_2$

(e) Auto - oxidation of 2-ethyl anthraquinone: This is the most modern method and needs H_2, atmospheric oxygen and water as the major raw materials.

First and foremost, 2-ethyl anthraquinone is catalytically reduced to 2-ethyl anthraquinol in organic solvent by H_2 and Pd (catalyst). Secondly, 2-ethyl anthraquinol is oxidised by air to 2-ethyl anthraquinone. H_2O_2 obtained in the process is extracted with water to give 20% H_2O_2 solution. 2-ethyl anthraquinone is thus reused. The process is repeated, thus it is a cyclic process.



7.2 Physical Properties of H_2O_2

(a) Pure H_2O_2 is weakly acidic in nature and exists as an associated liquid due to hydrogen bonding.

(b) Smell of H_2O_2 resembles like nitric acid.

(c) It causes blisters on skin.

(d) Stored in plastic containers after addition of stabilizers.

(e) A dilute solution of H_2O_2 is concentrated by vacuum distillation or by distillation under pressure.

7.3 Chemical Properties

(a) Decomposition $2H_2O_2 \xrightarrow{\Delta} 2H_2O+O_2$; $\Delta H = -196kJ$

(b) Oxidising and reducing nature : H_2O_2 acts as a strong oxidising agent under acidic and alkaline conditions. Oxidation in the acidic medium is slow while rapid in an alkaline solution as H_2O_2 itself is a weak acid.

$$H_2O_2 + 2H + 2e \longrightarrow 2\ H_2O$$

$$H_2O_2 \longrightarrow H_2O + [O]$$

$$PbS + 4H_2O_2 \longrightarrow PbSO_4 + 4H_2O$$

$$2KI + H_2O_2 \longrightarrow 2KOH + I_2$$

$$2KI + H_2SO_4 + H_2O_2 \longrightarrow K_2SO_4 + 2H_2O_2 + I_2$$

$$H_2O_2 + H_2S \longrightarrow 2H_2O + S$$

$$2K_4\left[Fe(CN)_6\right] + H_2O_2 \longrightarrow 2K_3\left[Fe(CN)_6\right] + 2KOH$$

$$K_2Cr_2O_7 + H_2SO_4 + 4H_2O_2 \longrightarrow K_2SO_4 + \underset{\text{(Blue)}}{2CrO_5} + 5H_2O$$

$$H_2O + 2OH^- + 2e^- \longrightarrow 2H_2O_2 + 2O_2$$

$$2HCHO + H_2O_2 \longrightarrow 2HCOOH + H_2$$

Reducing nature

$$2KMnO_4 + 3H_2SO_4 + 5H_2O_2 \longrightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$$

$$K_2Cr_2O_7 + 4H_2SO_4 + 3\,H_2O_2 \longrightarrow K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O + 3O_2$$

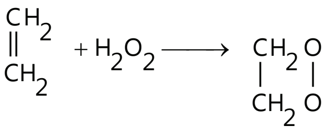
$$O_3 + H_2O_2 \longrightarrow H_2O + 2O_2$$

$$Cl_2 + H_2O_2 \longrightarrow 2HCl + O_2$$

$$2K_3\left[Fe(CN)_6\right] + 2KOH + H_2O_2 \longrightarrow 2K_4\left[Fe(CN)_6\right] + 2H_2O + O_2$$

(c) **Bleaching action:** H_2O_2 acts as a bleaching agent due to its oxidising nature e.g., bleached human hair (black to golden brown), ivory, silk, wool, feather etc. $H_2O_2 \longrightarrow H_2O_2 + [O]$

(d) **Addition properties**



$$\begin{array}{c} CH_2 \\ \| \\ CH_2 \end{array} + H_2O_2 \longrightarrow \begin{array}{cc} CH_2 & O \\ | & | \\ CH_2 & O \end{array}$$

7.4 Uses of H_2O_2

Its wide scale use has led to the tremendous increase in the industrial production of H_2O_2. Some of the uses are listed below:

(a) In daily life, it is used as a hair bleach and as a mild disinfectant. As an antiseptic, it is sold in the market as perhydrol.

(b) It is used to manufacture chemicals like sodium perborate and per-carbonate, which are used in high quality detergents.

(c) It is used in the synthesis of hydroquinone, tartaric acid and certain food products and pharmaceuticals (cephalosporin) etc.

(d) It is employed in the industries as a bleaching agent for textiles, paper pulp, leather, oils, fats, etc.

(e) Nowadays, it is also used in Environmental (Green) Chemistry. For example, in pollution control treatment of domestic and industrial effluents, oxidation of cyanides, restoration of aerobic conditions to sewage wastes, etc.

7.5 Tests for H_2O_2

(a) An acidified solution of titanium salt when treated with H_2O_2 a yellow or orange colour is developed due to formation of pertitanic acid.

$$Ti(SO_4)_2 + H_2O_2 + 2\,H_2O_2 \longrightarrow H_2TiO_4 + 2H_2SO_4$$

(b) It liberates iodine from KI solution which gives a blue colour with starch solution

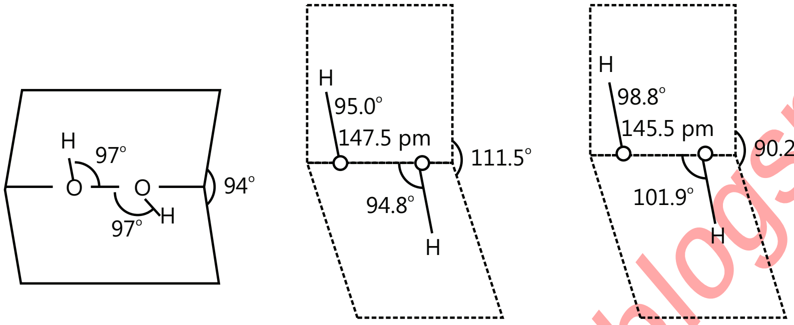
(c) H_2O_2 on shaking with acidified $K_2Cr_2O_7$ with little ether, blue colour is produced.

7.6 Structure of H_2O_2

All four atoms in H_2O_2 are non-planar. Structure of H_2O_2 has an open book structure having two leaves at 90°, the H-atoms are placed one on each core, the H–O making an angle of 101.5° with O–O bond.

Bond Angle: Dipole moment value of H_2O_2 suggests that all the four atoms in H_2O_2 do not lie in a plane, and the structure can be compared with a book open at angle 94°.

The H—O—O bond angle is 97°.



(a) Gas phase (b) Solid phase

Figure 15.5: Structure of H_2O_2

7.7 Strength of H_2O_2

(a) **As percentage:** The strength of H_2O_2 is sometimes reported in percentage. Bottles containing H_2O_2 are labelled as 40%, 60%... etc. This means that 100 ml solution of H_2O_2 contains 40 g H_2O_2.

(b) **As number volume:** The strength of hydrogen peroxide is often expressed in terms of the volume of oxygen evolved on heating. Bottles containing hydrogen peroxide are labelled as '10 Volume',

'20 Volume', '100 Volume' etc. This means that one volume of hydrogen peroxide solution gives so many volumes to oxygen (after complete decomposition) at N.T.P.

Thus 1 mL of '10 Volume' solution produces 10 mL of oxygen at N.T.P, 1,000 mL of a '10 Volume' solution produce 10,000 mL of oxygen at N.T.P, 1000 mL of a '20 Volume' solution produce 20,000 mL of oxygen at N.T.P. etc.

PLANCESS CONCEPTS

- % strength = $\frac{17}{56}$ × volume strength
- Volume strength = 5.6 × normality
- Volume strength = 11.2 × molarity

H_2O_2 is a very unstable compound which can easily decompose in the presence of metallic impurities sometimes leading to explosions. To avoid this, stabilizers such as H_3PO_4 or glycerol are use to maintain the equilibrium backward.

Neeraj Toshniwal (JEE 2009, AIR 21)

Illustration 1: (i) Convert 20 vol. H_2O_2 into % strength.

(ii) Convert 6.8% strength H_2O_2 into volume strength. **(JEE MAIN)**

Sol: (i) 20 vol. H_2O_2 means 1 mL of H_2O_2 solution gives 20 mLO_2

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

2 mole 1 mole

= 68g 22400 mL at NTP

$\therefore$ 22400 mL O_2 is obtained by 68 g H_2O_2

$\therefore$ 20 mL O_2 is obtained by $\frac{68 \times 20}{22400}$ = 0.0607 g H_2O_2

or 1 mL H_2O_2 solution = 0.0607g H_2O_2

$\therefore$ 100 mL H_2O_2 solution = 0.0607 × 100 g H_2O_2 = 6.07%

(ii) 6.8% strength H_2O_2 solution means 6.8 g H_2O_2 is present in 100 mL H_2O_2

$\therefore$ 68 g H_2O_2 gives 22400 mL O_2 at NTP

$\therefore$ 6.8g H_2O_2 gives $\frac{22400 \times 6.8}{68}$ = 2240 mL O_2

$\therefore$ Volume strength of H_2O_2 gives = $\frac{2240}{100}$ = 22.4 Volume

8. HYDRIDES

Binary compounds of hydrogen with other elements, are generally called hydrides, but strictly speaking, this term should be applied to compounds of hydrogen with elements, which are less electronegative than hydrogen. They may be of MH_n or M_mH_n type.

8.1 Ionic Hydrides

(a) They are hydrides of elements having low electronegativity (ranging between 0.9 to 1.2 usually). They are formed by alkali metals, alkaline earth metals (except Be and Mg) and some lanthanides.

(b) In these hydrides, hydrogen accepts electrons from combining elements and exists as H^-

(c) These hydrides can be prepared by heating (≈ 1000 – 1100 K) metals with hydrogen directly.

E.g. $2Na + H_2 \rightarrow 2NaH$

Some Important Chemical Properties

(a) **Stability:** Ionic hydrides have quite high heats of formation and consequently high stability. On moving down in the group, the stability decreases which may be attributed to a poor overlap between the relatively smaller 1s orbital of hydrogen and larger s-orbital of heavier metals. LiH > NaH > KH > RbH > CsH

(b) Gets hydrolyzed by giving alkali and H2 gas.

(c) At high temperatures, act as strong reducing agents.

8.2 Covalent Hydrides

(a) These hydrides are formed mainly by p-block elements (except noble gases) and by some s-block elements like Be and Mg.

(b) These hydrides usually consist of discrete covalent molecules held together by weak 'Vander Waals' forces and so these hydrides are usually volatile. The melting points and boiling points of covalent hydrides are low. Some of them are liquids or even solids in a few cases.

(c) They do not conduct electricity and their general formula may be MHX (for s-block metals) or MH(8–n) (for s-block elements), here n is the number of valence electrons. This generalization is not valid for the boron family.

Covalent hydrides can be electron deficient also such as DIBORANE B_2H_6 and other such bridge bond hydrides.

They can be electron precise as well as electron rich such as CH_4 and NH_3 respectively.

8.3 Metallic / Interstitial Hydrides

(a) These hydrides are formed by d- and f-block metals, with electronegativity ranging from 1.2 to 1.4.

(b) These hydrides are usually non-stoichiometric (e.g. $TiH_{1.73}$, $LaH_{2.8}$ etc.) and these hydrides have properties similar to those of parent metals i.e. why they are called metallic hydrides.

In these hydrides, hydrogen occupies some interstitial sites in the metallic lattice i.e. why they are called interstitial hydrides. However it is not certain whether the interstitial hydrogen is present as H or H^+ with delocalised electrons.

8.4 Polymeric Hydrides and Complex Hydrides

(a) Polymeric hydrides are formed by elements having electro- negativity in the range 1.4 to 2.0. e.g., $(BeH_2)_n$, $(AlH_{3n}$, $(InH_3)_n$, $(SiH_4)_n$ etc.

(b) In complex hydrides H^- acts as a ligand and is attached to the central metal atom, e.g.$LiAlH_4$, $LiBH_4$,$NaBH_4$ etc.

8.5 Hydrogen Economy - Use of Hydrogen as a Fuel

Advantage: (i) H_2 is an environmentally clean fuel because it gives water on combustion. However, a small amount of nitrogen oxides may be formed due to high temperatures.

(ii) H_2 has the highest calorific value and it is a better fuel than any other fuel.

8.6 Fuel Cell

In a fuel cell, H_2 and O_2 combines with each other, where, H_2 is oxidised at anode, while, O_2 is reduced at cathode. The fuels (H_2 and O_2), do not react directly.

A fuel cell is represented in the fig.

The cell contains porous carbon electrodes impregnated with metal catalysts and an electrolyte consisting of hot aqueous KOH or molten Na_2CO_3. The fuel (gaseous H_2) and the oxidising agent (gaseous O_2) do not react directly, but instead flow into separate cell compartments where H_2 is oxidised at the anode and O_2 is reduced at the cathode. The overall cell reaction is simply the conversion of hydrogen and oxygen to water.

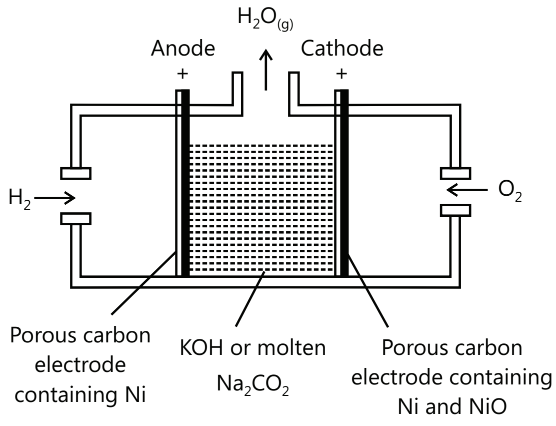


Figure 15.6: Fuel Cell

$$\begin{array}{ll} \text{Anode :} & 2H_{2(g)} + 4OH^- \longrightarrow 4H_2O_{(l)} + 4e^- \\ \text{Cathode :} & O_{2(g)} + 2H_2O_{(l)} + 4e^- \longrightarrow 4OH^- \\ \hline \text{Overall :} & 2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)} \end{array}$$

Or

$$\begin{array}{ll} \text{Anode :} & H_{2(g)} + CO_{3(l)}^{2-} \longrightarrow H_2O_{(g)} + CO_{2(g)} + 2e^- \\ \text{Cathode :} & \frac{1}{2}O_{2(g)} + CO_{2(g)} + 2e^- \longrightarrow CO_{3(l)}^{2-} \\ \hline \text{Overall :} & H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(g)} \end{array}$$

Fuel cells are very efficient and about 75% of bond energy is converted into electricity.

Disadvantages: No doubt, H_2 is the best alternative to fossil fuels, but the use of hydrogen as a fuel is very dangerous and needs attention. The storage of the mixture of H_2 and O_2 is very risky. In 1986, the space shuttle Challenger, an explosion occurred in the fuel tank containing H_2 and O_2.

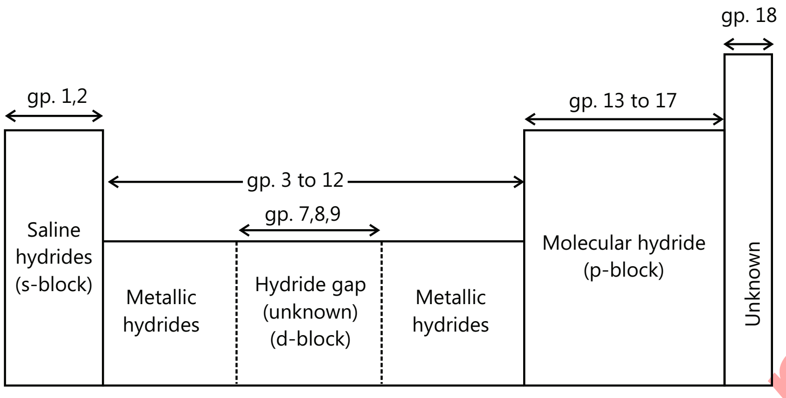


Figure 15.7: General classification of hydrides and some elements

PLANCESS CONCEPTS

- The above table shows a general classification of hydrides and some elements form intermediate hydrides while hydrides of some others are unknown or unstable.
- The hydrolysis of hydrides with H_2O is highly exothermic and may be explosive as H_2 catches fire. This fire can't be extinguished by CO_2 as it gets reduced by a hot metal hydride. Here only sand must be used.

Aman Gour (JEE 2012, AIR 230)

Illustration 2: On reaction of equal masses of LiH and CaH_2 with water, which will give more H_2? **(JEE MAIN)**

Sol: $$\underset{(1\text{ mole}=8\text{ g})}{LiH} + H_2O \longrightarrow LiOH + \underset{(1\text{ mole} = 2\text{ g})}{H_2}$$

$$\boxed{8\text{g LiH gives } 2\text{g } H_2}$$

$$\underset{(1\text{ mole} = 42\text{ g})}{CaH_2} + 2H_2O \longrightarrow Ca(OH)_2 + \underset{2\text{ mole}=4\text{g}}{2H_2}$$

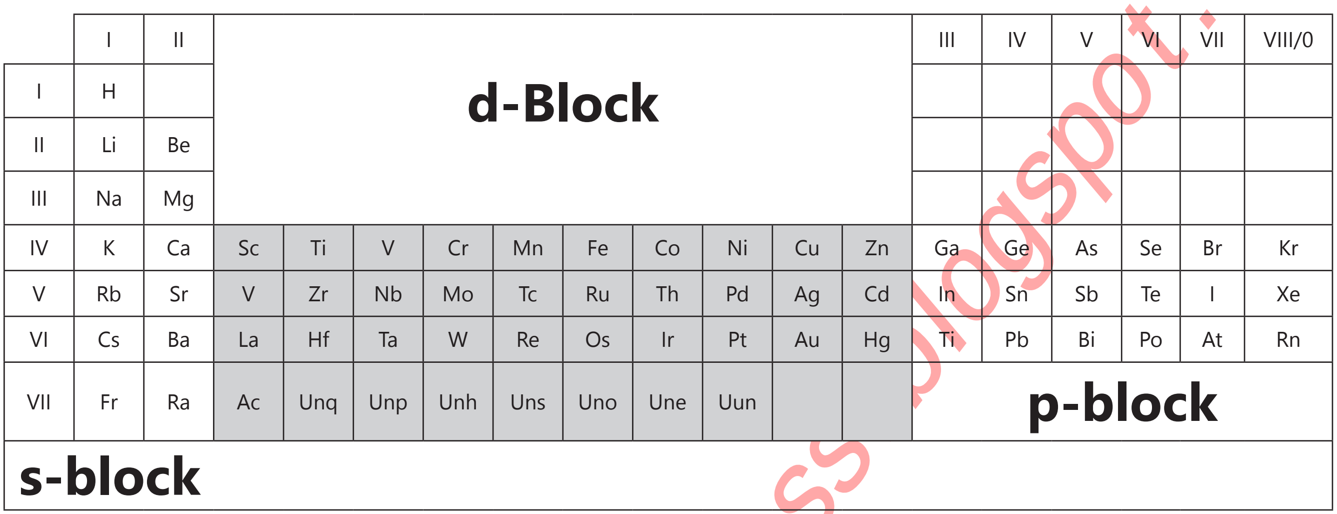
$$\frac{42}{2} = 21\,\text{g}\,CaH_2 \text{ gives } 2\text{g } H_2$$

$$\boxed{8\text{g } CaH_2 \text{ gives } \frac{2}{21}\times 8 = 0.762\text{ g } H_2}$$

s-block elements

1. INTRODUCTION

The elements in which the last electron enters the outermost s-orbital, belong to the s-block of elements. As the s-orbital can accommodate only two electrons, two groups (1 & 2) belong to the s-block of the periodic table.



	I	II											III	IV	V	VI	VII	VIII/0
I	H		d-Block															
II	Li	Be																
III	Na	Mg																
IV	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
V	Rb	Sr	V	Zr	Nb	Mo	Tc	Ru	Th	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
VI	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Ti	Pb	Bi	Po	At	Rn
VII	Fr	Ra	Ac	Unq	Unp	Unh	Uns	Uno	Une	Uun			p-block					
s-block																		

Figure 15.8: Position of s-block elements in the periodic table

Properties of s-block: Table Group 1 of the periodic table consists of the elements: lithium (Li), sodium (Na), potassium (K), rubidium (Rb), caesium (Cs) and francium (Fr). Collectively known as the alkali metals, because they form hydroxides on reaction with water, which are strongly alkaline in nature. The elements of Group 2 include beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba) and radium (Ra). These elements with the exception of beryllium are commonly known as the alkaline earth metals. These are so called because their oxides and hydroxides are alkaline in nature and these metal oxides are found in the earth's crust. The general electronic configuration of s- block elements is [noble gas] ns^1 for alkali metals and [noble gas] ns^2 for alkaline earth metals.

2. TRENDS IN PHYSICAL AND CHEMICAL PROPERTIES

2.1 Electronic Configuration

All alkali metals have one valence electron, ns^1 outside the noble gas core. The single valence electron is at a long distance from the nucleus and is held weakly. Hence, the loosely held s electrons in the outermost valence shell of these elements make them the most electropositive metals. They readily lose electrons to give monovalent M^+ ions. Hence, they are never found in the free state in nature. Alkaline earth metals have two electrons in the s-orbital of valence shell. The compounds of these elements are also predominantly ionic.

Table 15.1 : Electronic configuration of s-block elements

Element	Symbol	Electronic configuration
Lithium	Li	$1s^2 2s^2$
Sodium	Na	$1s^2 2s^2 2p^6 3s^1$
Potassium	K	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
Rubidium	Rb	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^1$

Element	Symbol	Electronic configuration
Caesium	Cs	$1s^22s^22p^63s^23p^63d^{10}4s^2$ $4p^64d^{10}5s^25p^66s^1$ or $[Xe]6s^1$
Francium	Fr	$[Rn]\ 7s^1$
Beryllium	Be	$1s^22s^2$
Magnesium	Mg	$1s^22s^22p^63s^2$
Calcium	Ca	$1s^22s^22p^63s^23p^64s^2$
Strontium	Sr	$1s^22s^22p^63s^23p^63d^{10}4s^24p^65s^2$
Barium	Ba	$1s^22s^62p^63s^23p^43d^{10}4s^2$ $4p^64d^{10}5s^25p^66s^2$ or $[Xe]\ 6s^2$
Radium	Ra	$[Rn]\ 7s^2$

2.2 Atomic and Ionic Radii

The alkali metal atoms have the largest size in a particular period of the periodic table. The atomic and ionic radii of alkali metals increase down the group i.e., they increase in size while going from Li to Cs. Due to the increased nuclear charge in these elements, the atomic and ionic radii of the alkaline earth metals are smaller than those of the corresponding alkali metals in the same periods. Within the group, the atomic and ionic radii increase with the increase in atomic number due to the increase in number of atomic shells.

2.3 Ionization Enthalpy

The ionization enthalpies of the alkali metals are considerably low and decrease down the group from Li to Cs. This is because the effect of increasing size outweighs the increasing nuclear charge and the outermost electron is very well screened from the nuclear charge. The second ionization energy is extremely high because of the removal of the 2nd electron from a stable noble gas electron configuration of the monovalent metal cation. The alkaline earth metals have low ionization enthalpies due to the fairly large size of the atoms. Since the atomic size increases down the group, their ionization enthalpy decreases. Due to their small size as compared to the corresponding alkali metals, the first ionization enthalpy of the alkaline earth metals is higher than those of the corresponding Group 1 metals for the same period. . The second ionization enthalpies of the alkaline earth metals are smaller than those of the corresponding alkali metals because for the alkali metals, the second electron is to be removed from an inert gas configuration.

Physical Properties: All alkali metals are silvery white, soft and light metals. This is due to having only one valence electron which participates in bonding. These elements have a low density which increases down the group from Li to Cs, because of their larger size. However, potassium is lighter than sodium because of its larger atomic volume. The melting and boiling points of the alkali metals are low, which indicate weak metallic bonding, due to the presence of only a single valence electron in them. The strength of the metallic bond decreases down the group, and the m.p. decreases accordingly. The m.p of lithium is nearly twice as high as that of sodium because of the stronger metallic bonding on account of its smaller size. However, the m.p. of all the others are close together. The alkali metals and their salts impart a characteristic colour to oxidizing flames. This is because the heat from the flame excites the outermost orbital electron to a higher energy level. When the excited electrons come back to the ground state, there is an emission of radiation in the visible region as given below:

Table 15.2 (a) : Characteristic flame color of group 1 elements

Metal	Li	Na	K	Rb	Cs
Colour	Crimson red	Yellow	Violet/Lilac	Red violet	Blue

When these elements are irradiated with light, the light energy absorbed may be sufficient to make an atom lose an electron. This property makes caesium and potassium useful as electrodes in photoelectric cells. The alkaline earth metals, in general, are silvery white, lustrous and relatively soft, but are however, harder than the alkali metals. Beryllium and magnesium appear to be somewhat greyish. The melting and boiling point of these metals are higher than alkali metals due to their smaller size and two valence electrons. Due to their low ionization enthalpies, they are strongly electropositive in nature. The electropositive character increases down the group from Be to Ba. Calcium, strontium and barium, all impart a characteristic colour to the flame.

Table 15.2 (b): characteristic flame color of group 2 elements

Metal	Be	Mg	Ca	Sr	Ba
Colour	No Colour	No colour	Brick red	Crimson	Apple green

The electrons in beryllium and magnesium are too strongly bound to get excited by the flame. Hence, these elements do not impart any colour to the flame. Like alkali metals, the electrical and thermal conductivity of alkaline earth metals are high.

PLANCESS CONCEPTS

Softness increases from Li to Cs due to weakening of interatomic attractions

Note: Trends of Melting and Boiling Points:

In case of Alkali Metals – Li > Na > K > Rb > Cs > Fr

In Case of alkaline earth metals – Be > Mg > Ca > Sr > Ba

Note-Trends in case of heat of atomization:

In case of alkali metals – Li > Na > K > Rb > Cs > Fr

Not – In Case of density, following trend is observed:

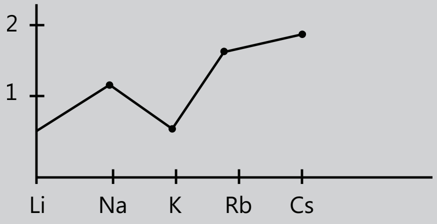


Figure 15.9: Density plot

The reason for this type of trend is:

Explanation: On moving down, both atomic mass and atomic volume increase, but increase in atomic volume can't compensate for the increase in atomic mass. An exceptionable is the lower density of K as compared to Na, which is due to the abnormal increase in the size of K.

Note: Trends of density in case of alkaline earth metals:

All are light metals, since the densities of alkaline earth metals decrease slightly from Be to Ca after which there is an increase.

Saurabh Gupta (JEE 2010, AIR 443)

2.4 Hydration Enthalpy

Hydration represents the dissolution of a substance in water by adsorbing a water molecule by weak valency forces.

Note: The hydration is an exothermic process, i.e., energy is released during hydration

PLANCESS CONCEPTS

Smaller the cation, greater is the degree of hydration energy

$Li^{\oplus} > Na^{\oplus} > K^{\oplus} > Rb^{\oplus} > Cs^{\oplus}$

Saurabh Gupta (JEE 2010, AIR 443)

The hydration enthalpies of alkali metal ions, decrease with the increase in ionic sizes. Li^+ has a maximum degree of hydration and for these reasons lithium salts are mostly hydrated e.g., $LiCl.2H_2O$. Like alkali metal ions, hydration enthalpies of alkaline earth metal ions decrease with the increase in ionic size down the group.

The hydration enthalpies of alkaline earth metal ions are larger than those of alkali metal ions. Thus compounds of alkaline earth are more extensively hydrated than those of alkali metals, e.g., $MgCl_2$ are $CaCl_2$ exist as $MgCl_2.6H_2O$ and $CaCl_2.6H_2O$ while NaCl and KCl do not form such hydrates.

PLANCESS CONCEPTS

$$\text{Relative conducting power} \propto \frac{1}{\text{Relative hydrated}}$$

Neeraj Toshniwal (JEE 2009, AIR 21)

Therefore, the Trend of Relative Conducting Power in case of Alkali Metals Would be:

$$Cs^{\oplus} > Rb^{\oplus} > K^{\oplus} > Na^{\oplus} > Li^{\oplus}$$

Note: The Trend in Case of Relative ionic radii is:

$$Cs^{\oplus} > Rb^{\oplus} > K^{\oplus} > Na^{\oplus} > Li^{\oplus}$$

Reverses in Case of Relative Hydrated radii:

$$Cr^{\oplus} > Rb^{\oplus} > K^{\oplus} > Na^{\oplus} > Li^{\oplus}$$

2.5 Standard Oxidation Potential and Reducing Properties in case of Alkali metals

(a) Since alkali metals easily lose electrons, they have high values of oxidation potential accounting for the good reducing nature.

(b) Standard oxidation potentials are listed below:

	Li	Na	K	Rb	Cs
E^0_{OP}	+3.05	+2.71	+2.93	+2.99	+2.99

(c) More the oxidation potential, more is the tendency, to get oxidized and thus more powerful is the reducing nature in an aqueous medium.

(d) Alkali metals liberate H_2 from H_2O and HCl

$$2H_2O + 2M \rightarrow 2MOH + H_{2;}\ 2HCl + 2M \rightarrow 2MCl + H_2$$

PLANCESS CONCEPTS

From the ionization energy trend, we expect Li to have the lowest oxidation potential. But that is not so. The greatest reducing nature of Li in an aqueous medium is accounted for, due to the maximum hydration energy of the $Li^{\oplus}$ ion.

Aman Gour (JEE 2012, AIR 230)

In case of Alkaline Earth Metals,

(a) Standard oxidation potential Ra > Ba > Sr > Ca > Mg > Be

(b) The reducing character increases from Be to Ba, due to the increasing order of the oxidation potential.

3. CHEMICAL PROPERTIES

Alkali metals are highly reactive due to their larger size and low ionization enthalpy. The reactivity of these metals increases down the group. The alkaline earth metals are less reactive than the alkali metals. The reactivity of these elements increases on going down the group.

Reasons for High Reactivity of Alkali Metals-

Alkali metals exhibit very high chemical reactivity, and the reasons for their high reactivity are:

(a) Low IE,

(b) Low heat of atomization

(c) High heats of hydration

3.1 Reactivity towards Air and Water

Alkali metals tarnish in dry air due to the formation of their oxides which in tum react with moisture to form hydroxides. They burn vigorously in oxygen, forming oxides.

Lithium forms a monoxide, sodium forms a peroxide, and the other metals form a superoxide. The superoxide O_2^- ion is stable only in the presence of larger cations such as K, Rb, Cs,

$4Li + O_2 \rightarrow 2Li_2O$ (oxide): $2Na + O_2 \rightarrow Na_2O_2$ (peroxide)

$M + O_2 \rightarrow MO_2$ (superoxide) (where M = K, Rb, Cs).

All five metals can be induced to form the normal oxides, peroxides or superoxides by dissolving the metal in liquid ammonia and bubbling in the appropriate amount of oxygen. Lithium shows exceptional behaviour in a reaction directly with nitrogen of air to form the nitride, Li_3N.Li_3N is ionic

($3Li^+$ and N^{3-}), and is ruby red.

$2Li_3N \xrightarrow[\text{Hight temp.}]{\Delta} 6Li + N_2$: $Li_3N + 3H_2O \rightarrow 3LiOH + NH_3$.

The alkali metals react with water to form hydroxides and dihydrogen. The reaction becomes increasingly violent on descending the group. Although lithium the has most negative electrode potential ($E^\ominus$) value, its reaction with water is less vigorous than that of sodium which has the least negative electrode potential ($E^\ominus$) value among the alkali metals. This behaviour of lithium is attributed to its small size and very high hydration energy. Other metals of the group react explosively with water.

$2M + 2H_2O \rightarrow 2MOH + H_2$ (M = alkali metal cation).

They also react with proton donors such as alcohol, gaseous ammonia and alkynes. This is because of their high reactivity towards air and water, the alkali metals are normally kept in kerosene oil. Beryllium and magnesium are inert to oxygen and water because of the formation of an oxide film on their surface. However, powdered beryllium burns brilliantly on ignition in air to give BeO and Be_3N_2.

Magnesium is more electropositive and burns with a dazzling brilliance in air to give MgO and Mg_3N_2.

Calcium, strontium and barium are readily attacked by air to form the oxide and nitride. They also react with water with increasing its reactivity.

3.2 Reactivity towards Dihydrogen

The alkali metals react with dihydrogen at about 673 K (lithium at 1073 K) to form hydrides. All the metal hydrides are ionic solids with high melting points.

All alkaline earth metals except beryllium combine with hydrogen upon heating to form their hydrides, MH_2, which are also high melting solids. BeH_2 however, can be prepared by the reaction of $BeCl_2$ with $LiAlH_4$.

$$2BeCl_2 + LiAlH_4 \rightarrow 2BeH_2 + LiCl + AlCl_3$$

3.3 Reactivity towards Halogens

Reactivity towards halogens: The alkali metals readily react vigorously with halogens to form ionic halides, MX. However, lithium halides are somewhat covalent. This is because of the high polarization capability of the lithium ion. The Li^+ ion is very small in size and has a high tendency to distort electron clouds around the negative halide ion. Since anion with larger sizes can be easily distorted, among halides lithium iodide is the most covalent in nature. All the alkaline earth metals combine with halogens at elevated temperatures forming their halides.

$$M + X_2 \rightarrow MX_2 \ (X = F, Cl, Br, I)$$

3.4 Reducing Nature

Alkali metals, are strong reducing agents, lithium being the most and sodium the least powerful with the small size of its ion, lithium has the highest hydration enthalpy which accounts for its high negative $E^\ominus$ value and its high reducing power. Like alkali metals, the alkaline earth metals are strong reducing agents. This is indicated by the large negative value of their reduction potentials. Beryllium has a less negative value compared to other alkaline earth metals, due to a relatively large value of the atomization enthalpy of the metal. However, its reducing nature is due to a large hydration energy associated with the small size of Be^{2+} ion.

3.5 Solution in Liquid Ammonia

The alkali metals dissolve in liquid ammonia giving deep blue solutions.

$$M + (x + y) NH_3 \rightarrow [M (NH_3)_x]^+ + [e (NH_3)_3]^-$$

In dilute solutions, the main species are metal ions (M^+) and electrons, which are solvated (i.e.ammoniated). The blue colour, corresponding to a broad absorption band near 1500 nm that falls into the visible range, is attributed to the solvated electron.

The blue solution of alkali metals in liquid ammonia, decompose very slowly with the liberation of hydrogen (i.e., reduction of the solvent).

$$M^+ (aq) + e^- (aq) + NH_3 (\ell) \rightarrow MNH_2 (aq) + 1/2 \ H_2 (g)$$

(Where 'am' denotes solution in ammonia). Or, $NH_3 + e^- \rightarrow NH_2^- + \frac{1}{2} H_2$.

Decomposition is accelerated by the presence of many transition metal compounds, e.g., by stirring the solution with a rusty iron wire. The solution of metals in liquid ammonia act as powerful reducing agents (it even reduces the aromatic ring).

$O_2 + e^- \rightarrow O_2^-$; $O_2 + 2e^- \rightarrow O_2^{2-}$ (change of oxidation states from 0 to –1).

$[Ni (CN)_4]^{2-} + 2e^- \rightarrow [Ni (CN)_4]^{4-}$ (change of oxidation states from +2 to 0).

$GeH_4 + e^- \rightarrow GeH_2^- + \frac{1}{2} H_2S \ + 2e^- \rightarrow S^{2-}$ (change of oxidation states from 0 to – 2).

$[Fe (CO)_5] + 2e^- \rightarrow [Fe (CO)_4]^{2-} + CO$ (change of oxidation states from 0 to – 2).

Like alkali metals, the alkaline earth metals, except beryllium, dissolve in liquid ammonia to give a deep blue-black solution forming ammoniated ions. The colour is due to the spectrum from solvated electrons.

$$M + (x + y) NH_3 \rightarrow [M (NH_3)_x]^{2+} + 2[e (NH_3)_y]^-$$

These solution decompose very slowly forming amides but the reaction is accelerated by many transition metals and their compounds. $2NH_3 + 2e^- \rightarrow 2NH_2^- + H_2$

Evaporation of ammonia from the solution of alkali metals yields the metal, but with alkaline earth metals evaporation of ammonia gives hexammoniates of the metals, $[M(NH_3)_6]^{2+}$. These slowly decompose to give amides. $M\ (NH_2)_3 \rightarrow M\ (NH_2)_3 + 4NH_2 + H$

Illustration 1: The correct order of size of the ions is: **(JEE MAIN)**

(A) $LI^+ > Na^+ > K^+ > Cs^+$ (B) $Cs^+ > K^+ > Na^+ > LI^+$

(C) $Cs^+ > Na^+ > K^+ > LI^+$ (D) $Cs^+ > Li^+ > Na^+ > K^+$

Sol: Down the group, the size of ions increases because of the increase in the number of atomic shells.

The increase in the number of atomic shells over weighs the increase in effective nuclear charge.

Therefore (B) option is correct.

Illustration 2: Which of the following has the highest hydration enthalpy in an aqueous solution?

(A) Na^+ (B) Be^{2+} (C) Ba^{2+} (D) Cs^+ **(JEE MAIN)**

Sol: The hydration enthalpies of alkaline earth metal ions are larger than those of alkali metal ions on earth metal ions decrease with increase in ionic size down the group.

$Be^{2+} > Mg^{2+} > Ca^{2+} > Sr^{2+} > Ba^{2+}$. Therefore (B) option is correct.

Illustration 3: Which one the following metals is most commonly used in photoelectric cells?

(A) Li (B) Ca (C) Cs (D) Fr **(JEE ADVANCED)**

Sol: The ionization enthalpies of the alkali metals are considerably low and decrease down the group from Li to Cs. This is because the effect increasing size outweighs the increasing nuclear charge, and the outermost electrons are very well screened from the nuclear charge. When alkali metals are irradiated with light, the light energy absorbed may be sufficient to make an atom lose an electron. This property make caesium and potassium useful as electrodes in photoelectric cells. Therefore (c) option is correct.

Illustration 4: A blue coloured solution of sodium in liquid ammonia at –33°C behaves as strong reducing agent because of: **(JEE ADVANCED)**

(A) The formation of ammoniated sodium (B) The formation of ammoniated electron

(C) The formation of sodium amide (D) The formation of sodium nitride

Sol: The solution of metals in liquid ammonia act as powerful reducing agents (it even reduces the aromatic ring) because of ammoniated electron,

$Na + (x + y)\ NH_3 \rightarrow [Na\ (NH_3)_x]^+ + [e\ (NH_3)_y]^-$

E.g., $O_2 + e^- \rightarrow O^{2-}$; $O_2 + 2e^- \rightarrow O_2^{2-}$ (change of oxidation states from 0 to – I),

$[Ni(CN)_4]^{2-} + 2e^- \rightarrow [Ni\ (CN)_4]^{4-}$ change of oxidation states from + II to 0).

4. GENERAL CHARACTERISTICS OF THE COMPOUNDS OF THE ALKALI METALS AND ALKALINE EARTH METALS

Compounds of the alkali metals are generally ionic in nature. On combustion, in the excess of air, alkali metals form different type of oxides as given in the following table:

Table 15.3: Principal Combustion Product (Minor Product)

Alkali Metal	Oxide	Peroxide	Superoxide
Li	Li_2O	(Li_2O_2)	
Na	(Na_2O)	Na_2O_2	
K			KO_2
Rb			RbO_2
Cs			CsO_2

The increasing stability of the peroxide or superoxide, as the size of the metal ion increases, is due to the stabilization of large anions by larger cations through lattice energy effects, these oxides are easily hydrolyzed by water to form hydroxides according to the following reactions:

$$M_2O + H_2O \rightarrow 2M^+ + 2OH^-$$

$$M_2O_2 + 2H_2O \rightarrow 2M^+ + 2OH^- + H_2O_2$$

$$2\ MO_2 + 2H_2O \rightarrow 2M^+ + 2OH^- + H_2O_2 + O_2$$

The oxides and the peroxides are colourless when pure, but the superoxides are yellow or orange in colour. LiO_2 and NaO_2 are yellow. KO_2 and CsO_2 are orange whereas RbO_2 is brown in colour. The superoxides are also paramagnetic. The hydroxide are all white crystalline solids. The alkali metal hydroxides are the strongest of all bases and dissolve freely in water with the evolution of much heat on the account of intense hydration. The melting and boiling points of alkali metal halides always follow the trend: fluoride > chloride > bromide > iodide. All alkali metal halides are generally soluble in water. The low solubility of LiF in water is due to its high lattice enthalpy whereas the low solubility of Cs is due to the smaller hydration enthalpy of its two ions. Other halides of lithium are soluble in ethanol. Acetone and ethyl acetate; LiCl is soluble in pyridine also.

The alkali metals form salts with all the oxo-acids. The thermal stability of oxy-acid salts generally increases down the group with increasing metallic character, i.e. electropositive character. They are generally soluble in water and thermally stable. Their carbonates (M_2CO_3) and in most cases the hydrogencarbonates ($MHCO_3$) also are highly stable to heat. As the electropositive character increases down the group, the stability of the carbonate and hydrogencarbonates increases.

Group 1 metals are so strongly basic, that they (except lithium) also form solid bicarbonates. No other metals form solid bicarbonates. Lithium carbonate is not so stable to heat. Its hydrogencarbonates do not exist as solids. Although NH_4HCO_3 also exists as a solid. The crystal structures of $NaHCO_3$ and $KHCO_3$ both show hydrogen bonding, but are different.

(a) In $NaHCO_3$, the HCO_3^- ions are linked into an infinite chain and (b) in $KHCO_3$, HCO_3^- forms a dimeric anion.

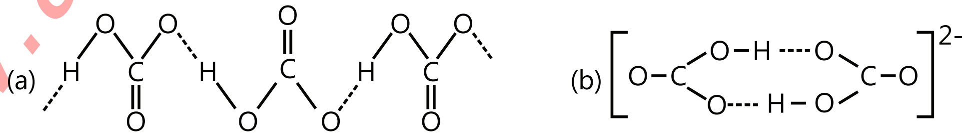


Figure 15.10: Hydrogen Bonding in $NaHCO_3$ and $KHCO_3$

The solubility of the alkali metal salts except fluorides, carbonates and hydroxides decreases down the group from Li to Cs. This is because of the fact that down the group with the increasing size of the cation the lattice energy as well as hydration energy also decrease but the change in hydration energy is more as compared to that of lattice energy. The alkaline earth metals form compounds which are predominantly ionic but less ionic than the alkaline earth metals, which forms compounds of alkali metals. This is due to an increased nuclear charge and smaller size. The oxide and other compounds of beryllium and magnesium are more covalent than those formed by the heavier and large sized member (Ca, Sr. Ba). The alkaline earth metals bum in oxygen to form the monoxide, MO which, except for BeO has a rock-salt structure. The BeO is essentially covalent in nature. The enthalpies of formation of these oxides are quite high and consequently they are very stable to heat. BeO is amphoteric while oxides of other elements are ionic in nature. All these oxides except BeO are basic in nature and react with water to form sparingly soluble hydroxides. $MO + H_2O \rightarrow M(OH)_2$.The solubility, thermal stability and the basic character of these hydroxides increases with the increasing atomic number from $Mg(OH)_2$ to Ba $(OH)_2$. The alkaline earth metal hydroxides are however, less basic and less stable than alkali metal hydroxides. Beryllium hydroxide is amphoteric in nature as it reacts with acid and alkali both.

$Be(OH)_2 + 2OH^- \rightarrow [Be(OH)_4]^{2-}$ (beryllate ion)

$Be(OH)_2 + 2HCl + 2H_2O \rightarrow [Be(H_2O)_4]Cl_2$.

The anhydrous halides of alkaline earth metals are polymeric .Except for beryllium halides, all other halides of alkaline earth metal are ionic in nature. Beryllium halides are essentially covalent and soluble in organic solvents. Beryllium chloride vapours contains $BeCl_2$ and $(BeCl_2)_2$ but the solid is polymerized. Beryllium chloride in the solid state has a chain structure as shown below:

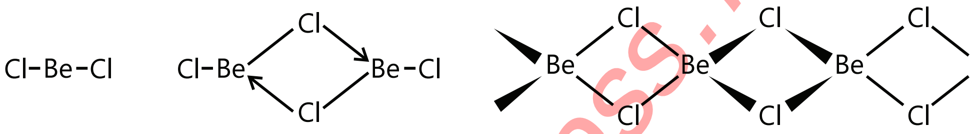


Figure 15.11: Beryllium chloride in solid state

In the vapour phase $BeCl_2$ tends to form a chloro-bridged dimer which dissociates into the linear monomer at a high temperature of the order of 1200 K. The tendency to form halide hydrates gradually decreases (for example, $MgCl_2.6H_2O$, $CaCl_2.6H_2O$, $SrCl_2.6H_2O$ and $BaCl_2.2H_2O$) down the group. The dehydration of hydrated chlorides, bromides and iodides of Ca, Sr and Ba can be achieved on heating; however, the corresponding hydrated halides of Be and Mg on heating suffer hydrolysis. The fluorides are relatively less soluble than the chlorides owing to their high lattice energies. Carbonate of alkaline earth metals are insoluble in water and can be precipitated by the addition of a sodium or ammonium carbonate solution to a solution of a soluble salt of these metals. The solubility of carbonates in water decreases as the atomic number of the metal ion increases. All carbonates decompose on heating to give carbon dioxide and the oxide. Beryllium carbonate is unstable and can be kept only in the atmosphere of CO_2. The thermal stability increases with increasing cationic size. The sulphates of the alkaline earth metals are all white solids and are stable to heat. $BeSO_4$ and $MgSO_4$ are readily soluble in water, the solubility decreases from $CaSO_4$ to $BaSO_4$. The greater hydration enthalpies of Be^{2+} and Mg^{2+} ions overcome the lattice enthalpy factor and therefore their sulphates are soluble in water.

The nitrates are made by the dissolution of the carbonate in dilute nitric acid, magnesium nitrate crystallizes with six molecules of water, whereas barium nitrate crystallizes as the anhydrous salt. This again shows a decreasing tendency to form hydrates with increasing size and decreasing hydration enthalpy. All of them decompose on heating to give an oxide like lithium nitrate.

$2M(NO_3)_2 \rightarrow 2MO + 4NO_2 + O_2$ (M = Be, Mg, Ca, Sr, Ba)

The solubility of the alkaline earth metal salts except hydroxides and fluorides decreases down the group from Be to Ba. This is because of the fact that down the group with the increasing size of the cation, the lattice energy as well as hydration energy also decreases, but the change in hydration energy is more as compare to that of lattice energy. Except BeF_2 all other fluorides are water insoluble. The solubility of beryllium fluoride in water is due to higher solvation energy on account of the higher polarizing power of Be^{2+}. The thermal stability of oxy-acid salts of alkaline earth metals generally increases down the group with increasing metallic character, i.e. electropositive character.

PLANCESS CONCEPTS

Low thermal stability of Li_2CO_3 can be explained as follows:

The small Li^+ ion exerts a strong polarizing action and distorts the electron cloud of nearby oxygen atom of the large CO_3^{2-} ion. This results in the weakening of C–O bond and strengthening of Li–O bond, favouring the formation of Li_2O and CO_2. High lattice energy of Li_2O than Li_2CO_3 also favours the decomposition of Li_2CO_3

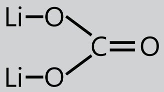


Figure 15.10: Li_2CO_3 molecule

B Rajiv Reddy (JEE 2012, AIR 11)

Illustration 5: Select the correct set of statements. **(JEE ADVANCED)**

(i) Solubility of alkali hydroxides is in order, CsOH > RbOH > KOH > NaOH > LiOH

(ii) Solubility of alkali carbonates is in order, $Li_2CO_3 > Na_2CO_3 > K_2CO_3 > K_2CO_3 > Rb_2CO_3 > Cs_2O_3$

(iii) Hydrated radii is in order, $Li < Na^+ < K^+ < Rb^+ < Cs^+$

(iv) Stability of peroxides is in order, $Na_2O_2 < K_2O_2 < Rb_2O_2 < Cs_2O_2$

The options are: (A) (i), (iv) (B) (i), (iii) (C) (ii), (iii), (iv) (D) All

Sol: Compare the lattice energy and the hydration energy of the cations.

(i) While going from lithium to cesium hydroxide, the decrease in lattice energy is more as compared to that of hydration energy. So, the solubility of hydroxides increases down the group (iv). This is because of fact that the bigger cation stabilizes the bigger anion through crystal lattice energy. Therefore (A) option is correct.

5. ANOMALOUS PROPERTIES OF LITHIUM

The anomalous behaviour of lithium is due to the: (i) exceptionally small size of its atom and ion, and (ii) high polarizing power (i.e., charge/radius ratio). As a result, there is an increased covalent character of lithium compounds, which is responsible for their solubility in an organic solvent. Further, lithium shows a diagonal relationship to magnesium.

Points of difference between lithium and other alkali metals

(a) Lithium is much harder. Its melting point and boiling point are higher than the other alkali metals.

(b) Lithium is the least reactive but the strongest reducing agent among all the alkali metals. On combustion in air it forms mainly monoxide, Li_2O and the nitride, Li_3N unlike other alkali metals.

(c) The lithium ion itself, and also its compounds are more heavily hydrated than those of the rest of the group. LiCl is deliquescent and crystallizes as a hydrate, $LiCl.2H_2O$ whereas other alkali metal chlorides do not form hydrates.

(d) Lithium hydrogencarbonates is not obtained in the solid form while all other elements form solid hydrogencarbonates.

(e) Lithium unlike other alkali metal forms no ethynide on reaction with ethyne.

(f) Lithium nitrate when heated gives lithium oxide, Li_2O, whereas other alkali metal nitrates decompose to give the corresponding nitrite.

$$4LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$$

$$2NaNO_3 \xrightleftharpoons{500^\circ C} 2NaNO_2 + O_2; \quad 4NaNO_3 \xrightarrow{500^\circ C} 2Na_2O + 5O_2 + 2N_2$$

$2NaNO_2 + 2HCl \rightarrow 2NaCl + H_2O + NO_2 + NO$; $2NO + O_2 \rightarrow 2NO_2$

$2NaNO_3 + C \rightarrow 2NaNO_2 + CO_2$; $KNO_3 + Zn \rightarrow KNO_2 + ZnO$

(g) LiF and Li_2O are comparatively much less soluble in water than the corresponding compounds of other alkali metals.

(h) Lithium hydroxide is less basic than the other hydroxides in the group and therefore, many of its salts are less stable, Li_2CO_3, $LiNO_3$ and LiOH all form the oxides on gentle heating; the analogues compounds of the rest of the group are stable. Another example of its less basic nature is that though lithium forms a bicarbonates in solution, it does not form a solid bicarbonate, whereas the other all form stable solid carbonates.

(i) Lithium reacts directly with carbon to form anionic carbide. None of the other group 1 elements do this, but group 2 elements all react similarly with carbon.

(j) Lithium has a great tendency to form complexes than have the heavier elements, and ammoniated salts such as $[Li\ (NH_3)_4]^+$ exist as solids.

Illustration 6: Which of the following alkali metal ions has the lowest mobility in aqueous solution?

(A) Li^+ (B) Na^+ (C) K^+ (D) Cs^+ **(JEE ADVANCED)**

Sol: Mobility depends upon the cationic size and the tendency of the cation to get hydrated. Because Li^+ has the smallest size, so it is highly hydrated and its effective size becomes larger therefore mobility decreases in aqueous medium.

Therefore (A) option is correct.

Illustration 7: Give the reaction of the thermal decomposition of the nitrate of sodium. Explain the occurrence of the reaction in term of energy factor. What is the pH expected of an aqueous solution of $NaNO_3$. Why?

(JEE ADVANCED)

Sol: The occurrence of the reaction depends upon the stability of the reactant and the products formed pH depends upon the hydrolysis extent.

$$NaNO_3(s) \rightarrow NaNO_2(s) + \frac{1}{2}O_2\ (g)$$

Since the size of NO_2^- is less than that of NO_3^-, this results in the formation of a more stable ionic lattice when bonded to a sodium ion. The pH of solution would be about 7 since neither the cation nor the anion undergoes hydrolysis to any appreciable extent.

6. POINTS OF SIMILARITIES BETWEEN LITHIUM AND MAGNESIUM

The similarity between lithium and magnesium is particularly striking and arises because of their similar size: atomic radii, Li = 152 pm, Mg = 160 pm; ionic radii: Li^+ = 76 pm, Mg^{2+} = 72 pm. The main points of similarity are:

(a) Both lithium and magnesium are harder and lighter than other elements in their respective groups.

(b) Lithium and magnesium react slowly with water. Their oxides and hydroxides are much less soluble and their hydroxides decompose on heating. Both form a nitride, Li_3N and Mg_3N_2, by a direct combination with nitrogen.

(c) The oxides. Li_2O and MgO do not combine with excess oxygen to give any superoxide.

(d) The carbonates of lithium and magnesium decompose easily on heating to form the oxides and CO_2. Solid hydrogencarbonates are not formed by lithium and magnesium.

(e) Both LiCl and $MgCl_2$ are soluble in ethanol.

(f) Both LiCl and $MgCl_2$ are deliquescent and crystallize from aqueous solution as hydrates, $LiCl.2H_2O$ and $MgCl_2.6H_2O$.

Illustration 8: About alkali metal-liquid NH_3 solution which of following statement is not true?

(A) Blue colour is due to ammoniated electrons. **(JEE ADVANCED)**

(B) Blue colour changes to bronze on dilution due to formation of metal ion clusters.

(C) With an increase in concentration of alkali metals paramagnetic nature decreases due to electron-electron combination.

(D) On heating, the blue colour becomes colourless due to the formation of a metal amide and H_2 gas.

Sol: The change depicts the formation of some complex structures.

Blue colour changes to bronze with increase in concentration of alkali metal due to formation of metal ion clusters. Therefore (B) option is correct.

Illustration 9: (A) Give the three different crystal structures of NaO_2? **(JEE ADVANCED)**

(B) Sodium sulphide is readily oxidized by air to form sodium thiosulphate. Write the chemical reaction only.

(C) Group 1 sulphides hydrolyze appreciably in water, giving strongly alkaline solutions. Explain?

Sol: Sodium, the alkali metal has been discussed over here, which is a highly reactive metal and forms sodium thiosulphate in its sulphide form.

(A) NaO_2 exists in following three different crystal structures at different temperatures.

(i) Marcasite structure at – 50°C,

(ii) Pyrite structure between –77°C and –50°C,

(iii) Calcium carbide structure at room temperature.

(B) $2Na_2S + 2O_2 + H_2O \rightarrow Na_2S_2O_3 + 2NaOH$

(C) Na_2S hydrolyses in water according to the following reaction. $2Na_2S + H_2O \rightarrow NaSH + NaOH$

Illustration 10: The properties of Li are similar to those of Mg. This is because. **(JEE ADVANCED)**

(A) Both have nearly the same size

(B) The ratio of their charge to size is nearly the same.

(C) Both have similar electronic configurations.

(D) Both are found together in nature

Sol: We discuss about the diagonal relation of the alkali and the alkaline earth metals over here, wherein similarities are pointed out.

They are diagonally related because of same polarizing power, polarizing power = charge on cation / size of cation. Therefore. (B) Option is correct.

Illustration 11: Magnesium burns in air to give: **(JEE ADVANCED)**

(A) MgO (B) Mg_3N_2 (C) $MgCO_3$ (D) MgO and Mg_3N_2 both

Sol: Magnesium

Mg burns in air to form both MgO and Mg_3N_2

$2Mg + O_2 \xrightarrow{\Delta} 2MgO$; $3Mg + N_2 \xrightarrow{\Delta} Mg_3N_2$ Therefore, (D) option is correct.

7. ANOMALOUS BEHAVIOUR OF BERYLLIUM

Beryllium, the first member of the Group 2 metals, shows anomalous behaviour as compared to magnesium and rest of the members of the group. Further, it shows a diagonal relationship to aluminium.

(a) Beryllium has an exceptionally small atomic and ionic size and thus does not compare well with other members of the group. Because of the high ionization enthalpy and small size it forms compound, which is largely covalent and gets easily hydrolyzed.

(b) Beryllium does not exhibit a coordination number more than four as in its valence shell there are only four orbitals. The remaining members of the group can have a coordination number of six by making use of d-orbitals.

(c) The oxide and hydroxide of beryllium, unlike the hydroxides of other elements in the group, are amphoteric in nature.

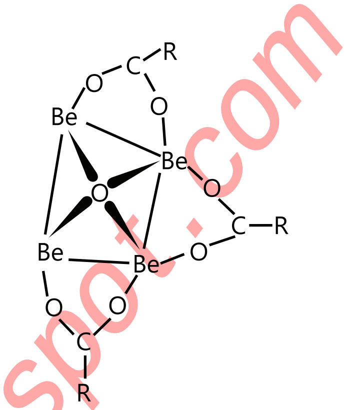


Figure 15.12: Complexes of Be

(d) Beryllium hydride is electron deficient and polymeric, with multi-center bonding like aluminium hydride.

(e) The most unusual oxygen containing complexes of Be have the formula $Be_4O\ (O_2CR)_6$ and are formed by refluxing $Be\ (OH)_2$ with carboxylic acids. These white crystalline compounds are soluble in non-polar organic solvents, such as alkanes, but are insoluble in water and lower alcohols. In a solution, the compounds are unionized and monomeric.

The central oxygen atom is tetrahedral surrounded by the four Be atoms and each Be atom is tetrahedrally surrounded by four oxygen atoms. The six acetate groups are arranged along the six edges of the tetrahedral ion.

Diagonal relationship between beryllium and aluminium

The ionic radius of Be^{2+} is estimated to be 31 pm; the charge/radius ratio is nearly the same as that of the Al^{3+} ion. Hence beryllium resembles aluminium in some ways. Some of the similarities are:

(a) Like aluminium, beryllium is not readily attacked by acids because of the presence of an oxide film on the surface of the metal, i.e. they are rendered passive by nitric acid.

(b) Beryllium hydroxide dissolves in excess of alkali to give a beryllate ion, $[Be\ (OH)_4]^{2-}$ just as aluminium hydroxide gives the aluminate ion, $[Al\ (OH)_4]^-$

(c) The chlorides of both beryllium and aluminium have Cl^- bridged chloride structure in the vapour phase.

(d) Both the chlorides are soluble in organic solvents and are strong Lewis acids. They are used as Friedel Craft catalysts.

(e) Beryllium and aluminium ions have a strong tendency to form complexes, BeF_4^{2-} and AlF_6^{3-} respectively.

8. COMPOUNDS OF ALKALI METALS

8.1 Sodium Oxide (Na_2O)

Preparation:

(a) By reduction of nitrites and nitrates of sodium with metallic sodium:

$$2NaNO_3 + 10Na \rightarrow 6Na_2O + N_2; \qquad 2NaNO_2 + 6Na \rightarrow 4Na_2O + N_2$$

(b) By heating sodium in limited supply of air at 180°C: $Na + O_2 \rightarrow Na_2O$

(c) Pure sodium oxide is formed when the mixture of sodium azide and sodium nitrite is heated

$$3NaN_3 + NaNO_2 \rightarrow 2Na_2O + 5N_2$$

Properties:

(a) It is a white amorphous substance. It reacts with water violently forming sodium hydroxide and evolving a large amount of heat energy $Na_2O + H_2O \rightarrow 2NaOH$

(b) On heating at 400°C, it decomposes forming sodium peroxide and metallic sodium vapour.

$$2Na_2O \xrightarrow{400^\circ C} Na_2O_2 + 2Na$$

(c) Reaction with liquid ammonia; $Na_2O + NH_3 \rightarrow NaNH_2 + NaOH$

Use: It is used as a dehydrating and polymerizing agent in organic chemistry.

8.1 Sodium Peroxide (Na_2O_2)

Preparation:

(a) It is formed by heating sodium in an excess of air, free from moisture and carbon dioxide or in excess of pure oxygen. $2Na + O_2 \text{ (excess)} \xrightarrow{350^\circ C} Na_2O_2$

(b) **Industrial method:** It is a two stage reaction in the presence of excess air.

$$2Na + \frac{1}{2}O_2 \rightarrow Na_2O; \qquad Na_2O + \frac{1}{2}O_2 \rightarrow Na_2O_2$$

Properties:

(a) It is a pale yellow (when impure) hygroscopic powder stable towards heat in dry air. On exposure to moist air, it becomes white as it reacts with moisture and carbon dioxide.

$$2Na_2O_2 + 2H_2O \rightarrow 4NaOH + O_2$$

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O; \qquad 2Na_2O_2 + 2CO_2 \rightarrow 2Na_2CO_3 + O_2$$

(b) **Action of water:** $Na_2O_2 + 2H_2O \xrightarrow{cold} 2NaOH + H_2O_2$; $2Na_2O_2 + 2H_2O \xrightarrow{warm} 4NaOH + O_2$

(c) **Action of acid:**

$$Na_2O_2 + H_2SO_4 \xrightarrow{cold} Na_2SO_4 + H_2O_2;$$

$$2Na_2O_2 + H_2SO_4 \xrightarrow{warm} 2Na_2SO_4 + 2H_2O + O_2$$

(d) **Reaction with CO and CO_2:** $Na_2O_2 + CO \rightarrow Na_2CO_3$; $2Na_2O_2 + 2CO_2 \rightarrow 2Na_2CO_3 + O_2$

So, it is used to purify the air in a submarine and confined spaces as it removes both CO and CO_2 and gives oxygen.

(e) It is a powerful oxidant and many of its reactions are dangerously violent, particularly with the reducing agents, such as Al powder charcoal, sulphur and many organic liquids.

(i) Chromic compounds are oxidized to chromates

$$2Cr(OH)_3 + 3Na_2O_2 \rightarrow 2Na_2CrO_4 + 2NaOH + 2H_2O \text{ or } 2Cr(OH)_3 + 3O_2^{2-} \rightarrow 2CrO_4^{2-} + 2OH^- + 2H_2O$$

(ii) Manganous salt is oxidized to sodium manganate.

$$MnSO_4 + 2Na_2O_2 \rightarrow Na_2MnO_4 + Na_2SO_4 \text{ or } Mn(OH)_2 + 2O_2^{2-} \rightarrow MnO_4^{2-} + 2OH^-$$

(iii) Sulphides are oxidized to corresponding sulphates

$$Na_2O_2 \rightarrow Na_2O + [O] \quad ; \quad Na_2S + 4[O] \rightarrow Na_2SO_4$$

(iv) $Na_2O_2 \rightarrow Na_2O + [O]$; $2Al + 3[O] \rightarrow Al_2O_3$

(v) Benzoyl peroxide (bleaching agent) is formed when C_6H_5COCl reacts with Na_2O_2.

$2C_6H_5COCl + Na_2O_2 \rightarrow (C_6H_5CO)_2O_2$ (benzoyl peroxide) $+ 2NaCl$

(vi) Reduces stronger oxidizing agent such as acidified $KMnO_4$

$2MnO_4^- + 16H^+ + 5O_2^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$; $Na_2O_2 + O_2 \xrightarrow[300atm]{450°} 2NaO_2$

Use:

(a) Used for the production of oxygen under the name ozone.

(b) It is used as a bleaching agent for bleaching wood pulp, paper and fabrics such as cotton and linen.

8.3 Potassium Superoxide (KO_2)

Preparation:

(a) It is prepared by burning potassium in the excess of oxygen free from moisture.

$K + O_2 \rightarrow KO_2$

Properties:

(a) It is an orange coloured (chrome yellow) powder and reacts with water according to following reaction. $2KO_2 + 2H_2O \rightarrow 2KOH + H_2O_2 + O_2$

(b) It reacts directly with CO and CO_2. $2KO_2 + CO \rightarrow K_2CO_3 + O_2$; $2KO_2 + CO_2 \rightarrow K_2CO_3 + \frac{3}{2}O_2$

If more CO_2, in presence of moisture is present; then $4KO_2 + 4CO_2 + 2H_2O \rightarrow 4KHCO_3 + 3O_2$

(c) On heating with sulphur, it forms potassium sulphate; $2KO_2 + S \rightarrow K_2SO_4$

Use: It is used as an oxidizing agent and air purifier in space capsules, submarine and Breathing mask as it produces O_2 and removes CO_2.

8.4 Potassium Sesquioxide (K_2O_3)

It is obtained when oxygen is passed through liquid ammonia containing potassium.

4K (dissolved in liquid NH_3) $\xrightarrow{3O_2} 2K_2O_3$

8.5 Sodium Hydroxide or Caustic Soda (NaOH)

Preparation: It is most conveniently manufactured by one of the following processes,

(a) Methods involving sodium carbonate as a starting material:

(i) **Gossage process** (causticising process): $Na_2CO_3 + Ca(OH)_2 \rightleftharpoons CaCO_3 + 2NaOH$

The most suitable concentration of sodium carbonate taken in this process is 15 – 20%. The caustic soda produced by this method is not pure and contains some calcium carbonate, sodium carbonate and calcium hydroxide as impurities.

(ii) **Lowig's process:** $Na_2CO_3 + Fe_2O_3 \xrightarrow{\text{red heat}} 2NaFeO_2 + CO_2$

The sodium ferrite is cooled and thrown into hot water, the hydrolysis of sodium ferrite occurs forming NaOH. $2NaFeO_2 + H_2O \rightarrow 2NaOH + Fe_2O_3$

(iii) Methods involving sodium chloride as starting material: Electrolysis of sodium chloride solution occurs according to following principle.

$NaCl \rightleftharpoons Na^+ + Cl^-$; $H_2O \rightleftharpoons H^+ + OH^-$

On passing electricity, Na^+ and H^+ ions move towards cathode and Cl^- and OH^- ions move towards the anode. The discharge potential of H^+ ions is less than Na^+ ions, thus hydrogen ions get discharged easily and hydrogen is liberated. Similarly, at anode Cl^- ions are easily discharged as their discharge potential is less than that of OH^- ions. Cl_2 gas is, therefore, liberated at the anode. It is necessary that chlorine should not come in contact with sodium hydroxide during electrolysis, otherwise the following reaction will take place. $2NaOH + Cl_2 \rightarrow NaCl + NaClO + H_2O$

To overcome this problem, the anode is separated from the cathode in the electrolytic cell either by using a porous diaphragm or by using a mercury cathode.

(a) **The mercury cathode cell (Castner-Kellner cell):** In this cell mercury flows along the bottom of the cell and is a made cathode. The brine solution flows in the same direction and the anode consists of a number of graphite blocks. The brine is electrolyzed and since, hydrogen has a high overvoltage at the mercury cathode, sodium is preferentially discharged forming an amalgam with mercury.

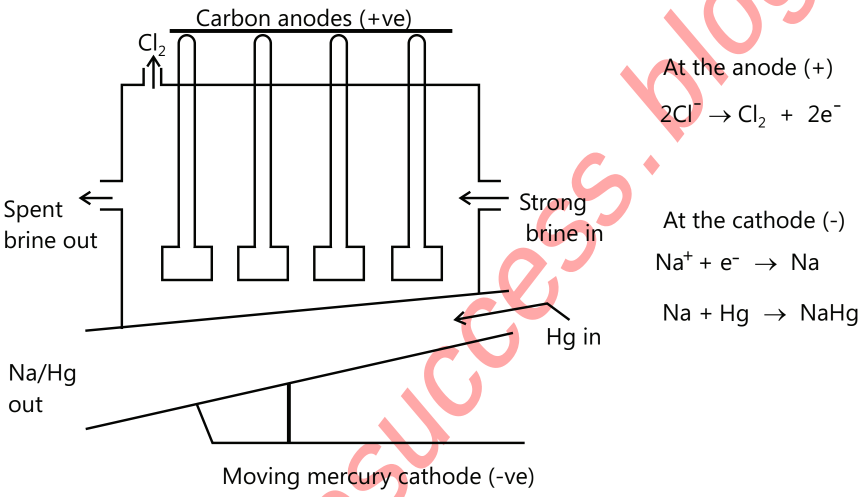


Figure 15.13 (a): Castner-Kellner cell

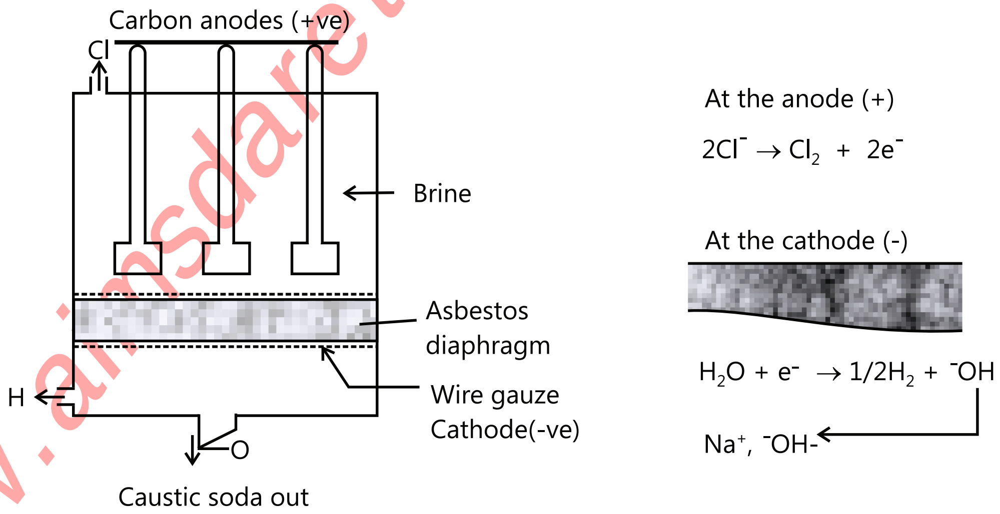


Figure 15.13 (b): Working of Castner-Kellner cell

The sodium amalgam flows out and is reacted with water to give NaOH

$$2NaHg + 2H_2O \rightarrow 2NaOH + 2Hg + H_2$$

The mercury is re-circulated to the cell. Hydrogen and chlorine are the two important by-products.

(b) **Diaphragm cell:** In this type of cell alkali and chlorine are kept separate by the use of a diaphragm and on contact with a negative wire gauze, electrolysis begins. Chlorine is liberated at the graphite anode and sodium hydroxide is formed at the outside edges of the cathode.

(c) **Using Nafion Membrane Cell:** The natural brine (NaCl) is now electrolyzed in a membrane cell in which the anode and the cathode are separated by a NAFION membrane. Nafion is a copolymer of tetrafluoromethylene and pentafluorosulphonyl ethoxyether. The copolymer is supported by a Teflon mesh.

$$2NaCl\ (aq) + H_2O\ (\ell) \xrightarrow{\text{Electrolysis}} 2NaOH\ (aq) + H_2\ (g) + Cl_2\ (g)$$

Presently the method makes use of Nafion membrane in place of diaphragm.

8.5.1 Preparation of Pure Sodium Hydroxide

Commercial sodium hydroxide is purified with the help of an alcohol. Sodium hydroxide dissolves in alcohol, while impurities like NaCl, Na_2CO_3, Na_2SO_4 etc., remain insoluble. The alcoholic filtrate is distilled. The alcohol distils off while pure solid sodium hydroxide is left behind.

Properties:

(a) It is a white crystalline solid and has a soapy touch.

(b) Its density is 2.13 g/mL and melting point is 318.4°C.

(c) It is highly soluble in water and is bitter in taste, and is corrosive in nature.

(d) Neutralization and hydrolysis reactions:

$3NaOH + H_3PO_4 \rightarrow Na_3PO_4 + 3H_2O$; $NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$

These are non-redox type of reactions.

(e) Reaction with acidic oxides: $2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

$2NaOH + 2NO_2 \rightarrow NaNO_2 + NaNO_3 + H_2O$; $2NaOH + SO_3 \rightarrow Na_2SO_4 + H_2O$

(f) Reaction with amphoteric oxides:

$PbO + 2NaOH \rightarrow Na_2PbO_2 + H_2O$; $ZnO + 2NaOH \rightarrow Na_2ZnO_2 + H_2O$

$SnO + 2NaOH \rightarrow Na_2SnO_2 + H_2O$; $SnO_2 + 2NaOH \rightarrow Na_2SnO_3 + H_2O$

(g) Reacts with non-metals:

(i) Halogens

- With cold & dilute NaOH: $2NaOH + Br_2 \rightarrow NaBr + NaOBr + H_2O$
- With hot & concentrated NaOH: $6NaOH + 3Br_2 \rightarrow 5NaBr + NaBrO_3 + 3H_2O$

F_2 with cold & dilute NaOH gives OF_2 and with hot & concentrated NaOH gives O_2

(ii) With white phosphorus: $3NaOH + P_4 \rightarrow 3NaH_2PO_2 + PH_3$

(iii) With sulphur: $6NaOH + 4S \rightarrow 2Na_2S + Na_2S_2O_3 + 3H_2O$

(iv) With boron: $2B + 6NaOH \rightarrow 2Na_3BO_3 + 3H_2$

(v) With silicon: $2NaOH + Si + H_2O \rightarrow Na_2SiO_3 + 2H_2$

(h) Reaction with metals and salts:

(i) Reaction with amphoteric metals (e.g. Al, Pb, Sn, Zn etc.):

They liberate hydrogen gas.

$4NaOH + 2H_2O + 2Al \rightarrow 2NaAlO_2 + 3H_2$

$6NaOH + 2Al \rightarrow 2Na_3AlO_3 + 3H_2$; $Zn + NaOH \rightarrow Na_2ZnO_2 + H_2$

(ii) Reaction with salts of amphoteric metals:

Salts dissolves in sodium hydroxide (excess)

$SnCl_2 + 2NaOH \rightarrow Sn(OH)_2\downarrow$ (white) $+ 2NaCl$; $Sn(OH)_2 + 2NaOH \rightarrow Na_2SnO_2 + 2H_2O$

(iii) Reaction with salts of Cr, Ni, Fe, Mn. Cu etc.

Form insoluble hydroxides

$CrCl_3 + 3NaOH \rightarrow Cr(OH)_3\downarrow$ (green) $+ 3NaCl$; $CuCl_2 + 2NaOH \rightarrow Cu(OH)_2\downarrow$ (blue) $+ 2NaCl$

(iv) Reaction with salts of Hg and Ag:

$HgCl_2 + 2NaOH \rightarrow Hg(OH)_2\downarrow + 2NaCl$; $Hg(OH)_2 \rightarrow HgO\downarrow$ (yellow or brown) $+ H_2O$

$2AgNO_3 + 2NaOH \rightarrow 2AgOH + 2NaNO_3$; $2AgOH \rightarrow Ag_2O\downarrow$ (black) $+ H_2O$

(v) Reaction with ammonium salts: It liberates ammonia from both ammonium salts and coordination complexes where ammonia acts as ligand.

$(NH_4)_2SO_4 + NaOH \xrightarrow{\Delta} Na_2SO_4 + 2NH_3 + 2H_2O$;

$6NaOH + 2[Co(NH_3)_6]Cl_3 \rightarrow 12NH_3 + Co_2O_3 + 6NaCl + 3H_2O$

(vi) Reaction with carbon monoxide: $NaOH + CO \xrightarrow[5-10atm]{150-200°C} HCOONa$

(vii) Reaction with H_2S: $NaOH + H_2S \rightarrow NaSH + H_2O$; $NaSH + NaOH \rightarrow Na_2S + H_2O$.

It is used to remove mercaptans from petroleum products.

(viii) Reaction with alcohols: $NaOH + EtOH \rightarrow NaOEt + H_2O$.

Caustic property: Sodium hydroxide is a powerful cautery and breaks down the proteins of skin to a pasty mass. On account of this property, it is commonly called caustic soda.

8.6 Potassium Hydroxide (KOH)

It is prepared by the electrolysis of KCl solution. KOH resembles NaOH in all its reactions. However KOH is much more soluble in alcohol. This accounts for the use of alcoholic KOH in organic chemistry.

KOH is called caustic potash, because of their corrosive properties (for example on glass or on skin) and its aqueous solution is known as potash lye.

$2KOH + 4NO \rightarrow 2KNO_2 + N_2O + H_2O$; $4KOH + 6NO \rightarrow 4KNO_2 + N_2 + 2H_2O$

It is used for the absorption of gases like CO_2, SO_2, etc. It is used for making soft soaps.

8.7 Sodium Carbonate or Washing Soda (Na_2CO_3)

Preparation:

(a) By Solvay ammonia soda process: It involves followings steps.

(i) Saturation of brine with ammonia and CO_2 (In ammonia absorber):

$2NH_3 + CO_2 + H_2O \rightarrow (NH_4)_2CO_3$

$CaCl_2 + (NH_4)_2CO_2 \rightarrow CaCO_3\downarrow + 2NH_4Cl$; $MgCl_2 + (NH_4)_2CO_3 \rightarrow MgCO_3\downarrow + 2NH_4Cl$

Ammoniated brine is filtered to remove calcium and magnesium impurities as their insoluble carbonates.

(ii) Formation of insoluble $NaHCO_3$ (In carbonation tower):

$NH_3 + CO_2 + H_2O \rightarrow NH_4HCO_3$; $NH_4HCO_3 + NaCl \xrightarrow{30°C} NaHCO_3 + NH_4Cl$

Reaction is exothermic and hence there is a cooling arrangement.

$NaHCO_3$ is insoluble in cold brine solution because of the common ion effect. It is separated by filtration and the filtered is used for recovering NH_3 & CO_2

(iii) Calcination to get sodium carbonate: $2NaHCO_3 \xrightarrow{150°C} Na_2CO_3 + CO_2 + H_2O$

(iv) Recovery of ammonia and carbon dioxide (In recovery tower):

$NH_4HCO_3 \xrightarrow[\text{(steam)}]{\Delta} NH_3 + CO_2 + H_2O$; $2NH_4Cl + Ca(OH)_2 \xrightarrow[\text{(steam)}]{\Delta} 2NH_3 + 2H_2O + CaCl_2$

$CaCl_2$ is obtained as by product.

(v) Preparation of CO_2 (In lime kiln):

$CaCO_3 \xrightarrow{1375k} CaO + CO_2$; $CaO + H_2O \rightarrow Ca(OH)_2$ (slaked lime)

(b) Le-Blanc process: It involves following steps

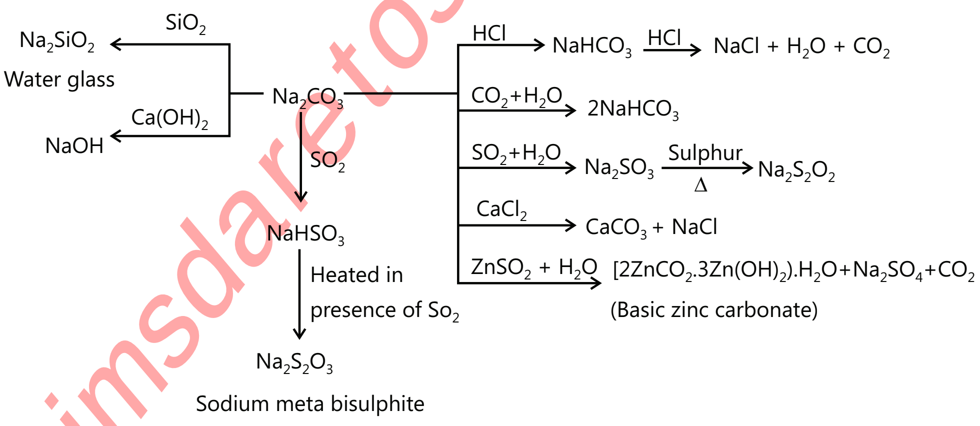
(i) $NaCl + H_2SO_4 \text{ (cone.)} \xrightarrow[\text{fumace}]{\Delta} NaHSO_4 \text{ (salt cake)} + HCl$

(ii) $NaHSO_4 + NaCl \xrightarrow[\text{fumace}]{\Delta} Na_2SO_4 + HCl$

(iii) $Na_2SO_4 + CaCO_3 + 4C \xrightarrow[\text{fumace}]{\Delta} \underbrace{Na_2CO_3 + CaS}_{\text{Black ash}} + 4CO$

Black ash contains 45% Na_2CO_3 is extracted with water when Na_2CO_3 dissolves leaving behind insoluble as impurities called as alkali sludge or waste.

Properties:



Flowchart 15.1: Chemical properties of sodium carbonate

(a) It is white crystalline solid. It is known in several hydrated forms. The common form is decahydrate, $Na_2CO_3.10H_2O$. This form is called washing soda. The decahydrate form on standing in air effloresces and crumbles to powder. It is the monohydrate, $Na_2CO_3.H_2O$.

(b) It is soluble in water with the evolution of considerable amount of heat. The solution is alkaline in nature due to hydrolysis. $Na_2CO_3 + 2H_2O \rightleftharpoons 2NaOH + H_2CO_3$

$Na_2CO_3 + NO + NO_2 \rightarrow 2NaNO_2 + CO_2$

Bicarbonates precipitate normal carbonates while carbonates precipitate basic carbonates from some metal salt solutions.

$MgCl_2 + NaHCO_3 \rightarrow MgCO_3\downarrow + 2NaCl + CO_2 + H_2O$

$MgCl_2 + 2Na_2CO_3 + H_2O \rightarrow MgCO_3 + Mg(OH)_2\downarrow + 4NaCl + CO_2$

$NaNO_3 + HCl \rightarrow KNO_3 + NaCl$

8.8 Potassium Carbonate, Potash or Pearl Ash (K_2CO_3)

Preparation:

(a) By Le-Blanc process:

$KCl + H_2SO_4 \rightarrow KHSO_4 + HCl$; $KHSO_4 + KCl \rightarrow K_2SO_4 + HCl$

$K_2SO_4 + CaCO_3 + 2C \rightarrow K_2CO_3 + CaS + 2CO_2$

(b) By Prechts process:

(i) $2KCl + 3(MgCO_3 . 3H_2O) + CO_2 \rightarrow 2(MgCO_3 . KHCO_3 . 4H_2O) + MgCl_2$

(ii) $2(MgCO_3 . KHCO_3 . 4H_2O) \xrightarrow{140°C} 2MgCO_3\downarrow + K_2CO_3 + 9H_2O + CO_2$ or

$2(MgCO_3 . KHCO_3 . 4H_2O) + MgO \xrightarrow{20°C} 3(MgCO_3 . 3H_2O)\downarrow + K_2CO_3$

It is a white powder and deliquescent in nature. The mixture of K_2CO_3 and Na_2CO_3 is used as a fusion mixture in the laboratory. $2HNO_3 + K_2CO_3 \rightarrow 2KNO_3 + CO_2 + H_2O$

The potassium carbonate like sodium carbonate, cannot be prepared by Solvay process because of the intermediate, $KHCO_3$ formed which is soluble in an appreciable amount in water.

8.9 Sodium Bicarbonate or Baking Soda ($NaHCO_3$)

It is obtained as the intermediate product in the Solvay ammonia soda process. Normal carbonate can be changed to bicarbonate by passing carbon dioxide through its saturated solution. $Na_2CO_3 + CO_2 + H_2O \rightarrow 2NaHCO_3$ (sparingly soluble)

Properties: It is a white crystalline solid, sparingly soluble in water. The solution is alkaline in nature due to hydrolysis. The solution is weakly basic and gives a yellow colour with methyl orange but no colour with phenolphthalein. $NaHCO_3 + H_2O \rightleftharpoons NaOH + H_2CO_3$

On heating, it loses carbon dioxide and water forming sodium carbonate.

$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$

Use: It is largely used for making baking powder. Baking powder contains $NaHCO_3$, Ca $(H_2PO_4)_2$ and starch. The Ca (H_2PO_4) is acidic and when water is added, it reacts with $NaHCO_3$, giving CO_2. The starch is a filler. Improved baking powder contains about 40% starch, 30% $NaHCO_3$, 20% NaAl $(SO_4)_2$ and 10% Ca $(H_2PO_4)_2$. The NaAl $(SO_4)_2$ slows the reaction down so the CO_2 is given off more slowly.

Illustration 12: What happens when- **(JEE ADVANCED)**

(A) Anhydrous potassium nitrate is heated with excess of metallic potassium.

(B) Solution containing sodium carbonate and sodium sulphide is treated with sulphur dioxide.

Sol: Self-explanatory

(A) $2KNO_3 + 10K \rightarrow 6K_2O + N_2$ (B) $Na_2CO_3 + 2Na_2S + 4SO_2 \rightarrow 3Na_2S_2O_3 + CO_2$

8.10 Sodium Sulphate ($Na_2SO_4.10H_2O$)

It is also known as Glauber's salt.

Preparation:

(a) **By heating NaCl with concentrated. H_2SO_4:** $2NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2HCl$

(b) **By Hargreaves process:** $4NaCl$ (dry lumps) $+ 2SO_2\,(g) + 2H_2O\,(g) + O_2\,(g) \rightarrow 2Na_2SO_4 + 4HCl$

Properties:

(a) It is a white crystalline solid and effloresces readily in dry air to form anhydrous sodium sulphate.

(b) It is reduced to sodium sulphide when heated with carbon. $Na_2SO_4 + 4C \rightarrow Na_2S + 4CO\uparrow$

(c) It forms sodium bisulphate when reacted with concentrated H_2SO_4. $Na_2SO_4 + H_2SO_4 \rightarrow 2NaHSO_4$

(d) Reaction with metal salts. $BaCl_2 + Na_2SO_4 \rightarrow BaSO_4\downarrow + 2NaCl$; $Pb\,(NO_3) + Na_2SO_4 \rightarrow PbSO_4\downarrow + 2NaNO_3$

8.11 Potassium Sulphate (K_2SO_4)

Preparation:

(a) It is prepared by the reaction of potassium chloride or hydroxide with concentrated. H_2SO_4.

$2KCl + H_2SO_4 \rightarrow K_2SO_4 + 2HCl$; $2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$;

(b) $K_2SO_4\,.\,MgSO_4.6H_2O + 2KCl \rightarrow 2K_3SO_4 + MgCl_2 + 6H_2O$

Properties: It is a white crystalline solid and soluble in water. It is used as a fertilizer for tobacco and wheat.

Illustration 13: Why is there a white deposit in the glass vessel containing NaOH solution noticed after some time? **(JEE ADVANCED)**

Sol: SiO_2 present in glass reacts with NaOH to give insoluble silicate.

$2NaOH + SiO_2 \rightarrow Na_2SiO_3 + H_2O$

Illustration 14: $KO_2 + CO_2 + H_2O \xrightarrow{\text{more } CO_2} [X] + [Y]$ **(JEE ADVANCED)**

Products [X] and [Y] are respectively: (A) K_2CO_3, O_2 (B) $KHCO_3$, O_2 (C) KOH, K_2CO_3 (D) $KHCO_3$, H_2O

Sol: $KO_2 + CO_2 + H_2O \xrightarrow{\text{more } CO_2} \underbrace{KHCO_3}_{X} + \underbrace{O_2}_{Y}$

9. COMPOUNDS OF ALKALINE EARTH METALS

9.1 Magnesium Oxide or Magnesia (MgO)

Preparation: It can be prepared by following reaction.

$2Mg + O_2 \xrightarrow{\text{burning}} 2MgO$; $Mg\,(OH)_2 \xrightarrow{\text{heated}} MgO + H_2O$

$2Mg\,(NO_3)_2 \xrightarrow{\text{heated}} 2MgO + 4NO_2 + O_2$; $MgCO_3 \xrightarrow{\text{heated}} MgO + CO_2$

Properties:

(a) It is slightly soluble in water and forms magnesium hydroxide. $MgO + H_2O \rightarrow Mg\,(OH)_2$

(b) It is basic in nature. It reacts with acids to form corresponding salts. $MgO + 2HCl \rightarrow MgCl_2 + H_2O$

(c) It is reduced by carbon at a very high temperature. $MgO + C \rightarrow Mg + CO$

Magnesium oxide when mixed with a saturated solution of magnesium chloride sets to a hard mass like cement known as magnesia cement or Sorel's cement. The composition is $MgCl_2 .5MgO. xH_2O$.

9.2 Magnesium Hydroxide [$Mg(OH)_2$]

Preparation:

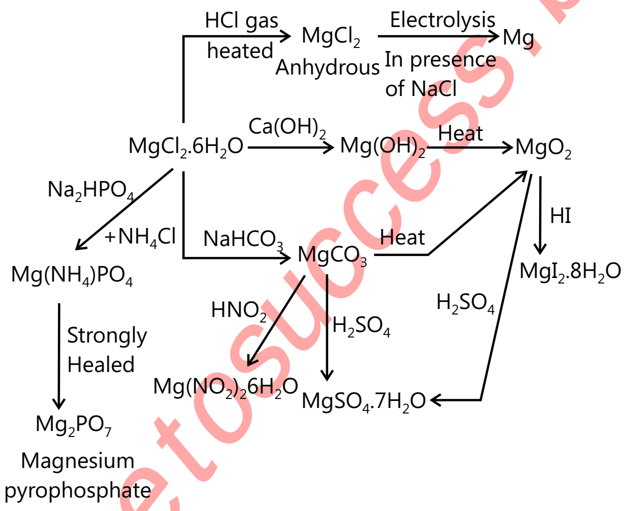
(i) $MgO + H_2O \rightarrow Mg\ (OH)_2$

(ii) $MgCl_2 + Ca\ (OH)_2 \rightarrow Mg\ (OH)_2 + CaCl_2$,

(iii) $MgCl_2 + 2NaOH \rightarrow Mg\ (OH)_2 + 2NaCl$

Properties: It is a white powder. It is sparingly soluble in water. It is basic in nature and forms a salt with acids. It decomposes on heating. It readily dissolves in ammonium chloride solution and is, therefore, not precipitated in group IIIrd of qualitative analysis.

$Mg\ (OH)_2 + 2NH_4Cl \rightleftharpoons MgCl_2 + 2NH_4OH.$



Flowchart 15.2: Chemical properties of Magnesium Hydroxide

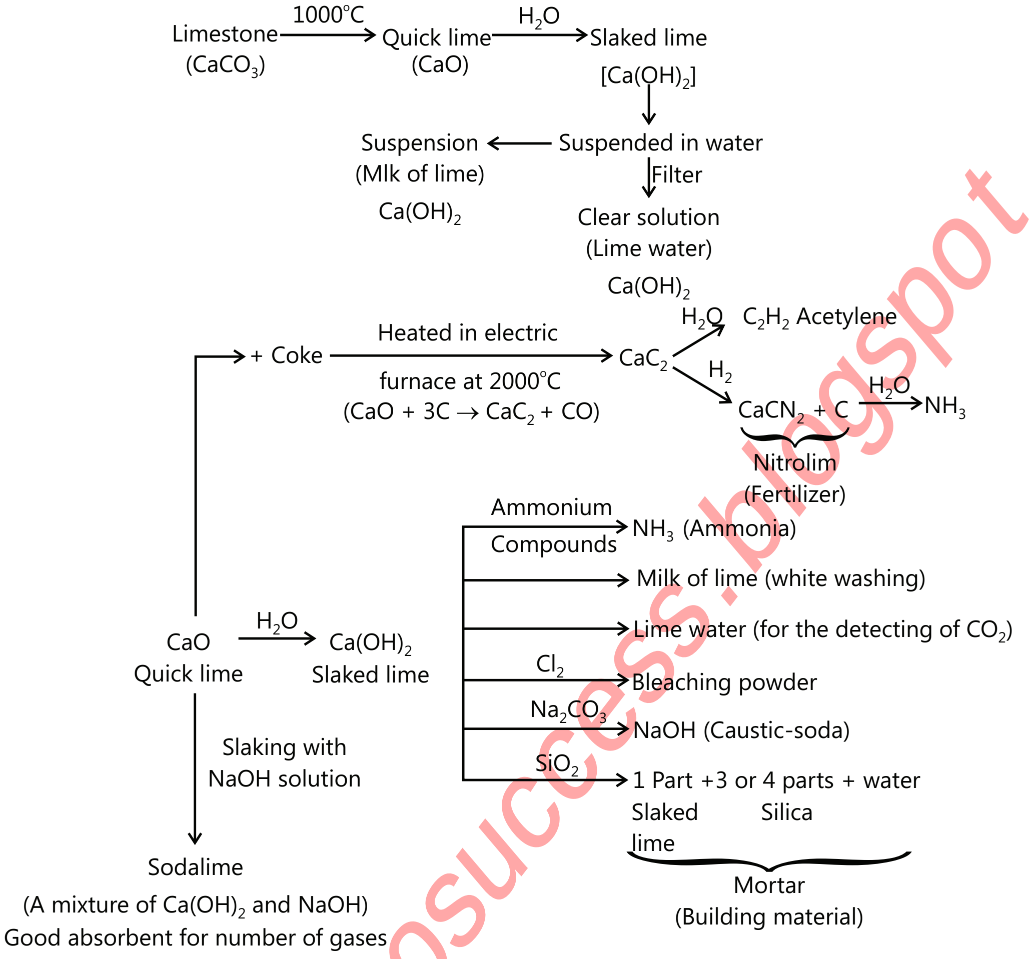
Use: A suspension of $Mg\ (OH)_2$ in water is used in medicine as an antacid under the name, milk of magnesia.

9.3 Magnesium Chloride ($MgCl_2.6H_2O$)

It occurs in nature as mineral carnallite, $KCl, MgCl_2. 6H_2O$.

Properties: It is a colourless crystalline solid, highly deliquescent and highly soluble in water.

9.4 Quick Lime, Slaked Lime and Lime Water



Flowchart 15.3: Reactions of Quick lime,slaked lime and lime water

9.5 Magnesium Carbonate ($MgCO_3$)

Preparation:

(a) It can be prepared by adding sodium bicarbonate to a hot solution of magnesium salt.

$MgSO_4 + 2NaHCO_3 \rightarrow MgCO_3 + Na_2SO_4 + H_2O + CO_2$

(b) $2MgSO_4 + 2Na_2CO_3 + H_2O \rightarrow MgCO_3.\ Mg(OH)_2 + 2Na_2SO_4 + CO_2$

When CO_2 gas is passed through the suspension of the basic carbonate of magnesium, magnesium bicarbonate is formed which on heating forms $MgCO_3$.

$MgCO_3.\ Mg(OH)_2 + 3CO_2 + H_2O \rightarrow 2Mg(HCO_3)_2$; $Mg(HCO_3)_2 \xrightarrow{\Delta} MgCO_3 + H_2O + CO_2$

Properties:

(a) It dissolves readily in water containing an excess of carbon dioxide.

$MgCO_3 + CO_2 + H_2O \rightarrow Mg(HCO_3)_2$

(b) It dissolves in acids forming salts with evolution of CO_2.

$MgCO_3 + 2HCl \rightarrow MgCl_2 + H_2O + CO_2$

On heating, it decomposes with the evolution of CO_2.

$MgCO_3 \rightarrow MgO + CO_2$

(c) It forms double carbonates with alkali metal carbonates.

$MgCO_3 + Na_2CO_3 \rightarrow Na_2Mg(CO_3)_2$ (soluble)

9.6 Calcium Carbonate ($CaCO_3$)

Preparation: It can be obtained by passing carbon dioxide through lime water or by adding sodium carbonate solution to $CaCl_2$ $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$; $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$

The precipitate of $CaCO_3$ thus obtained is known as precipitated chalk.

Properties: It is a white powder insoluble in water. It dissolves in the presence of CO_2 due to the formation of calcium bicarbonate. $CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$

Uses:

(a) Precipitated chalk is used in tooth pastes and face powders, in medicine for indigestion, in adhesives and in cosmetics.

(b) Chalk is used in paints and distempers.

9.7 Magnesium Sulphate ($MgSO_4$)

It occurs in nature as minerals kiesserite ($MgSO_4.H_2O$), epsom salt ($MgSO_4.7H_2O$) and kainite ($KCl.MgSO_4.3H_2O$).

Preparation: It is prepared by reacting magnesite ($MgCO_3$) or dolomite with dilute sulphuric acid.

$MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + H_2O + CO_2$

$MgCO_3.CaCO_3$ (dolomite) $+ 2H_2SO_4 \rightarrow MgSO_4 + CaSO_4 + 2CO_2 + 2H_2O$

Properties:

(a) **Heating effect:** When heated to 150°C, it changes to monohydrate. On further heating, it becomes anhydrous at 200°C. On strong heating, it decomposes into MgO.

$$MgSO_4.7H_2O \xrightarrow{150°C} MgSO_4.H_2O \xrightarrow{200°} MgSO_4 \xrightarrow[\text{heating}]{\text{strong}} MgO + SO_2 + \frac{1}{2}O_2.$$

(b) Magnesium sulphate when heated with lamp black at 800°C produces SO_2 and CO_2 gases.

$2MgSO_4 + C \rightarrow 2MgO + 2SO_2 + CO_2$

(c) It forms double salts with alkali metal sulphates, e.g., K_2SO_4. $MgSO_4.6H_2O$.

9.8 Calcium Sulphate ($CaSO_4$)

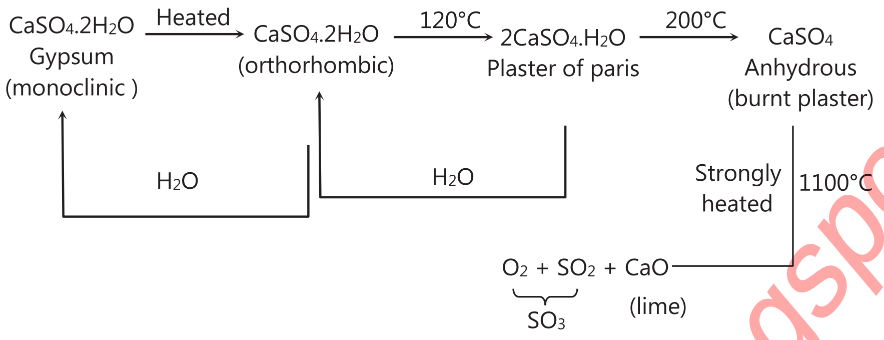
It is found in nature as an anhydride ($CaSO_4$) and gypsum ($CaSO_4.2H_2O$)
It can be prepared by reacting any calcium salt with either sulphuric acid or a soluble sulphate.
$CaCl_2 + H_2SO_4 \rightarrow CaSO_4 + 2HCl$; $CaCl_2 + Na_2SO_4 \rightarrow CaSO_4 + 2NaCl$

Properties:

(a) It is a white crystalline solid. It is sparingly soluble in water and solubility decreases as temperature increases.

(b) It dissolves in dilute acids. It also dissolves in ammonium sulphate due to the formation of double sulphate, $(NH_4)_2SO_4.CaSO_4.H_2O$

(c) Gypsum when heated first changed from monoclinic form to orthorhombic form without loss of water. At 120°C, it loses three-fourth of its water of crystallization and forms hemihydrate, ($2CaSO_4.H_2O$) which is commonly known as the Plaster of Paris. At 200"C. it becomes anhydrous. The anhydrous form is known as burnt plaster or dead plaster.



Flowchart 15.4: Chemical Properties of calcium sulphate

(d) Dead plaster has no setting property as it takes up water only very slowly.

(e) A suspension of gypsum when saturated with ammonia and carbon dioxide forms ammonium sulphate, a nitrogenous fertilizer $2NH_3+CaSO_4 + CO_2 +H_2O \rightarrow (NH_4)_2SO_4 + CaCO_3$

(f) When strongly heated with carbon, it forms calcium sulphide. $CaSO_4 + 4C \rightarrow CaS + 4CO$

Use: (a) For preparing blackboard chalk. **(b)** In anhydrous form as drying agent.

9.9 Plaster of Paris ($2CaSO_4.H_2O$) (Calcium sulphate hemihydrate)

Preparation: It is obtained when gypsum, calcium sulphate dihydrate ($CaSO_4.2H_2O$), is heated at 120°C (393K).

$2[CaSO_4.2H_2O] \rightarrow 2CaSO_4.H_2O$ (calcium sulphate hemihydrate) + $3H_2O$

Gypsum Plaster of Paris

Properties:

(a) Plaster of Paris is a white powder.

(b) It has the property of setting to a hard mass when a paste with water is allowed to stand aside for some time. Slight expansion occurs during the setting as water is absorbed to reform $CaSO_4.\ 2H_2O$ (gypsum). The setting process is exothermic. The process of setting takes place in stages. In the first stage, there is a conversion of Plaster of Pairs into an orthorhombic form of gypsum (setting step) and in the second stage the orthorhombic form changes into a monoclinic form (hardening step).

$$2CaSO_4H_2O \xrightarrow[H_2O]{\text{Setting}} CaSO_4\ .\ 2H_2O \xrightarrow{\text{Hardening}} CaSO_4.\ 2H_2O$$

Plaster of Paris Orthorhombic Monoclinic

The setting of Plaster of Paris may be catalysed by sodium chloride while it is retarded by borax or alum. Addition of alum to Plaster of Paris makes the setting very hard. The mixture is known as Keene's cement.

Illustration 15: An element X exhibits only the +2 oxidation state in its compounds. The compounds are white and frequently crystallize as hydrates. Its hydroxide used as an antacid is the least soluble one in its family and can be precipitated from solutions containing X^{2+} by NH_3 (g). Identity the element and give the balanced equations.

(JEE MAIN)

(a) For the effect of heat on its (hexahydrate) chloride.

(b) For the precipitation of the hydroxide using aq. NH_3.

Sol: The element is magnesium as its hydroxide known as milk of magnesia is used as an antacid.

$$MgCl_2 . 6H_2O(s) \xrightarrow{\Delta} MgO(s) + 2HCl\ (g) + 5H_2O\ (g)$$

$$Mg^{2+}\ (aq.) + 2NH_3\ (aq) + 2H_2O\ (\ell) \rightarrow Mg\ (OH_2)\ (s) + 2NH_4^+\ (aq)$$

PROBLEM SOLVING TACTICS

The correct order of stability of for the following supper oxides is:

(A) $KO_2 > RbO_2 > CsO_2$ (B) $RbO_2 > CsO_2 > KO_2$ (C) $CsO_2 > RbO_2 > KO_2$ (D) $KO_2 > CsO_2 > RbO_2$

Solution: The approach should be as follows

(i) The stability of super oxides depend on the polarizing power of the cation. Lesser the polarizing power, greater is the stability of the superoxide ion.

(ii) The polarizing power of cations of the same charge decreases with the increase in the size.

(iii) Therefore, the stability of super oxides increases with increase in the size of cations.

(iv) The increasing order of size of ions is: $K^+ < Rb^+ < Cs^+$.

(v) The correct order of stability is: $CsO_2 > RbO_2 > KO_2$

Which one of the following orders presents the correct sequence of the increasing basic nature of the given oxides?

(A) $K_2O < Na_2O < Al_2O_3 < MgO$ (B) $Al_2O_3 < MgO < Na_2O < K_2O$

(C) $MgO < K_2O < Al_2O_3 < Na_2O$ (D) $MgO < K_2O < Na_2O < Al_2O_3$

Explanation: (i) Basic nature of oxides increases with increase in the size of cation.

(ii) The increasing order of cations is: $Al^{3+} < Mg^{2+} < Na^+ < K^+$

(iii) Therefore the increasing correct order of basic strength is: $Al_2O_3 < MgO < Na_2O < K_2O$

Conclusion: Correct option is: 'B'.

POINTS TO REMEMBER

Trends in Physical Properties of Alkaline Earth Metals:

Characteristic	Trend
Oxidation state	All elements show +2 oxidation state
Atomic / ionic radii	Be < Mg < Ca < Sr < Ba Size of the alkaline earth metals increases from top to bottom due to increase in the number of shells.
Ionization enthalpy	Be > Mg > Ca > Sr > Ba As the size increases it becomes easier to remove an electron from the outermost shell.

Electronegativity	Be > Mg > Ca > Sr > Ba As the electropositive character increases from top to bottom due to decrease in ionization energy, electronegativity decreases from top to bottom.
Metallic character	Be < Mg < Ca < Sr < Ba Metallic character increases as we go down the group due to increase in electropositive character.
Density	Generally density increases from top to bottom as the atomic mass increases.
Melting point and boiling point	They show higher values of melting and boiling points as compared to alkali metals because of the smaller size and stronger metallic bonds. There is no regular trend down the group. It depends upon packing.
Flame coloration	Except Be and Mg (due to small size and higher ionization enthalpy) all other alkaline earth metals impart characteristic colours to the Bunsen flame. Ca: Brick red Sr: Crimson Red Ba: Sea green

Solved Examples

JEE Main/Boards

Hydrogen

Example 1: When Ionic hydrides react with water it gives?

Sol: s-block elements form ionic hydrides which form basic hydroxide with water. Ex – NaOH

Example 2: H_2O_2 reduces $K_3[Fe(CN)_6]$ in which medium and give complete reaction ?

Sol: Potassium Ferricyanide is reduced by H_2O_2 in basic medium

$$2\,K_3[Fe(CN)_6] + 2\,KOH + H_2O_2 \rightarrow 2K_4[Fe(CN)_6] + 2H_2O + O_2$$

(basic medium)

Example 3: In alkaline medium, H_2O_2 reacts with $Fe^{3+}$and Mn^{2+} separately give reaction?

Sol: $K_3Fe(CN)_6$ is reduced by H_2O_2 in alkaline medium.

$$2K_3Fe(CN)_6 + 2KOH + H_2O_2 \rightarrow 2K_4Fe(CN)_6 + 2H_2O + O_2$$

$Mn(OH)_2$ is oxidised by H_2O_2 in alkaline medium

$$Mn(OH)_2 + H_2O_2 \rightarrow MnO_2 + 2H_2O$$

Example 4: Give chemical reaction of H_2 formation by Bosch and Lane process?

Sol: (i) Bosch process

$$C + H_2O \rightarrow CO + H_2$$

(ii) Lane process

$$3Fe + 4H_2O \xrightarrow{1000°C} Fe_3O_4+4H_2$$

Example 5: What is the physical property of H_2?

Sol: (i) Colourless, odourless, tasteless gas

(ii) Sparingly soluble in water due to non-polar nature

(iii) Density is 0.09 gm/t

(iv) B.P is 20.4 K

(v) Pd metal can adsorb H_2 gas.

JEE Advanced/Boards

Hydrogen

Example 1: Which metals can adsorb largest volumes of hydrogen gas?

Sol: Acc. to amount of hydrogen occluded metal in decreasing order are - Colloidal Pd > Pt > Au > Ni

Example 2: Give one method of removal of Permanent hardness of water.

Sol: Permanent hardness of water can be removed by adding calgon $(NaPO_3)_n$. $(NaPO_3)_n$ is used in calgon process, it forms soluble complex with Ca^{2+} and Mg^{2+} ions.

Example 3: What is the ratio of volumes of hydrogen evolved under similar conditions of pressure and temperature?

Sol: 2g of aluminium is treated separately with excess of dilute H_2SO_4 and excess of NaOH.

$2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$;

$2Al + 2NaOH + 2H_2O_2 \rightarrow 2NaAlO_2 + 3H_2$

Thus, ratio of volumes of hydrogen evolved is 1:1

Example 4: What is the degree of hardness of a sample of water containing 24 mg of $MgSO_4$ (molecular mass 120) per kg of water?

Sol: 24 mg of $MgSO_4$ present in 103 g of water 106g water will contain 24000 mg of $MgSO_4$ = 24g of $MgSO_4$

120 g of $MgSO_4$ = 10 g of $CaCO_3$

So, 24g of $MgSO_4$ = $\frac{100}{120} \times 24$ = 20 g of $CaCO_3$

Hardness of water = 20 ppm

Example 5: Define ortho and para hydrogen

Sol: Ortho and para hydrogen: When the spins of both the protons (nucleus) in the hydrogen molecule are in the same direction then this form is known as ortho hydrogen. The molecule of hydrogen in which both the protons are spinning in opposite directions known as para hydrogen. These are nuclear isomers. At normal temperature the ratio of ortho and para hydrogen is 3: 1, but as the temperature is lowered, the proportion of para hydrogen increases (at 20°C).

JEE Main/Boards

Hydrogen

Exercise 1

Q.1 What is the importance of heavy water with regard to nuclear power generation?

Q.2 Name two compounds which retard the decomposition of H_2O_2 solution?

Q.3 What is water gas? How is it prepared?

Q.4 What is meant by autoprotolysis of water?

Q.5 Explain why electrolysis of ordinary water occurs faster than heavy water?

Q.6 How is dihydrogen obtained from:

(i) Water, (ii) Dilute acids, (iii) Alkalis

Q.7 What are interstitial hydrides? Discuss their important uses?

Q.8 Explain why water has high boiling and melting point as compared to H_2?

Q.9 What happens when H_2O_2 is treated with

(i) Acidified potassium permanganate.

(ii) Lead sulphide.

(iii) Alkaine potassium ferricyanide.

(iv) Acidified ferrous sulphate.

(v) Sulphurous acid.

(vi) Sodium arsenite.

Q.10 What is the action of heavy water on

(i) Sodium

(ii) Sodium hydroxide

(iii) Ammonium chloride

(iv) Sulphur trioxide

Q.11 Find the volume of oxygen gas liberated at STP when 25 ml of '30 volumes' H_2O_2 is completely decomposed.

Q.12 Calculate the volume strength of 13.6% solution of H_2O_2

Q.13 Which solution is used for the removal of AsH_3 and PH_3 present in very small amounts in hydrogen sample?

Q.14 Complete the following reactions

(i) An alkaline solution of potassium ferricyanide is treated with hydrogen peroxide.

(ii) Chromium hydroxide is treated with hydrogen peroxide in the presence of NaOH.

Q. 15 Why are the melting and boiling points of D_2O are higher than those of ordinary water?

Q.16 Why the presence of water is avoided in the preparation of H_2O_2 from Na_2O_2?

Q.17 Why a mixture of hydrazine and H_2O_2 is used as a rocket propellant?

Q.18 Why hydrogen peroxide acts as an oxidizing agent as well as a reducing agent.

Q.19 20mL of H_2O_2 after acidification with dilute H_2SO_4 required 30 mL of N/12 $KMnO_4$ for complete oxidation. Calculate the percentage of H_2O_2 in the solution. Equivalent mass of H_2O_2= 17.

Q.20 Why statues coated with white lead on long exposure to atmosphere turn black & the original colour can be restored on treatment with H_2O_2?

Q.21 When a substance A reacts with water, it produces a combustible gas B and a solution of substance C in water. D reacts with this solution C and produces the same gas B on warming. D can also produce gas B on reaction with dilute H_2SO_4. A imparts a deep golden yellow colour to smokeless flame. A, B, C and D respectively are?

Q.22 What is false about H_2O_2?

Q.23 What happens, when H_2O_2 is added to ice cold solution of acidified potassium dichromate in ether and the contents are shaken and allowed to stand?

Q.24 25 mL of H_2O_2 is reacted with excess amount of I^- to liberate I_2. I_2 thus liberated reacts completely with 20 mL of 0.3 N $Na_2S_2O_3$. Calculate volume strength of H_2O_2.

Q.25 The electrolysis of water for manufacturing hydrogen gas is always carried out in presence of acid (H_2SO_4) or alkali (KOH), yet no SO_4^{2-} or K^+ ions are discharged. Explain.

Q.26 Painting coated with white lead on long exposure to atmosphere turns black and the original colour can be restored on treatment with H_2O_2. Explain.

Q.27 Why H_2O_2 is stored in wax lined amber coloured bottles?

Q.28 A small amount of phosphoric acid or glycerol or acetanilide is added in H_2O_2 during its storage. Explain.

Q.29 Find out the normality of the hydrogen peroxide bottle labelled as '10 V H_2O_2'

Q.30 When electrolysis of 50% H_2SO_4 is done compound (A) is obtained which acts as oxidising agent as well as reducing agent. (A) when reacted with Cr^{+3} in basic medium gives (B) and which reacted with PbS gives (C). Find out (A),(B) and(C)

Exercise 2

Single Correct Choice Type

Q.1 Calgon (a water softener) is:

(A) $Na_2[Na_4(PO_3)_6]$
(B) $Na_4[Na(PO_3)]_6$
(C) $Na_2[Na_4(PO_4)]_6$
(D) $Na_4[Na_2(PO_4)_6]$

Q.2 Which gas in cold, liquid form expands when it is further cooled:

(A) Liquid He
(B) Liquid NH_3
(C) Liquid H_2
(D) Liquid O_2

Q.3 Hydrogen has a tendency to gain one electron in order to acquire helium configuration. It thus resembles:

(A) Alkali metals
(B) Noble gases
(C) Halogens
(D) Alkaline earth metals

Q.4 When a molten metal hydride is electrolysed?

(A) H^+ ions produced move towards the cathode

(B) H^- ions produced move towards the anode

(C) H_2 is liberated at anode

(D) H_2 is liberated at cathode

Q.5 Which is true statement?

(A) The layer of ice on the surface of river in the winter acts as a thermal insulator between the water below and the air above

(B) The fish and other marine organism are enabled to survive long periods of freezing water due to the fact that ice is lighter than water

(C) Both is correct

(D) None is correct

Q.6 A sample of water contains sodium chloride. It is

(A) Hard water (B) Soft water

(C) Moderately hard (D) None of these

Q.7 The bleaching properties of H_2O_2 are due to its

(A) Reducing properties (B) Oxidising properties

(C) Unstable nature (D) Acidic nature

Q.8 When 50% solution of H_2SO_4 is electrolysed by passing a current of high density at low temperature the main products of electrolysis are

(A) Oxygen and hydrogen

(B) H_2 and peroxy disulphuric acid

(C) H_2 and SO_2

(D) O_2 and peroxy disulphuric acid

Q.9 Hardness producing salt, whose solubility in water decreases with rise of temperature is-

(A) $CaCl_2$ (B) $CaSO_4$ (C) $Ca(HCO_3)_2$ (D) $MgSO_4$

Q.10 Hydrolysis of one mole of peroxy disulphuric acid produces:

(A) Two moles of sulphuric acid

(B) Two moles of peroxymono sulphuric acid

(C) One mole of sulphuric acid and one mole of peroxy mono sulphuric acid

(D) One mole of sulphuric acid, one mole of peroxy monosulphuric acid and one mole of hydrogen peroxide.

Q.11 Which of the following is not a redox reaction

(A) $KCl + K_2Cr_2O_7 + con.H_2SO_4 \longrightarrow CrO_2Cl_2 + K_2SO_4 + H_2O$

(B) $K_2Cr_2O_7 + H_2O_2 + con.H_2SO_4 \longrightarrow K_2SO_4 + CrO_5 + H_2O$

(C) $K_2Cr_2O_7 + H_2O_2 + dil.\ H_2SO_4 \longrightarrow K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O + 3O_2$

(D) $K_2Cr_2O_7 + 2KOH \longrightarrow 2K_2CrO_4 + H_2O$

Q.12 A sample of water containing some dissolved table sugar and common salt is passed through organic ion exchange resins. The resulting water will be -

(A) Tasteless (B) Sweet (C) Salty (D) None of these

Q.13 Which of the following reaction does not take place

(A) $CuSO_4 + Zn \longrightarrow ZnSO_4 + Cu$

(B) $HgCl_2 + Fe \longrightarrow FeCl_2 + Hg$

(C) $NaH + H_2O \longrightarrow NaOH + H_2$

(D) $Na_2SO_3 + CO_2 \longrightarrow Na_2CO_3 + SO_2$

Q.14 If –O–H bond is weaker than –O–D bond,

(A) The biological growth of a plant which is fed by D_2O is fast

(B) The biological growth of a plant which is fed by H_2O is fast

(C) The biological growth of a plant which fed both by H_2O or D_2O are same

(D) Water does not have any role in plant growth.

Q.15 Water obtained by purification with organic ion Exchange resins is -

(A) Pure water

(B) Free from only Ca^{2+}, Mg^{2+} ions

(C) Free from HCO_3^-, SO_4^{2-} and Cl^- ions only

(D) None of these

Q.16 When two ice cubes are pressed over each other, they unite to form one cube. Which of the following forces is responsible to hold them together?

(A) Hydrogen bond formation

(B) Vander Waals' forces

(C) Covalent attraction

(D) Ionic interaction

Q.17 Which of the following can effectively remove all types of hardness of water

(A) Soap (B) Washing soda

(C) Slaked lime (D) None of these

Q.18 Fenton reagent is

(A) $FeSO_4 + H_2O_2$ (B) Zn + HCl

(C) Sn + HCl (D) None of the above

Q.19 Which of the following is used as rocket fuel?

(A) Liquid O_2 (B) Liquid N_2

(C) Liquid NH_3 (D) Liquid H_2

Q.20 Which of the following could act as propellant for rockets?

(A) Liquid oxygen + liquid argon

(B) Liquid nitrogen + liquid oxygen

(C) Liquid hydrogen + liquid oxygen

(D) Liquid hydrogen + liquid nitrogen

Q.21 Water is oxidised to oxygen by

(A) Ozone (B) $KMnO_4$

(C) H_2O_2 (D) F_2

Q.22 H_2O_2 on reaction with PbS gives

(A) PbO (B) $PbSO_4$

(C) PbO_2 (D) $PbHSO_4$

Q.23 Hydrogen burns in air with a

(A) Light bluish flame (B) Yellow flame

(C) Green flame (D) None of these

Q.24 What is the product of the reaction of H_2O with Cl_2

(A) O_2 + HOCl (B) HCl + O_2

(C) H_2O + HCl (D) HCl + H_2

Q.25 When electric current is passed through an ionic hydride in molten state

(A) Hydrogen is liberated at anode

(B) Hydrogen is liberated at cathode

(C) Hydride ion migrates towards cathode

(D) Hydride ion remains in solution

Q.26 Among CaH_2 NH_3, NaH and B_2H_6, which are covalent hydrides ?

(A) NH_3 and B_2H_6 (B) NaH and CaH_2

(C) NaH and NH_3 (D) CaH_2 and B_2H_2

Q.27 Hydrogen is not obtained when zinc reacts with

(A) Steam (B) Hot NaOH solution

(C) Conc. H_2SO_4 (D) Dilute HCl

Q.28 The hardness of water sample containing 0.002 mole of magnesium sulphate dissolved in a litre is expressed as

(A) 20 ppm (B) 200 ppm

(C) 2000 pM (D) 120 ppm

Q.29 The bond angle and dipole moment of water respectively are -

(A) 109.5°, 1.84D (B) 107.5°, 1.56D

(C) 104.5°, 1.84 D (D) 102.5°, 1.56 D

Q.30 Blackened oil painting can be restored into original form by the action of-

(A) Chlorine (B) BaO_2

(C) H_2O_2 (D) MnO_2

Q.31 Ortho and para hydrogen have

(A) identical chemical properties but different physical properties

(B) identical physical and chemical properties

(C) identical physical properties but different chemical properties

(D) different physical and chemical properties

Q.32 $CO + H_2 \xrightarrow[\text{X(catalyst)}]{300°C / 300\,atm} CH_3OH$

The catalyst X is-

(A) Fe (B) Cr_2O_3/ZnO

(C) V_2O_5 (D) Al_2O_3

Q.33 Which one of the following undergoes reduction with H_2O_2 in an alkaline medium ?

(A) Mn^{2+} (B) HOCl

(C) PbS (D) Fe^{2+}

Q.34 The reagent(s) used for softening the temporary hardness of water is/are

(A) $Ca_3(PO_4)_2$

(B) $Ca(OH)_2$

(C) Na_2CO_3

(D) NaOCl

Q.35 Polyphosphates are used as water softening agents because they:

(A) Form soluble complexes with anionic species

(B) Precipitate anionic species

(C) Form soluble complexes with cationic species

(D) Precipitate cationic species

Q.36 Pick out the correct statement-

(A) By decreasing the temperature pure parahydrogen can be obtained

(B) By increasing the temperature pure orthohydrogen can be obtained

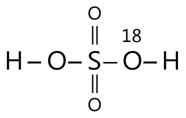
(C) By decreasing the temperature pure orthohydrogen can be obtained

(D) By increasing the temperature pure parahydrogen can be obtained

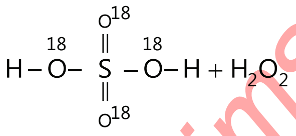
Q.37 $H_2SO_5 + H_2O^{18} \rightarrow$ product

(A) $H_2SO_4 + H\overset{18}{O}-O-H$

(B) $H_2SO_4 + H-\overset{18}{O}-\overset{18}{O}-H$

(C) 

$H-O-\underset{\underset{O}{\|}}{\overset{\overset{O}{\|}}{S}}-\overset{18}{O}-H$

(D) 

$H-\overset{18}{O}-\underset{\underset{O^{18}}{\|}}{\overset{\overset{O^{18}}{\|}}{S}}-\overset{18}{O}-H + H_2O_2$

Q.38 Which of the following statement is incorrect

(A) Germination of seeds in heavy water stops or slowdown

(B) The growth of plant slows down in heavy water

(C) Small fish die in heavy water

(D) In heavy water, NaCl solubility is more than normal water

Previous Years' Questions

Q.1 Polyphosphates are used as water softening agents because they ***(2002)***

(A) Form soluble complexes with anionic species

(B) Precipitate anionic species

(C) Forms soluble complexes with cationic species

(D) Precipitate cationic species

Q.2 One mole of calcium phosphide on reaction with excess water gives ***(1999)***

(A) One mole of phosphine

(B) Two moles of phosphoric acid

(C) Two moles of phosphine

(D) One mole of phosphorus pentoxide

Q.3 Hydrogen will not reduce ***(1985)***

(A) Heated cupric oxide

(B) Heated ferric oxide

(C) Heated stannic oxide

(D) Heated aluminium oxide

Q.4 HCl is added to following oxides. Which one would give H_2O_2 ***(1998)***

(A) MnO_2

(B) PbO_2

(C) BaO_2

(D) None of these

Q.5 Which of the following pair will not produce dihydrogen gas ***(1994)***

(A) Cu + HCl(dil.)

(B) Fe + H_2SO_4

(C) Mg + steam

(D) Na +alcohol

Q.6 The amount of H_2O_2 present in 1L of 1.5 N H_2O_2 solution is ***(1991)***

(A) 2.5 g

(B) 25.5 g

(C) 3.0 g

(D) 8.0 g

Q.7 Hydrogen is evolved by the action of cold dil. HNO_3 on ***(1998)***

(A) Fe (B) Mn (C) Cu (D) Al

Read the following questions and answer as per the direction given below:

(A) Assertion is true; reason is true; reason is the correct explanation of assertion.

(B) Assertion is true; reason is true; reason is not the correct explanation of assertion.

(C) Assertion is true; reason is false.

(D) Assertion is false; reason is true

Q.8 Assertion: Decomposition of H_2O_2 is a disproportionate reaction. ***(1999)***

Reason: H_2O_2 molecule simultaneously undergoes oxidation and reduction.

Q.9 Assertion: H_2O_2 has higher boiling point than water. ***(1997)***

Reason: H_2O_2 has stronger dipole-dipole interactions than water.

Q.10 In which of the following pairs of molecules / ions, both the species are not likely to exist? ***(2013)***

(A) H_2^+, He_2^{2-} (B) H_2^-, He_2^{2-} (C) H_2^{2+}, He_2 (D) H_2^-, He_2^{2+}

Q.11 In which of the following reactions H_2O_2 acts as a reducing agent? ***(2014)***

(a) $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$

(b) $H_2O_2 2e^- \rightarrow O_2 + 2H^+$

(c) $H_2O_2 + 2e^- \rightarrow 2OH^-$

(d) $H_2O_2 + 2OH^- - 2e^- \rightarrow O_2 + 2H_2O$

(A) (a), (c), (B) (b), (d)

(C) (a), (b) (D) (c), (d)

Q.12 From the following statements regarding H_2O_2 choose the **incorrect** statement : ***(2015)***

(A) It can act only as an oxidizing agent

(B) It decomposes on exposure to light

(C) It has to be stored in plastic or wax lined glass bottles in dark

(D) It has to be kept away from dust

JEE Advanced/Boards

Exercise 1

Q.1 What is understood by "Water gas shift reaction"? Discuss its use for the preparation of hydrogen.

Q.2 A solution of ferric chloride acidified with HCl is unaffected when hydrogen is bubbled through it, but gas gets reduced when zinc is added to acidified solution. Why?

Q.3 What is r_H value?

Q.4 Neutron diffraction data can usually give quite precise location of H-bonding but X-ray diffraction does not, why?

Q.5 Explain the H-bond formed between NH_3 and H_2O.

Q.6 Presence of water is avoided in the preparation of H_2O_2 from Na_2O_2.

Q.7 Write down disproportionation reaction in H_2O_2

Q.8 Calculate the hardness of water sample which contains 0.001 mole of $MgSO_4$ dissolved per litre of water.

Q.9 What mass of CaO will be required to remove the hardness of 1000 litres of water containing 1.62 g of calcium bicarbonate per litre?

Q.10 100 mL of tap water containing $Ca(HCO_3)$ was titrated with N/50 HCl with methyl orange as indicator. If 30 mL of HCl were required, calculate the temporary hardness as parts of $CaCO_3$ per 10^6 parts of water.

Q.11 When 1.823 g of the hydrogen $CaCrO_4.XH_2O$ was heated to 200°C, 1.479 of anhydrous $CaCrO_4$ was formed. What is the formula of hydrate?

Q.12 What happens when

(i) Chromium hydroxide is treated with hydrogen peroxide in the presence of sodium hydroxide. Write the chemical equation.

(ii) Concentrated caustic potash solution is spilled on granulated zinc. Write the chemical equation.

(iii) Hydrolith is treated with water. Write the chemical equation.

(iv) Heavy water reacts with aluminium carbide. Write the chemical equation.

Q.13 An aqueous solution of an unknown compound (X) gives the following reactions:

(i) It gives brown ppt. with alkaline $KMnO_4$ solution.

(ii) It forms HCl and evolves O_2 when reacts with Cl_2 gas.

(iii) It liberates I_2 form an acidified KI solution.

(iv) It gives orange yellow colour with acidified titanic sulphate solution.

Identify (X) and give the chemical equations for the reactions (i), (ii), (iii).

Q.14 (i) Convert 20 vol. H_2O_2 into % strength.

(ii) Convert 6.8 % strength H_2O_2 into volume strength.

Q.15 What is the volume strength of 1 molar solution of H_2O_2?

Q.16 Half litre each of three samples of H_2O_2 labelled 10 vol., 15 vol., 20 vol., are mixed and then diluted with equal volume of water. Calculate relative strength of resultant H_2O_2 solution.

Q.17 What mass (in mg) of available per litre is present in a solution of H_2O_2. 10 mL of which when treated requires 25 mL of N/20 $KMnO_4$ for complete oxidation of it.

Q.18 25 mL of hydrogen peroxide solution were added to excess of acidified potassium iodide solution. The iodine so liberated required 20 mL of 0.1 N sodium thiosulphate solution. Calculate strength in terms of normality, percentage and volume.

Q.19 Excess of KI and dil. H_2SO_4 were mixed in 50 mL H_2O_2. The I_2 liberated requires 20 mL of 0.1 N $Na_2S_2O_3$. Find out the strength of H_2O_2 in g/litre.

Q.20 20 mL of H_2O_2 after acidification with dilute H_2SO_4 required 30 mL of N/12 $KMnO_4$ for complete oxidation. Calculate the percentage of H_2O_2 in g/litre. Equivalent mass of H_2O_2 = 17.

Q.21 What happens when?

(i) An alkaline solution of potassium ferricyanide reacts with H_2O_2.

(ii) Hydrogen peroxide is added to acidified potassium permaganate

(iii) Hydrogen peroxide is added to ferrous ammonium sulphate solution.

Exercise 2

Single Correct Choice Type

Q.1 Nascent hydrogen consists of:

(A) Hydrogen atoms with excess energy

(B)Hydrogen molecules with excess energy

(C) Hydrogen ions in excited state

(D) Solvated protons

Q.2 30 volume hydrogen peroxide means:

(A) 30% H_2O_2 solution

(B) 30 cm^3 of the solution contains 1 g of H_2O_2

(C) 1 cm^3 of the solution liberates 30cm^3 of O_2 at STP

(D) 30 cm^3 of the solution contains 1 mole of H_2O_2

Q.3 The molarity of a 100 mL solution containing 5.1 g hydrogen peroxide is:

(A) 0.15M (B) 1.5 M (C) 3.0M (D) 50.0M

Q.4 Moist hydrogen cannot be dried over concentrated H_2SO_4 because:

(A) It can catch fire

(B) It is reduced by H_2SO_4

(C) It is oxidised by H_2SO_4

(D) It decomposes H_2SO_4

Q.5 An aqueous solution of hydrogen peroxide is:

(A) Alkaline (B) Neutral

(C) Strongly acidic (D) Weakly acidic

Q.6 The structure of H_2O_2

(A) In gas phase as well as in solid phase is same with the same dihedral angle

(B) In gas phase, is with dihedral angle of 111.5°

(C) Both (A) and (B)

(D) In solid phase, is with the dihedral angle of 180°

Q.7 Which is not reduced by H_2 in hot solution:

(A) Fe_2O_3 (B) CuO (C) K_2O (D) Ag_2O

Q.8 Hydrogen is evolved by the action of cold dilute HNO_3 on:

(A) Fe (B) Mg or Mn (C) Cu (D) Al

Q.9 H_2O_2 when added to a solution containing $KMnO_4$ and H_2SO_4 acts:

(A) As an oxidising agent

(B) As a reducing agent

(C) Both as an oxidising as well as a reducing agent

(D) $KMnO_4$ will not react with H_2O_2 in acidic in medium.

Q.10 Hydrogen can be produced by heating

(A) Cu with H_2SO_4 (B) Sodium formate

(C) Sodium oxalate (D) None of these

Q.11 Which of the following chemical reaction is not feasible?

(A) $PbO_2 + \text{dil. } H_2SO_4 \longrightarrow PbSO_4 + H_2O + O_2$

(B) $H_2SO_5 + H_2O_2 \longrightarrow H_2SO_4 + H_2O_2$

(C) $H_2O_2 + N_2H_4 \longrightarrow N_2 + H_2O$

(D) $Ti(SO_4)_2 + H_2O_2 + 2H_2O \longrightarrow H_2TiO_3 + H_2SO_4$

Q.12 The reaction involved during the removal of temporary hardness of water is:

(A) $2CaCl_2 + (NaPO_3)_6 \longrightarrow Na_2(Ca_2(PO_3)_6) + 4NaCl$

(B) $CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2NaCl$

(C) $MgSO_4 + Na_2Al_2Si_2O_8.xH_2O \longrightarrow MgAl_2Si_2O_7.xH_2O + Na_2SO_4$

(D) $Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 + H_2O + CO_2\uparrow$

Q.13 Plumbosolvency is a health hazard in the transportation of

(A) Hard water only

(B) Soft water only

(C) Both (A) and (B)

(D) Water containing plum juice

Q.14 In the laboratory, H_2O_2 is prepared by the action of

(A) Cold dilute H_2SO_4 on hydrated BaO_2

(B) Dil. HCl on MnO_2

(C) Cold H_2SO_4 on MnO_2

(D) Aqueous alkali on Na_2O_2

Q.15 When 50% solution of H_2SO_4 is electrolysed by passing a current of high density at low temperature the main products of electrolysis are

(A) Oxygen and hydrogen

(B) H_2 and peroxy disulphuric acid

(C) H_2 and SO_2

(D) O_2 and peroxy disulphuric acid

Multiple Correct Choice Type

Q.16 Which of the following will give hydrogen peroxide on hydrolysis

(A) $H_2S_2O_8$ (B) H_2SO_5 (C) H_3PO_5 (D) $HClO_4$

Q.17 When zeolite, which is hydrated sodium aluminium silicate, is treated with hard water the sodium ions are exchanged with

(A) H^+ ion (B) Ca^{++} ions

(C) SO_4^- ions (D) Mg^{++}ions

Q.18 Hydrogen can be obtained from water, by the action of water on-

(A) Calcium carbide (B) Calcium hydride

(C) Calcium oxide (D) Calcium

Q.19 What is true about ice

(A) Its density is more than water

(B) It is a good conductor of heat

(C) It is a thermal insulator

(D) Its density is less than water

Q.20 Hydrogen is obtained when zinc reacts with

(A) Cold water
(B) Hot NaOH solution
(C) Conc, sulphuric acid
(D) Dilute HCl

Assertion Reasoning Type

(A) Statement-I is true, statement-II is true and statement-II is correct explanation for statement-I.

(B) Statement-I is true, statement-II is true and statement-II is NOT the correct explanation for statement-I.

(C) Statement-I is true, statement-II is false.

(D) Statement-I is false, statement-II is true

Q.21 Statement-I: ZrH_2 is a non- stoichiometric hydride.

Statement-II: The composition of ZrH_2 is exact same as its chemical formula.

Q.22 Statement-I: D_2 molecules are more stable than H_2.

Statement-II: The bond dissociation energy of D_2 is more than of H_2.

Q.23 Statement-I: Acetanilide acts as a negative catalyst for the decomposition of H_2O_2.

Statement-II: In the presence of acetanilide, the stability of H_2O_2 increases

Q.24 Statement-I: Polarity of H_2O_2, is more than H_2O but H_2O is a better solvent.

Statement-II: In chemical reactions, H_2O_2 is decomposed but H_2O does not.

Q.25 Statement-I: When blood is added to a solution of H_2O_2, the solution bubbles furiously

Statement-II: Catalase (an enzyme) present in blood decomposes H_2O_2 and produces bubbles of O_2.

Q.26 Statement-I: Pure zinc reacts slowly with sulphuric acid to produce hydrogen.

Statement-II: Hydrogen produced initially forms an extremely thin layer on zinc surface which prevents its dissolution in sulphuric acid.

Comprehension Type

Paragraph 1: Hydrogen peroxide is a powerful oxidizing agent. It is an electron acceptor in acidic and alkaline mediums.

$$H_2O_2 + 2H^+ + 2e^- \longrightarrow 2H_2O$$

(in acidic medium)

$$H_2O_2 + 2e^- \longrightarrow 2OH^- \text{ (in alkaline medium)}$$

It can also act as a reducing agent towards powerful oxidizing agents.

$$H_2O_2 \longrightarrow 2H^+ + O_2 + 2e^-$$

In alkaline medium, however, its reducing nature is more effective.

$$H_2O_2 + 2OH^- \longrightarrow 2H_2O + O_2 + 2e^-$$

Q.27 In which of the following reaction, H_2O_2 acts as a reducing agent.

(A) $PbO_2 + H_2O_2 \longrightarrow PbO + H_2O + O_2$

(B) $Na_2Sb_3 + H_2O_2 \longrightarrow Na_2SO_4 + H_2O$

(C) $2KI + H_2O_2 \longrightarrow 2KOH + I_2$

(D) $KNO_2 + H_2O_2 \longrightarrow KNO_3 + H_2O$

Q.28 What is the product of the reaction of H_2O_2 with Cl_2?

(A) O_2 + HOCl
(B) HCl + O_2
(C) H_2O + HCl
(D) HCl + H_2

Paragraph 2: Be and Mg, some amongst the p-block elements and most of the d-block elements give metallic or interstitial hydrides on reacting with hydrogen. The density of each compound is less than that of the metal itself and the properties are not much different from that of the metal. They give out hydrogen easily and are strong reducing agents. This suggests that hydrogen is present in the atomic state. These compounds are non-stoichiometric. The f-block elements (i.e., lanthanide and actinides) also form non-stoichiometric hydrides. These hydrides have lower densities than their respective metals. The metals of group 7, 8 and 9 do not form hydrides. This region of the periodic table is called 'hydride gap'.

Q.29 Which type of hydride is formed by the clement having atomic number, Z = 43 ?

(A) Metallic hydride
(B) Saline hydride
(C) Covalent hydride
(D) No hydride

Q.30 Which of the following has highest electrical conductance?

(A) BeH_2 (B) MgH_2 (C) CaH_2 (D) ZrH_2

Q.31 Interstitial hydride can not be used as,

(A) Storage of H_2

(B) Catalysts for hydrogenation reaction

(C) Rocket propellant

(D) Electric conductor

Paragraph 3: Hydrogen peroxide can be prepared in the laboratory by the action of dilute acids on metallic peroxide. In one method, sodium peroxide is added in small amount at a time to a dilute solution of sulphuric acid in cold. Sodium peroxide can be replaced by barium peroxide. In this case, a paste of $BaO_2.8H_2O$ is prepared and added gradually to an ice-cold dilute sulphuric acid. Barium sulphate precipitates out leaving behind a dilute solution of hydrogen peroxide. Phosphoric acid can also be used in place of sulphuric acid.

Q.32 The oxide that gives hydrogen peroxide on treatment with a dilute acid is:

(A) PbO_2 (B) SrO_2 (C) MnO_2 (D)TiO_2

Q.33 The correct increasing order of the acidity of CO_2, H_2O and H_2O_2 is

(A) $CO_2 < H_2O_2 < H_2O$ (B) $H_2O < H_2O_2 < CO_2$

(C) $H_2O < H_2O_2 > CO_2$ (D) $H_2O_2 > CO_2 > H_2O$

Q.34 Which of the following is used for the preparation of H_2O_2?

(A) Anhydrous BaO_2 (B) Anhydrous Na_2O_2

(C) TiO_2 (D) PbO_2

Paragraph 4: Hydrogen peroxide has an ability to function as an oxidant as well as reductant in both acid and alkaline solutions. Hydrogen peroxide provides an atom of oxygen (Nascent oxygen) readily for oxidation and takes up an atom of oxygen to give water and oxygen gas. The strength of commercially available H_2O_2 sample is described as volume strength. 30 volumes of H_2O_2 means 30 cm1 O_2 is obtained at STP by decomposing 1 cm^3 of H_2O_2 solution. Dark paraffin bottles are used for storage of H_2O_2 as it is decomposed in light and catalysts

Q.35 The normality of 30 volume H_2O_2 solution is

(A) 5.3 N (B) 11.2 N (C) 2 N (D)1 N

Q.36 $xK_2Cr_2O_7 + y\ H_2SO_4 + z\ H_2O_2 \longrightarrow K_2SO_4 + Cr_2(SO_4)_3 + w\ H_2O + jO_2$, x, y, z are

(A) 4,1,3 (B) 2,4,8 (C) 1,8,2 (D)1,4,3

Q.37 $H_2O_2 + Na_3AsO_3 \longrightarrow X + Y$. X and Y respectively are

(A) $Na_3AsO_4+H_2O$ (B) $As_2O_3 + H_2O$

(C) $As(OH)_3 + H_2$ (D) $As(OH)_5 + H_2$

Q.38 For the decomposition of H_2O_2 in H_2O and O_2, ΔG is

(A) +ve (B)-ve (C) Zero (D) Either +ve or zero

Paragraph 5: Ordinary water is an oxide of common isotope of hydrogen called Protium while heavy water is oxide of heavier isotope of hydrogen called Deuterium. It is represented as D_2O and as molecular weight of D_2O is more than H_2O, there are slightly stronger Vander der Waals forces between D_2O molecules. Like ordinary water, heavy water is a colorless, odorless and tasteless mobile liquid.

Q.39 Heavy water is used in atomic reactor as

(A) Coolant

(B) Moderator

(C) Both moderator and coolant

(D) Neither coolant nor moderator.

Q.40 Heavy water freezes at

(A) 0° C (B) 3.8° C (C) 38°C (D) -0.38°C

Q.41 The pH of D_2 O andH_2O at 298 K is

(A) 7.0,7.0 (B) 7.35,7.0

(C) 7.0,6.85 (D) 6.85, 7.35

Q.42 Which of the following is not true?

(A) Ordinary water is electrolysed more rapidly than D_2 O

(B) Reaction between H_2 and Cl_2 is much faster than D_2 and Cl_2

(C) D_2O freezes at lower temperature than H_2O

(D) Bond dissociation energy for D_2 is greater than H_2.

Match the Columns

Q.43

Column I (For the production of H_2O_2)	Column II
(A) $BaO_2.8H_2O$	(p) Reduction and oxidation
(B) Na_2O_2	(q) reacts with NaOH
(C) H_2SO_4	(r) electrolysis then hydrolysis
(D) Ethyl derivative of anthraquinone	(s) Reacts with H_2SO_4

Q.44

Column –I (Compound)	Column – II (Properties)
(A) Perhydrol	(p) Dilute solution of H_2O_2
(B) Water gas	(q) Manufacture of H_2
(C) Bosch's process	(r) CO+ H_2
(D) CH_4 + H_2O	(s) Antiseptic and germicide

Q.45

Column –I (Compound)	Column - II (Properties)
(A) $LiAlH_4$	(p) Binary hydride
(B) $NaBH_4$	(q) Reducing agent
(C) CaH_2	(r) Complex hydride
(D) LiH	(s) Alanate

Q.46 Match the List I with List II and select the correct answer using the codes given below in the lists:

List I	List II
(A) Heavy water	(p) Bicarbonates of Mg and Ca in water
(B) Temporary hard water	(q) No foreign ions in water
(C) Soft water	(r) D_2O
(D) Permanent hard water	(s) Sulphates and chlorides of Mg and Ca in water

Previous Years' Questions

Q.1 A sample of water contains sodium chloride. It is ***(1986)***

(A) Hard water (B) Soft water

(C) Moderately hard (D) None of these

Q.2 Pick out the correct statement ***(2008)***

(A) By decreasing the temperature pure para-hydrogen can be obtained

(B) By increasing the temperature pure ortho-hydrogen can be obtained

(C) By decreasing the temperature pure ortho-hydrogen can be obtained

(D) By increasing the temperature pure para-hydrogen can be obtained

Q.3 Hydrogen can be produced by heating ***(1992)***

(a) Cu with H_2SO_4 (B) Sodium formate

(C) Sodium oxalate (D) None of these

Q.4 Plumbosolvancy is a health hazard in the transportation of ***(1994)***

(A) Hard water only (B) Soft water only

(C) Both (a) and (B) (D) Water containing plum juice

Q.5 The critical temperature of water is higher than that of O_2 because the H_2O molecule has ***(1997)***

(A) Fewer electrons than O_2 (B) Two covalent bonds

(C) V-shape (D) Dipole moment

Q.6 When zeolite, which is hydrated sodium aluminium silicate, is treated with hard water, the sodium ions are exchanged with ***(1990)***

(A) H^+ ions (B) Ca^{2+} ions

(C) SO_4^{2-} ions (D) Mg^{2+}ions (E) OH^- ions

Q.7 The reagent (s) used for softening the temporary hardness of water is (are) ***(2010)***

(A) $Ca_3(PO_4)_2$ (B) $Ca(OH)_2$ (C) Na_2CO_3 (D) NaOCl

Q.8 $H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$; E° = -0.68 V. This equation represents which of the following behaviour of H_2O_2 ***(1995)***

(A) Reducing (B) Oxidising

(C) Acidic (D) Catalytic

Q.9 The structure of H_2O_2 is ***(1999)***

(A) Open book like (B) Linear

(C) Closed book (D) Pyramidal

Q.10 On shaking H_2O_2 with acidified potassium dichromate and ether, ethereal layer becomes ***(1998)***

(A) Green (B) Red (C) Blue (D) Black

Q.11 Hydrogen peroxide in its reaction with KIO_4 and NH_2OH respectively, is acting as a ***(2014)***

(A) Reducing agent, oxidising agent

(B) Reducing agent, reducing agent

(C) Oxidising agent, oxidising agent

(D) Oxidising agent, reducing agent

JEE Main/Boards

s-block Elements

Exercise 1

Q.1 Why Alkali and alkaline earth metals, cannot be obtained by chemical reduction methods?

Q.2 Why sodium cannot be prepared by the electrolysis of aqueous solution of sodium chloride using platinum cathode?

Q.3 Which of the two, sodium or potassium has higher melting point?

Q.4 Complete the following equations for the reaction between,

(A) $Ca + H_2O$ (B) $Ca(OH)_2 + Cl_2$

(C) $BeO + 2NaOH$ (D) $BaO_2 + H_2SO_4$

Q.5 Differentiate between (a) quick lime (b) lime water (c) Slaked lime

Q.6 Arrange the following in the order or increasing covalent character; MCl, MBr MF & MI, where M is alkali metal.

Q.7 Ionization enthalpies of alkali metals decrease as the atomic number increases.

Q.8 State as to why:

(i) Lithium on being heated in air mainly forms monoxide and not peroxide.

(ii) An aqueous solution carbonate is alkaline in nature.

(iii) Sodium is prepared by electrolytic reduction method and not by chemical reduction method.

Q.9 How would you explain LiI is more soluble than KI?

Q.10 Identity the following

$$Na_2CO_3 \xrightarrow{SO_2} A \xrightarrow{Na_2CO_3} B \xrightarrow[\Delta]{\text{Elemental S}}$$

$$C \xrightarrow{I_2} D$$

Also mention the oxidation state of S in all the compounds.

Q.11 Why is sodium metal kept under kerosene oil?

Q.12 What is the formula of gypsum? What happens when it is heated?

Q.13 What is dead burnt plaster? What is formula of plaster of paris?

Q.14 Why super oxide of alkali metals are para magnetic while normal oxides are diamagnetic?

Q.15 It is necessary to add gypsum in the final stages of preparation of cement Explain why?

Q.16 Why are potassium and caesium, rather than lithium used in photoelectric cells?

Q.17 Explain the following:

(i) Alkali metals are not in free form in nature

(ii) Alkali metals are good reducing agents.

Q.18 Explain the following:

(i) The softness of group IA metals increases down the group with increasing atomic number.

(ii) Lithium salts have a greater degree of covalent character than other halides of the group.

Q.19 Explain the following:

(A) Alkali metals are obtained by the electrolysis of the molten salts and not by the electrolysis of their aqueous solutions.

(B) Calcium chloride is added to NaCl in the electrolytic manufacture of sodium.

(C) On exposure to air, sodium hydroxide becomes liquid and after sometimes it changes to white powder.

(D) Sodium Carbonate is made by Solvay process but the same process is not extended to the manufacture of potassium carbonate,

(E) An aqueous solution of iodine becomes colorless on adding excess of sodium hydroxide

Q.20 Complete and balance the following equations

(A) $KO_2 + H_2O \rightarrow$ .... + O_2

(B) $PbO_2 + NaOH \xrightarrow{Heat}$ ....+ H_2O (conc.)

(C) $KI + H_2SO_4 + H_2O_2 \rightarrow I_2$ +.....+ H_2O

(D) $NaOH + I_2 \rightarrow$ ...... + $NaIO_3 + H_2O$

Q.21 Answer the following:

(i) What is meant by black ash?

(ii) What is the action of NaOH on ammonium salts?

(iii) What is washing soda?

Q.22 What happens when?

(i) Hot and concentrated caustic soda solution reacts with iodine.

(ii) White phosphorus is heated with caustic soda.

(iii) Excess of caustic soda reacts with zinc sulphate solution

(iv) Excess of NaOH is added to $AlCl_3$ solution

(v) Anhydrous potassium nitrate is heated with excess of metallic potassium

(vi) Sodium is strongly heated in oxygen and the product is treated with H_2SO_4

Q.23 Write the balanced equations of the reactions of Caustic soda on the following

(i) Zinc, (ii) Silver nitrate, (iii) Phosphorus

Q.24 Give one test each to make distinction between the folio wing pairs:

(i) NH_4Cl and KCl (ii) Na_2SO_3 and Na_2SO_4

(iii) NaCl and KCl

Q.25 Arrange the following as indicated:

(A) LiOH, NaOH, KOH (Increasing solubility in water)

(B) $LiHCO_3$, $NaHCO_3$, $KHCO_3$ (Increasing solubility in water)

(C) Li_2CO_3, Na_2CO_3, K_2CO_3 (Increasing solubility in water)

(D) Li^+, Na^+, K^+, Rb^+, Cs^+ (Increasing size of hydrated ion)

Q.26 What happen when the following are heated?

(A) Hydrated magnesium chloride,

(B) Gypsum,

(C) Bicarbonates of alkaline earth metals,

(D) Epsom salt, (v) Barium nitrate.

Q.27 How would you explain?

(i) BeO is insoluble but $BeSO_4$ is soluble water.

(ii) BaO is soluble but $BaSO_4$ is insoluble water.

Q.28 Explain the following:

(i) Alkali metals salts impart color to the flame.

(ii) Sodium is kept under kerosene

(iii) Potassium and caesium are used photoelectric cells.

Q.29 Explain the following:

(i) Li^+ ion is far smaller than the other alkali metal ions but it moves through a solution less rapidly than the others.

(ii) Lithium fluoride has the lowest solubility of the group IA metal halides.

(iii) Salts of lithium having small anions are more stable than the salts having larger anions.

Q.30 Answer the following:

(A) What is the intermediate product in Solvay's process?

(B) Which chloride of an alkali metal is soluble in alcohol?

(C) Which substance is added to sodium chloride as to reduce its fusion temperature during manufacture of sodium?

(D) What product is formed when carbon monoxide is passed through sodium hydroxide under high pressure?

Exercise 2

Single Correct Choice Type

Q.1 $NaNO_3$ on heating gives

(A) O_2 (B) O_2 and NO_2 (C) NO_2 (D) N_2O and O_2

Q.2 Sodium metal is prepared commercially by electrolysis of fused NaCl by

(A) Down's process (B) Nelson cell

(C) Solvay process (D) Castner and Kellner's cell

Q.3 When hydrated magnesium chloride is heated

(A) MgO is formed

(B) $Mg(OH)_2$ is formed

(C) Mg (OH) Cl is formed

(D) Anhydrous $MgCl_2$ is formed

Q.4 Magnesium bums in air to give

(A) MgO (B) Mg_3N_2 (C) $MgCO_3$ (D) Both (A) and (B)

Q.5 Which of the following is a Magnesite ore?

(A) $CaCO_3 . MgCO_3$ (B) $MgSO_4 . 7H_2O$

(C) KCl. $MgCl_2 . 6H_2O$ (D) $MgCO_3$

Q.6 On mixing with an adequate quantity of water, Plaster of Paris sets into a hard solid having the composition

(A) $CaSO_4.2H_2O$ (B) $CaSO_4.H_2O$

(C) $CaSO_4.Ca(OH)_2$ (D) $(CaSO_4)_2.H_2O$

Q.7 Which of the following are arranged in correct increasing order of solubility?

(A) $CaCO_3 < KHCO_3 < NaHCO_3$

(B) $NaHCO_3 < KHCO_3 < CaCO_3$

(C) $KHCO_3 < NaHCO_3 < CaCO_3$

(D) $CaCO_3 < NaHCO_3 < KHCO_3$

Q.8 Nitrolim is

(A) $CaCN_2 + C$ (B) $Ca(CN)_2 + C$

(C) $CaC_2 + C$ (D) All of these

Q.9 Sodium sulphate is soluble in water but barium sulphate is sparingly soluble because

(A) The hydration energy of Na_2SO_4 is more than its lattice energy while the lattice energy of $BaSO_4$ is more than its hydration energy

(B) The lattice energy has no role to play in solubility

(C) The lattice energy of Na_2SO_4 is more than its hydration energy

(D) None of these

Q.10 The following are some of the methods commonly employed for the extraction of metals from their ores. Which of the following methods is generally employed for the extraction of sodium?

(A) Reduction of an oxide with coke

(B) Electrolysis of an aqueous solution of a chloride

(C) Electrolysis of a molten chloride

(D) Reduction of a chloride with more reactive Metal

Q.11 Anhydrone is the name given to

(A) $Mg(OH)_2. 6H_2O$ (B) $MgSO_4.7H_2O$

(C) Mg (OH). $7H_2O$ (D) $Mg(ClO_4)_2$

Q.12 The smallest alkali metal cation is

(A) Li^+ (B) Na^+ (C) K^+ (D) Fr^+

Q.13 Considering greater polarization in LiCl compared to that in NaCl, which of the following statements you would expect to be wrong?

(A) LiCl has lower melting point that NaCl

(B) LiCl dissolves more in organic solvents

(C) LiCl will ionize in water more than NaCl

(D) Fused LiCl would be less conducting than fused NaCl

Q.14 Amongst the alkali metals, lithium is the strongest reducing agent in the aqueous solution. This is because within the group, it has the highest

(A) Ionization energy (B) Electrode potential

(C) Hydration energy (D) Electronegativity

Q.15 A solid is a compound of group 1 element and it gives a bright red color in the flame test.

The solid is

(A) NaCl (B) KCl (C) LiBr (D) CsCl

Q.16 Alkali metals readily dissolve in liquid ammonia to give blue colored solutions. The blue color is believed to be due to

(A) Ammoniated cations

(B) Ammoniated anions

(C) Ammoniated electrons

(D) Ammoniated cations and ammoniated electrons

Q.17 Which of the following compounds possesses the largest lattice energy?

(A) LiF (B) NaCl (C) KH (D) CsI

Q.18 On heating sodium metal in a current of dry ammonia, the compound formed is

(A) Sodium nitride (B) Sodium hydride

(C) Sodium amide (D) Sodium azide

Q.19 The pair of compounds which cannot exist together in solution is

(A) $NaHCO_3$ and NaOH (B) $NaHCO_3$ and H_2O

(C) $NaHCO_3$ and Na_2CO_3 (D) Na_2CO_3 and NaOH

Q.20 Among alkali metal salts, the lithium salts are the poorest conductors of electricity in aqueous solution because of

(A) Easy diffusion of Li^+ ions

(B) Lower ability of Li^+ ions to polarize water molecules

(C) Lowest charge to radius ratio

(D) Higher degree of hydration of Li^+ ions

Q.21 The order of decreasing polarity in the compounds CaO, CsF, KCl, and MgO is

(A) CaO, CsF, KCl, MgO (B) MgO, KCl, CaO, CsF

(C) KCl, CaO, CsF, MgO (D) CsF, KCl, CaO, MgO

Q.22 One of the following statements is incorrect.

(A) Elements of group 2 are good conductors of electricity and heat

(B) Compounds of group 2 elements are diamagnetic in nature

(C) The salts of group 2 elements are highly hydrated than those of elements of group 1

(D) Elements of group 2 are more electropositive than group 1 elements.

Q.23 Alkaline earth metals form dipositive ions instead of unipositive ions because

(A) Dipositive ions carry more charge

(B) Their second ionization energies are not different from first ionization energy

(C) Unipositive ions do not have stable configuration

(D) Compounds containing dipositive ions have more lattice energy

Q.24 Which element possesses maximum electropositive character?

(A) Mg (B) Be (C) P (D) Al

Q.25 BeF_2 is highly soluble in water whereas the fluorides of other alkaline earth metals are almost insoluble because

(A) BeF_2 is ionic in nature

(B) BeF_2 is covalent in nature

(C) Hydration energy of BeF_2 is much higher than its lattice energy

(D) Lattice energy of BeF_2 is much higher than that of its hydration energy.

Q.26 Both Be and Al become passive on treatment with cone. HNO_3 due to

(A) Non-reacting nature of the metals

(B) Non-oxidizing nature of the acid

(C) The formation of an inert layer of the oxide on the surface of the metals

(D) All are correct

Q.27 The value of x is maximum for

(A) $MgSO_4 . xH_2O$ (B) $CaSO_4 . xH_2O$

(C) $BaSO_4 . xH_2O$ (D) All have the same value of x

Q.28 The name 'Blue John' is given to which of the following compounds

(A) CaH_2 (B) CaF_2 (C) $Ca_3 (PO_4)_2$ (D) CaO

Q.29 Amongst LiCl, RbCl, $BeCl_2$ and $MgCl_2$ the compounds with greatest and the least ionic character, respectively, are

(A) LiCl and RbCl (B) RbCl and $BeCl_2$

(C) RbCl and $MgCl_2$ (D) $MgCl_2$ and $BeCl_2$

Q.30 Among the following: NaOH, Ca $(OH)_2$

KOH and Zn $(OH)_2$, the weakest base is

(A) NaOH (B) Ca $(OH)_2$

(C) KOH (D) Zn $(OH)_2$

Q.31 The decreasing order of the second ionization potential of K, Ca and Ba

(A) K > Ca > Ba (B) Ca > Ba > K

(C) Ba>K>Ca (D) K>Ba>Ca

Previous Years' Questions

Q.1 Aqueous solution of $Na_2S_2O_3$ on reaction with Cl_2 gives: ***(2008)***

(A) $Na_2S_4O_6$ (B) $NaHSO_4$ (C) NaCl (D) NaOH

Q.2 Which of the following chemicals, in addition to water, are used in the manufacture of Na_2CO_3 by Solvay process: ***(1999)***

(A) NaCl, CO and NH_3 (B) NaCl, CO_2 and NH_3

(C) NaCl, NH_4Cl and CO_2 (D) $NaHCO_3$, CO and NH_3

Q.3 When KI is added to acidified solution of sodium nitrite: ***(2008)***

(A) NO gas is liberated & I_2 is set free

(B) N_2 gas is liberated & HI is produced

(C) N_2O gas is liberated & I_2 is set free

(D) N_2 gas is liberated & HOI is produced

Q.4 The metallic lustre exhibited by sodium is explained by: ***(1987)***

(A) Diffusion of sodium ions

(B) Oscillation of loose electrons

(C) Excitation of free protons

(D) Existence of body centered cubic lattice

Q.5 Which of the following pair can't exist in solution: ***(1999)***

(A) $NaHCO_3$ and NaOH (B) Na_2CO_3 and NaOH

(C) Na_2CO_3 and NaCl (D) $NaHCO_3$ and NaCl

Q.6 Sodium thiosulphate is prepared by: ***(1996)***

(A) Reducing Na_2SO_4 solution with H_2S

(B) Boiling Na_2SO_3 solution with S in alkaline medium

(C) Neutralizing $H_2S_2O_3$ solution with NaOH

(D) Boiling Na_2SO_3 solution with S in acidic medium

Read the following questions and answer as per the direction given below:

(A) Assertion is true; reason is true; reason is the correct explanation of assertion.

(B) Assertion is true; reason is true; reason is not the correct explanation of assertion.

(C) Assertion is true; reason is false.

(D) Assertion is false; reason is true.

Q.7 Assertion: Radium is most abundant s-block element. ***(1997)***

Reason: s-block elements are non-radioactive in nature.

Q.8 Assertion: LiCl is predominantly a covalent compound. ***(1998)***

Reason: Electronegativity difference between Li and Cl is too small.

Q.9 Assertion: The first ionization energy of Be is greater than that of B. ***(2001)***

Reason: 2p-orbital is lower in energy than 2s orbital.

Q.10 Assertion: The alkali metals can form ionic hydrides which contains the hydride ion. ***(1994)***

Reason: The alkali metals have low electronegativity, their hydrides conduct electricity when fused and liberate hydrogen at the anode.

Q.11 Assertion: Be does not impart any characteristic color to the Bunsen flame. ***(1990)***

Reason: Due to its very high ionization energy, beryllium requires a large amount of energy for excitation of the electrons.

Q.12 The coagulating power of electrolytes having ions Na^+, Al^{3+} and Ba^{2+} for arsenic sulphide sol increases in the order: ***(2013)***

(A) $Al^{3+} < Ba^{2+} < Na^+$ (B) $Na^+ < Ba^{2+} < Al^{3+}$

(C) $Ba^{2+} < Na^+ < Al^{3+}$ (D) $Al^{3+} < Na^+ < Ba^{2+}$

Q.13 Which one of the following alkaline earth metal sulphates has its hydration enthalpy greater than its lattice enthalpy? ***(2015)***

(A) $CaSO_4$ (B) $BeSO_4$ (C) $BaSO_4$ (D) $SrSO_4$

JEE Advanced/Boards

Exercise 1

Q.1 For the alkali metals, which of the following increases with increasing atomic number?

(A) First ionization energy

(B) Electronegativity

(C) Hydration energy of the univalent ion

(D) Atomic radius

Q.2 Which of the following statement about the sulphate of alkali metal is correct?

(A) Except Li_2SO_4 all sulphate of other alkali metals are soluble in water

(B)All sulphate salts of alkali metals except lithium sulphate forms alum.

(C) All sulphate salts of alkali metals except lithium sulphate do not decompose at high temperature

(D) All of these

Q.3 Which metal bicarbonates does not exist in solid state?

(i) $LiHCO_3$ (ii) $Ca(HCO_3)_2$ (iii) $Zn(HCO_3)_2$ (iv) $AgHCO_3$

(A) i, ii, iii, iv (B) i, ii, iii (C) i, ii, iv (D) ii, iii, iv

Q.4 When a standard solution of NaOH is left in air for a few hours:

(A) A precipitate will form

(B) Strength of solution will decrease

(C) The strength of solution will increase

(D) The concentration of Na^+ ion in solution will remains same

Q.5 $CaCl_2$ is preferred over NaCl for clearing ice on roads particularly in very cold countries. This is because:

(A) $CaCl_2$ is less soluble in H_2O than NaCl

(B) $CaCl_2$ is hygroscopic but NaCl is not

(C) Eutectic mixture of $CaCl_2/H_2O$ freezes at –55°C while that of $NaCl/H_2O$ freezes at –18°C

(D) NaCl makes the road slippery but $CaCl_2$ does not

Q.6 Calcium imide on hydrolysis gives gas (B) which on oxidation by bleaching powder gives gas (C) Gas (C) on reaction with magnesium give compound (D) which on hydrolysis gives again gas (B). Identify (B), (C) and (D).

(A) NH_3, N_2, Mg_3N_2 (B) N_2, NH_3, MgNH

(C) N_2, N_2O_5, $Mg(NO_3)_2$ (D) NH_3, NO_2, $Mg(NO_2)_2$

Q.7 Which of the following statement is false?

(A) The milk of magnesia used as antacid is chemically MgO + $MgCl_2$

(B) Stability of alkali metal peroxides increases with increase in atomic number

(C) Hydration energy of AgF is higher than its lattice energy

(D) Anhydrous $MgCl_2$ cannot be prepared by direct heating of $MgCl_2.6H_2O$

Q.8 Nitrogen dioxide cannot be obtained from:

(A) $Cu(NO_3)_2$ (B) $Hg(NO_3)_2$ (C) $NaNO_3$ (D) $AgNO_3$

Q.9 On treatment with cold water, an element (A) reacts readily liberating a colorless, odorless gas (B) and a solution (C). Lithium is reacted with (B) yielding a solid product (D) which effervesce with water to give a strongly basic solution (E). When CO_2 gas is bubbled through solution (C), a white ppt. (F) is formed but this redissolved forming solution (G) when more CO_2 is passed. Precipitate (F) effervesced when moistened with conc. HCl and give deep red coloration to a Bunsen burner flame, (F) on heating with excess of carbon at 2000°C give Answer the following questions on the basis of above passage. Metal (A) may be:

(A) Be (B) Ca (C) Sr (D) Ba

Q.10 solution (G) contains a salt which:

(i) Causes permanent hardness of water

(ii) Cannot be obtained in solid state

(iii) Causes temporary hardness of water

(iv) Can be obtained in solid state

Select the correct statements:

(A) (i) and (ii) (B) (i) and (iv)

(C) (ii) and (iii) (D) (ii) and (iv)

Q.11 Solid (H) on hydrolysis gives a gas, which on passing through ammonical $AgNO_3$ solution, yields:

(A) White ppt. (B) Red ppt.

(C) No ppt. (D) Brown ppt.

Q.12 Lithium only forms monoxide when heated in oxygen. Sodium forms monoxide and peroxide in excess of oxygen. Other alkali metals form superoxide with; oxygen, i.e. MO_2. The abnormal behavior of lithium is due to small size. The larger size of higher alkali metals also decides the role in formation of superoxides. All the three anions abstract proton from water. The three anions are related to each other as follows:

$$O^{2-} \xrightarrow{\frac{1}{2}O_2} O_2^{2-} \xrightarrow{O_2} 2O_2^-$$

Oxide ion peroxide ion superoxide ion

Consider the following reaction:

$M + O_2 \rightarrow MO_2$

(M = alkali metal) (Stable superoxide)

(A) M cannot be Li and Na

(B) M cannot be Cs and Rb

(C) M cannot be Li and Rb

(D) None of these

Q.13 Which anion is stable towards water?

(A) O^{2-} (B) O_2^{2-} (C) O_2^- (D) None of these

Q.14 Which compound will liberate oxygen when reacts with water?

(A) Na_2O_2 (B) KO_2 (C) Na_2O (D) Cs_2O_2

Q.15 Choose the correct statement(s):

(A) $BeCO_3$ is kept in the atmosphere of CO_2 since, it is least thermally stable

(B) Be dissolves in an alkali solution forming $[Be(OH)_4]^{2-}$

(C) BeF_2 forms complex ion with NaF in which Be goes with cation

(D) BeF_2 forms complex ion with NaF in which B goes with anion

Exercise 2

Single Correct Choice Type

Q.1 When an aqueous solution of sodium chloride is electrolyzed using platinum electrodes, the ions discharged at the electrodes are:

(A) Sodium and hydrogen

(B) Sodium and chloride

(C) Hydrogen and chloride

(D) Hydroxyl and chloride

Q.2 In the Caster-Kellner cell used for the manufacture of NaOH, the cathode in the central compartment is made up of

(A) Carbon (B) Iron (C) Mercury (D) Nickel

Q.3 In the manufacture of NaOH by electrolysis of an aqueous solution of sodium chloride, the cathode and anode are separated by using a diaphragm or slate partitions because

(A) It increases the yield of Cl_2

(B) It prevents the reaction taking place between NaOH and Cl_2

(C) It prevents the mixing of NaOH and NaCl

(D) It prevents the reaction taking place between Na and Cl_2

Q.4 A compound X on heating gives a colorless gas. The residue is dissolved in water to obtain Y. Excess CO_2 is passed through aqueous solution of Y when Z is formed. Z on gentle heating gives back X. The compound X is:

(A) $NaHCO_3$ (C) $Ca(HCO_3)_2$ (B) Na_2CO_3 (D) $CaCO_3$

Q.5 Potassium metal is commercially prepared by the reduction of molten KCl with metallic sodium at 850°C (1123 K). This method is based upon the following principle

(A) Sodium is more reactive than potassium at this temperature

(B) Potassium being more volatile distils off thus shifting the reaction forward

(C) Sodium prefers to bind to chloride ions in preference to potassium ions

(D) Potassium and sodium form an alloy at this temperature.

Q.6 If Na^+ ion is larger than Mg^{2+} ion and S^{2}ion is larger than Cl^- ion, which of the following will be least soluble in water?

(A) Sodium chloride (B) Sodium sulphide

(C)Magnesium chloride (D) Magnesium sulphide

Q.7 Magnesium burns in CO_2 to form:

(A) MgO and CO (B) $MgCO_3$

(C) MgO and C (D) MgO_2

Q.8 Which one of the following is most soluble in water?

(A) $Mg(OH)_2$ (B) $Sr(OH)_2$ (C) $Ca(OH)_2$ (D) $Be(OH)_2$

Q.9 The right order of the solubility of sulphates of alkaline earth metals in water is:

(A) Be > Ca > Mg > Ba > Sr

(B) Mg > Be > Ba > Ca > Sr

(C) Be > Mg > Ca > Sr > Ba

(D) Mg > Ca > Ba > Be > Sr

Q.10 A metal salt solution forms a yellow precipitate with potassium chromate in acetic acid, a white precipitate with dilute sulphuric acid but gave no precipitate with sodium chloride or iodide. The white precipitate obtained when sodium carbonate is added to the metal salt solution will consist of

(A) Lead carbonate (B) Basic lead carbonate

(C) Barium carbonate (D) Strontium carbonate

Q.11 Which of the following statement is false?

(A) Strontium decomposes water readily than beryllium

(B) Barium carbonate melts at a higher temperature than calcium carbonate

(C) Barium hydroxides is more soluble in water than magnesium hydroxide

(D) Beryllium hydroxide is more basic than barium hydroxide

Q.12 A salt on treatment with dil. HCl gives a pungent smelling gas a yellow precipitate. The salt gives green flame test and a yellow precipitate with potassium chromate. The salt is:

(A) $NiSO_4$ (B) BaS_2O_3 (C) PbS_2O_3 (D) $CuSO_4$

Multiple Correct Choice Type

Q.13 In hydrolysis, the alkali metal oxides, peroxides and superoxides act as:

(A) Bronsted acid (B) Bronsted base

(C) Lewis acid (D) Lewis base

Q.14 Identify the incorrect statement (s):

(A) Magnesium is lighter than calcium

(B) The atomic radius of Mg is greater than that of Ca

(C) Mg alloys are used in the construction of air crafts

(D) Mg is used as a reducing agent

Q.15 Which of the following statements about the elements, Mg, Ca, Sr and Ba and their compounds is true?

(A) Solubility of the hydroxides in water increases with increasing atomic number

(B) Thermal stability of the carbonates increases with increasing atomic number

(C) All given elements react with water or steam to give hydrogen

(D) Metal chlorides are all liquids at room temperature

Q.16 Which statement is correct regarding the diagonal relationship between the Al and Be?

(A) BeO and Al_2O_3 are amphoteric in nature

(B) Both carbide on hydrolysis produce same gas

(C) Both can form complex

(D) Both have nearly close m.p.

Comprehension Type

Paragraph 1: The thermal stability of the salts of the s-block elements is dependent upon three main factors. Firstly, the greater the charge of the ions involved, the stronger the interionic attraction and the more stable the salt. Also, the smaller the ions become in terms of their ionic radii the closer they approach each other in the crystal lattice of their salts and the more stable the salt. Thirdly, if the ions in the lattice are of comparable size, the crystal lattice is arranged in a more uniform fashion and thus possesses greater thermal stability. There is one other factor that affects thermal stability. The larger the anions in the crystal, for example CO_3^{2-}, unless the cation is of comparable size, the anions decompose on heating to give smaller anions such as O^{2-}. This point is especially important when considering the thermal stability of the carbonates, nitrates and hydroxides of the s-block elements.

Q.17 Comparing calcium oxide and magnesium oxide, which of the two would be more stable?

(A) Magnesium oxide would be more stable because the Magnesium cation is smaller

(B) Magnesium oxide would be more stable because Magnesium has a lower atomic mass than Calcium

(C) Calcium oxide would be more stable because the calcium anion is smaller than the Magnesium cation

(D) Calcium oxide would be more stable because calcium has a greater atomic mass than magnesium

Q.18 The nitrates of the Group-I elements mainly decompose not to the oxide but to the nitrite (NO_2^-) although O^{2-} is smaller than NO_2^- Why?

(A) Because only doubly charged anion like CO_3^{2-} decompose to the oxide

(B) Because the double charge on the oxygen would make the salt less stable than a singly charge nitrite anion

(C) Because the nitrite anion contains two oxygen atoms while the oxide anion contains only one

(D) Because the nitrite anion is probably about the same size as the Group I cations.

Q.19 Given that CO_3^{2-} anion is approximately the same size as the early Group I cations, what would occur if Na_2CO_3 were heated

(A) If would decompose to yield Na_2O

(B) If would decompose to yield $Na_2O + CO_2$

(C) If would decompose to yield NaOH

(D) No decomposition would occur

Q.20 Li_2O is often considered to be covalent in nature because of the unusually high electronegativity of lithium. Which of the following would be a possible Lewis dot structure for the compound?

(A) $\mathrm{Li-Li-\underset{\cdot\cdot}{\overset{\cdot\cdot}{O}}}$ (B) $\mathrm{Li-\underset{\cdot\cdot}{\overset{\cdot\cdot}{O}}-Li}$ (C) $\mathrm{Li{=}O{=}Li}$ (D) $\mathrm{Li\text{-}\ \underset{\cdot\cdot}{\overset{\cdot\cdot}{O}} = Li}$

Paragraph 2: Most of the s-block metals form saline or ionic hydrides. These are non-volatile, non-conducting crystalline solids. However BeH_2 and MgH_2 have covalent polymeric structure. These ionic hydrides have rock salt like structure.

Electrolysis of solution of saline hydride produces H_2 at anode. Saline hydrides react explosively with H_2O. The fire so produced cannot be extinguished with CO_2 as it get reduced by hot metal hydrated. Only sand is useful as it is a solid.

Q.21 When $NaBH_4$ is dissolved in water

(A) It decomposes with the evolution of H_2

(B) Na^+ and BH_4^- are formed which are stable

(C) BH_4^- ions formed initially decompose to produce OH^- ions, which prevent further decomposition

(D) NaH and B_2H_6 are produced.

Q.22 $LiAlH_4$ is obtained by reacting an excess of... with an ethereal solution of $AlCl_3$

(A) LiCl (B) LiH (C) Li (D) LiOH

Q.23 Alkali metal hydrides react with water to give

(A) Acidic solution (B) Basic solution

(C) Neutral solution (D) Hydride ion

Q.24 Amongst the alkali metal hydrides, the most stable one is

(A) LiH (B) NaH (C) KH (D) RbH

Q.25 Ionic hydrides are usually

(A) Good electrically conductors when solid

(B) Easily reduced

(C) Good reducing agents

(D) Liquid at room temperature.

Assertion Reasoning Type

Each of the questions given below consists of two statements, an Assertion and Reason. Select the number corresponding to the appropriate alternative as follows

(A) If both assertion and reason are true and R is the correct explanation of Assertion.

(B) If both assertion and reason are true but reason is not the correct explanation of assertion.

(C) If assertion is true but reason is false.

(D) If both assertion and reason are false.

Q.26 Assertion: The radius of Na+ in aqueous solution is more than that of Li^+ ion.

Reason: Na^+ is with high hydration energy compared to Li^+ ion in aqueous solution. $LiNO_3$

Q.27 Assertion: and KNO_3 both on decomposition give respective oxide and NO_2 gas. Group-I.

Reason: Nitrates are highly stable, they do not undergo decomposition. Temperature.

Q.28 Assertion: Required for the decomposition of $MgCO_3$ is less than that of $CaCO_3$.

Reason: Thermal stability of group II carbonates increases down the. Group.

Q.29 Assertion: .Li_3N is known but K_3N is not known.

Reason: Smaller sizes of lithium ion is able to form stable p bond with nitride ion.

Q.30 Assertion: Lithium can't be stored under kerosene whereas sodium can be stored.

Reason: Density of lithium is lower than that of sodium.

Previous Years' Questions

Q.1 The following compounds have been arranged in order of their increasing thermal stabilities. Identify the correct order. ***(1996)***

(I) K_2CO_3 (II) $MgCO_3$ (III) $CaCO_3$ (IV) $BeCO_3$

(A) I< II < III < IV (B) IV< II < III < I

(C) IV < II <I < III (D) II < IV < III < I

Q.2 A dilute aqueous solution of Na_2SO_4 is electrolyzed using platinum electrodes. The products at the anode and cathode are respectively ***(1996)***

(A) O_2, H_2 (B) $S_2O_8^{2-}$, Na

(C) O_2, Na (D) $S_2O_8^{2-}$, H_2

Q.3 A sodium salt of an unknown anion when treated with $MgCl_2$ gives white precipitate only on boiling. The anion is: ***(2004)***

(A) SO_4^{2-} (B) HCO_3^- (C) CO_3^{2-} (D) NO_3^-

Q.4 The compound(s) formed upon combustion of sodium metal in excess air is (are): ***(2007)***

(A) Na_2O_2 (B) Na_2O (C) NaO_2 (D) NaOH

Q.5 The reagent(s) used for softening the temporary hardness of water is (are): ***(2010)***

(A) $Ca_3(PO_4)_2$ (B) $Ca(OH)_2$

(C) Na_2CO_3 (D) NaOCl

Q.6 $MgCl_2.6H_2O$ on heating gives anhydrous $MgCl_2$ ***(1982)***

Q.7 Sodium when burnt in excess of oxygen gives sodium oxide. ***(1987)***

Q.8 A white solid is either Na_2O or Na_2O_2. A piece of red litmus paper turns white when it is dipped into a freshly made aqueous solution of the white solid.

(i) Identify the substance and explain with balanced equation.

(ii) Explain what would happen to the red litmus if the white solid were the other compound. ***(1999)***

Q.9 Give reasons for the following in one or two sentences only: "$BeCl_2$ can be easily hydrolyzed." ***(1992)***

Q.10 Identify (X) in the following synthetic scheme and write their structures.

$BaCO_3 + H_2SO_4 \rightarrow$ X (gas) (C* denotes C^{14}) ***(2001)***

PlancEssential Questions

JEE Main/Boards

Hydrogen

Exercise 1

Q.6 Q.19 Q.21

Exercise 2

Q.8 Q.15 Q.25 Q.29

Previous Years' Questions

Q.5

JEE Advanced/Boards

Exercise 1

Q.10 Q.17 Q.19

Exercise 2

Q.6 Q.12 Q.43

Previous Years' Questions

Q.6 Q.10

JEE Main/Boards

s-Block Elements

Exercise 1

Q.3 Q.8 Q.13
Q.16 Q.19(iv) Q.23
Q.26 (iv,v) Q.30

Exercise 2

Q.6 Q.9 Q.11
Q.17 Q.25

Previous Years' Questions

Q.6

JEE Advanced/Boards

Exercise 1

Q.4 Q.9 Q.12
Q.15

Exercise 2

Q.2 Q.4 Q.10
Q.22 Q.23

Previous Years' Questions

Q.2 Q.3 Q.9

Answer Key

JEE Main/Boards

Hydrogen

Exercise 1

Q.11 750 ml of O_2, at NTP

Q.12 44.8.

Q.13 $AgNO_3$ solution is used for the removal of AsH_3 and PH_3 present in very small amounts in hydrogen sample.

Q.14 (A) Potassium ferricyanide is reduced

$2K_3Fe(CN)_6 + 2KOH + H_2O_2$??$2K_4Fe(CN)_6 + 2H_2O + O_2$

(B) $Cr(OH)_3$ is converted into yellow colored Na_2CeO_4

$2Cr(OH)_3 + 4\ NaOH + 3H_2O_2 \rightarrow$

$2Na_2CrO_4 + 8H_2O$

Q.15 D_2O has more molecular mass and greater degree of association than H_2O and thus shows higher m.pt. and b.pt.

Q.16 Water reacts with Na_2O_2 to produce NaOH which increases the decomposition of H_2O_2.

Q.17 The reaction is highly exothermic. It brings large increase in volume also.

$N_2H_4 + 2H_2O \rightarrow N_2(g) + 4H_2O(g)$

Q.18 This is due to the following reactions.

Oxidizing agent:

$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$ (acidic medium)

$H_2O_2 + 2e^- \rightarrow 2OH^-$ (alkaline medium)

Reducing agent:

$H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$

Q.19 0.2125

Q.20 White lead is used as a pigment. The statues coated with white lead get blackened due to the action of H_2S present in atmosphere in traces.

$\underset{\text{White lead}}{Pb(OH)_2.2PbCO_3} + 3H_2S \rightarrow 3\ PbS + 2CO_2 + 4H_2O$ When blackened statues are treated with 11,O,. the Pbs is oxidised to $PbSO_4$ which is colourless (white)

$PbS + 4H_2O_2 \rightarrow \underset{(\text{white})}{PbSO_4} + 4H_2O$

Q.21 Na, H_2, NaOH, Zn

Q.22 Two OH bonds lie in the same plane

Q.23 A blue colour is obtained in ether due to formation of CrO_5

Q.24 1.344

Q.25 As potential discharge of K^+ is higher than H^+ ion and potential discharge of SO_4^{2-} is higher than OH^- ion.

Q.26 Pb from painting reacts with atmospheric H_2S to give black coloured PbS which on reaction with H_2O_2 converts into $PbSO_4$.

Q.27 Traces of alkali present in glass bottles accelerates the decomposition of H_2O_2, hence glass is coated with wax.

Q.28 During the storage of H_2O_2, addition of small amount of phosphoric acid or glycerol or acetanilide inhibits the decomposition of H_2O_2.

Q.29 1.7 N

Q.30 (A) H_2O_2 (B) CrO_4^{2-} (C) $PbSO_4$

Exercise 2

Single Correct Choice Type

Q.1 A **Q.2** C **Q.3** C **Q.4** C **Q.5** C **Q.6** B **Q.7** B

Q.8 B **Q.9** B **Q.10** C **Q.11** D **Q.12** B **Q.13** D **Q.14** B

Q.15 D **Q.16** A **Q.17** A **Q.18** A **Q.19** D **Q.20** C **Q.21** D

Q.22 B **Q.23** A **Q.24** B **Q.25** A **Q.26** A **Q.27** C **Q.28** B

Q.29 C **Q.30** C **Q.31** B **Q.32** B **Q.33** A **Q.34** B **Q.35** C

Q.36 B **Q.37** C **Q.38** D

Previous Years' Questions

Q.1 C **Q.2** C **Q.3** D **Q.4** C **Q.5** A **Q.6** B **Q.7** B

Q.8 A **Q.9** C **Q.10** C **Q.11** B **Q.12** A

JEE Advanced/Boards

Exercise 1

Q.1 B **Q.2** C **Q.3** D **Q.4** B **Q.5** D **Q.6** B **Q.7.** D

Q.8 A **Q.9** A **Q.10** A **Q.11** D **Q.12** C **Q.13** D **Q.14** B

Q.15 A **Q.16** B **Q.17** A **Q.18** A **Q.19** C **Q.20** B **Q.21** C

Q.22 C **Q.23** A **Q.24** B **Q.25** A **Q.26** B **Q.27** C **Q.28** B

Q.29 C **Q.30** D

Exercise 2

Single Correct Choice Type

Q.1 A **Q.2** C **Q.3** B **Q.4** C **Q.5** D **Q.6** B

Q.7 C **Q.8** B **Q.9** B **Q.10** B **Q.11** D **Q.12** D

Q.13 B **Q.14** A **Q.15** B

Multiple Correct Choice Type

Q.16 A, B, C **Q.17** B, D **Q.18** B, D **Q.19** C, D **Q.20** A, B, D

Assertion Reasoning Type

Q.21 C **Q.22** A **Q.23** A **Q.24** A **Q.25** A **Q.26** A

Comprehension Type

Q.27 A **Q.28** B **Q.29** D **Q.30** D **Q.31** C **Q.32** B

Q.33 B **Q.34** B **Q.35** A **Q.36** D **Q.37** A **Q.38** B

Q.39 C **Q.40** B **Q.41** B **Q.42** C

Match the Columns

Q.43 A → s; B → s; C → r; D → p **Q.44** A → p, s; B → q, r; C → q, r; D → q, r

Q.45 A → q, r, s; B → q, r; C → p, q; D → p, q **Q.46** A → r; B → p; C → q; D → s

Previous Years' Questions

Q.1 B **Q.2** A **Q.3** B **Q.4** B **Q.5** C, D **Q.6** B, D

Q.7 B, C **Q.8** A **Q.9** A **Q.10** C **Q.11** A

JEE Main/Boards

s-Block Elements

Exercise 2

Single Correct Choice Type

Q.1 A **Q.2** A **Q.3** C **Q.4** D **Q.5** D **Q.6** A **Q.7** D

Q.8 A **Q.9** A **Q.10** C **Q.11** D **Q.12** A **Q.13** C **Q.14** C

Q.15 C **Q.16** C **Q.17** A **Q.18** C **Q.19** A **Q.20** D **Q.21** D

Q.22 D **Q.23** D **Q.24** A **Q.25** C **Q.26** C **Q.27** A **Q.28** B

Q.29 B **Q.30** D **Q.31** A

Previous Years' Questions

Q.1 B **Q.2** B **Q.3** A **Q.4** B **Q.5** A **Q.6** B **Q.7** D

Q.8 C **Q.9** C **Q.10** A **Q.11** A **Q.12** B **Q.13** B

JEE Advanced/Boards

Exercise 1

Q.1 D **Q.2** A **Q.3** B **Q.4** C **Q.5** A **Q.6** A **Q.7** C

Q.8 B **Q.9** C **Q.10** A **Q.11** A **Q.12** D **Q.13** B **Q.14** B

Q.15 A

Exercise 2

Single Correct Choice Type

Q.1 C **Q.2** B **Q.3** B **Q.4** D **Q.5** C **Q.6** C **Q.7** D

Q.8 B **Q.9** C **Q.10** C **Q.11** D **Q.12** B

Multiple Correct Choice Type

Q.13 A, B **Q.14** C, D **Q.15** A, B, C **Q.16** A, B, D

Comprehension Type

Q.17 A **Q.18** D **Q.19** A **Q.20** B **Q.21** C **Q.22** B **Q.23** B

Q.24 A **Q.25** C

Assertion Reasoning Type

Q.26 D **Q.27** D **Q.28** A **Q.29** A **Q.30** A

Previous Years' Questions

Q.1 B **Q.2** A **Q.3** B **Q.4** A,B **Q.5** B, C, D

Solutions

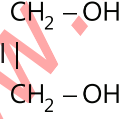
JEE Main/Boards

Exercise 1

Hydrogen

Sol 1: Heavy water (D_2O) is used as moderator as well as coolant in nuclear power generation D_2O is a stable molecule as compared to H_2O because molar mass of D_2O is greater so its bond have less vibration and they are more stable so thermal neutrons which are produced in nuclear fission, can be stopped or absorbed by D_2O.

Sol 2: Compound in which H_2O_2 is stable is used as inhibitor in decomposition of H_2O_2 is stable, is used as inhibitor in decomposition of H_2O_2 solution.

Eg. Glycerol  , Acetoanilide.

$$\begin{array}{l} CH_2-OH \\ | \\ CH_2-OH \end{array}$$

Sol 3: Water gas: CO + H_2

This gas is made by passing steam over a red hot carbon fuel such as coke:

$H_2O + C \rightarrow H_2 + CO; \Delta n = +ve$

Sol 4: H_2O is a polar molecule so it can also dissociate into H^+ and OH^- and this equilibrium have its constant.

$H_2O \rightleftharpoons H^+ + OH^-$ $K_w = 10^{-14}$

This reaction is autoprotolysis of water and k_w is autoprotolysis constant.

So, 1 out of 10^{14} molecules of H_2O dissociate in H^+ and OH^{-1}

Sol 5: H_2O molar mass is less than H_2O

$\therefore$ – O – H bond have more vibration than – O – D bond

So, – O – H bond is water than – O – D so it is easy to dissociate H_2O, D_2O is strong.

$\therefore$ Electrolysis of weaker occur faster than heavy water.

Sol 6: (i) Water $\xrightarrow{\text{Electrolysis}} H_2 + O_2$

(ii) dilute acids $\xrightarrow[\text{Na, Zn, Al}]{\text{metals}} MCl_2 + H_2$

(iii) alkalis $\xrightarrow[\text{metals}]{\text{amphoteric}} Zn(OH)_2 + H_2$

Sol 7: Interstitial hydrides are formed by Be, Mg (s-block) and transition metals. These are interstitial compound as the hydrogen atoms occupy interstitial places in the metallic lattices these are non-stoichiometric compounds and give out hydrogen easily and are used as strong reducing agents. This suggests that hydrogen is in atomic state having oxidation number zero.

Sol 8: Boiling point, melting point such physical properties depend upon intermolecular weak forces of attraction. H_2O have hydrogen bonding with each other and it has comparatively high molar mass which result in more strong Vander waals forces than H_2

$\therefore$ H_2S boiling point / melting point is less than H_2O.

Sol 9: (a)

$$\underbrace{2KMnO_4 + 3H_2SO_4 + 5H_2O_2 \longrightarrow K_2SO_4 + 2MnSO_4}_{\text{Reduction}} + 8H_2O + 5O_2$$

(b) $\underbrace{PbS + H_2O_2 \longrightarrow PbSO_4}_{\text{Oxidation}} + 4H_2O$

(c) $\underbrace{FeSO_4 + H_2SO_4 + 5H_2O_2 \longrightarrow FeSO_4}_{\text{Oxidation}} + H_2O$

(d) $2K_4\,\underbrace{[Fe^{+2}(CN)_6] + H_2O_2 \longrightarrow 2K_3[Fe^{+3}}_{\text{Oxidation}}(CN)_6 + 2KOH$

(e) $\underbrace{H_2SO_3 + H_2O_2 \longrightarrow H_2SO_4}_{\text{Oxidation}} + H_2O$

(f) $Na_3\,\underbrace{As^{+3}O_4 + H_2O_2 \longrightarrow Na_3ASO_3}_{\text{Reduction}} + H_2O$

Sol 10: (i) $Na + D_2O \longrightarrow NaOD + D_2$

(ii) $NaOH + D_2O \longrightarrow NaOD + H_2O$

(iii) $NH_4Cl + D_2O \longrightarrow ND_4Cl + H_2O$

(iv) $SO_3 + D_2O \longrightarrow D_2SO_4$

Sol 11: $H_2O_2 \longrightarrow H_2O + \frac{1}{2}O_2$

30 volume means

1 ml of H_2O_2 gives 30 ml of H_2O_2

$\therefore$ 25 ml will give 750 ml of H_2O_2

Sol 12: In 100 gm solution, 13. 6 gm H_2O_2

$$\text{Molarity} = \frac{13.6/34}{100} \times 1000$$

$\therefore$ Volume strength = Molarity × 11. 2 = 44. 8

Sol 13: $AgNO_3$ solution is used for removal of AsH_3 and PH_3 present in very small amounts in hydrogen sample.

Sol 14: (a) $2K_3[Fe(CN)_6] + 2KOH + H_2O_2 \longrightarrow 2K_4[Fe(CN)_6] + 2H_2O + O_2$

Reduction $Fe^{3+} \longrightarrow Fe^{2+}$

(b) $Cr(OH)_3 + H_2O_2 + OH^- \longrightarrow Cr(OH) + O_2 + H_2O$

Reduction

Sol 15: D_2O has more molecular mass and greater degree of association than H_2O and thus shows higher m.pt. and b.pt.

Sol 16: $Na_2O_2 + H_2SO_4 \longrightarrow H_2O_2 + Na_2SO_4$

But if water is added then, Na_2O_2 will form NaOH which will retard the production of H_2O_2

Sol 17: $N_2H_4 + 2H_2O \longrightarrow \underset{(g)}{N_2} + 4H_2\underset{(g)}{O}$

The reaction is highly exothermic. It brings large increase in volume also.

Sol 18: H_2O_2 act as oxidising as well as reducing agent because oxidation no. of oxygen in H_2O_2 is –1 which is an intermediate state so it can go to –2 by reduction and also to O forming O_2

Sol 19: $N_1V_1 = N_2V_2$

$20 \times N_1 = 30 \times \frac{1}{12}$;

$N_1 = \frac{1}{8} \Rightarrow 0.2125\%$ of H_2O_2 in solution.

Sol 20: Statues coated with white lead get blackened due to the action of H_2S present in atmospheric in traces.

$\underset{\text{white lead.}}{Pb(OH)_2 \,.\, 2PbCO_3} + 3H_2S \longrightarrow 3PbS + 2CO_2 + 4H_2O$

When blackened statues are treated with H_2O_2 the PbS is oxidised to $PbSO_4$ which is colourless (white)

$PbS + 4H_2O_2 \longrightarrow \underset{\text{(white)}}{PbSO_4} + 4H_2O$

Sol 21:

$$\begin{tikzcd} A + H_2O \arrow[r] & B\uparrow + C_{(ag)} \arrow[d, "\Delta"'] & & \\ & B\uparrow & D \arrow[r, "\text{dil.}", "H_2SO_4"'] & B\uparrow \end{tikzcd}$$

Deep golden yellow flame: Na

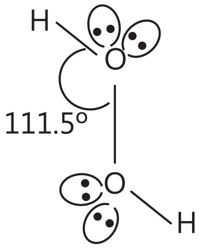
A: - Na

B: - H_2 inflammable gas

C: - NaOH

D: - Zn Amphoteric metal

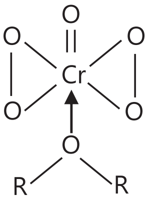
Sol 22: H_2O_2 is a non-planar molecule with open book structure



Sol 23:

$$H_2O_2 + K_2Cr_2O_7 + H_2SO_4 \longrightarrow K_2SO_4 + \underset{\text{(Blue)}}{2CrO_5} + 5H_2O$$

CrO_5 is stable at low temperature and only in ether solution



Stabilise

Sol 24:

$$\begin{tikzcd} H_2O_2 + I^- \arrow[r] & I_2 \arrow[d, "Na_2SO_3"] \\ & I^- + Na_2S_4O_6 \end{tikzcd}$$

Equivalents of $Na_2S_2O_3 = 20 \times 0.3 \times 10^{-3}$

= equivalents of I_2 = equivalents of H_2O_2

$25 \times N_{H_2O_2} \times 10^{-5} = 20 \times 0.3 \times 10^{-3}$

$N_{H_2O_2} = 0.24$ N

∴ Volume strength = 1. 344

Sol 25: Discharge of any metal or non-metal depends on its discharge of potential. So, as potential of discharge of K^+ is higher than H^+ ion and potential discharge of SO_4^{2-} is higher than OH^- ion.

Sol 26: Pb from painting reacts with atmospheric H_2S to give black coloured PbS which on reaction with H_2O_2 converts into $PbSO_4$.

Sol 27: H_2O_2 is a very unstable compound and readily decomposes in H_2O and O_2 in presence of any catalyst or sunlight. Traces of alkali present in glass bottles accelerates the decomposition of H_2O_2 hence glass is coated with wax.

Sol 28: During the storage of H_2O_2, addition of small amount of phosphoric acid or glycerol or acetanilide inhibits the decomposition of H_2O_2.

Sol 29: Volume strength = 10 V

$$\text{Normality} = \frac{\text{volume strength}}{5.6} = \frac{10}{5.6} = 1.7$$

Sol 30:

$$\begin{tikzcd} H_2SO_4 \arrow[r, "50\text{ L}", "\text{electrolysis}"'] & A \arrow[r, "Cr^{3+}", "HO^-"'] & Ⓑ \arrow[d, "PbS"] \\ & & Ⓒ \end{tikzcd}$$

(A) H_2O_2 Oxidising as well as reducing agent

(B) CrO_4^{2-}

(C) $PbSO_4$

Exercise 2

Single Correct Choice Type

Sol 1: (A) Calgon: $Na_2\,[Na_4\,(PO_3)_6]$

It is a water softer because it removes Ca and Mg ions from hard water by forming a soluble complex.

$2Ca^{2+} + Na_2\,[Na_4\,(PO_3)_6 \longrightarrow Na_2\,[Ca_2\,(PO_3)_6] + 2Na$

hard water Calgon Soluble complex

Sol 2: (C) In liquid H_2, the intermolecular weak attractive forces are dominate then repulsive forces.

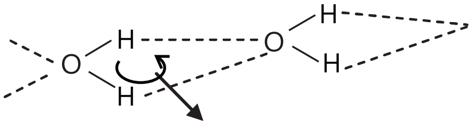
∴ Liquid H_2 expands while cooling.

Sol 3: (C) Hydrogen electronic configuration is $1s^1$

∴ By gaining 1 electron it can acquire helium $1s^2$ configuration. Hydrogen has a tendency which resembles it to halogen because halogens are also only 1 electron has to stable noble gas configuration.

Sol 4: (C) H^- is oxidised at anode to H_2

Sol 5: (C) Ice is lighter than water because ice has less density than water for this hydrogen bonding is responsible.



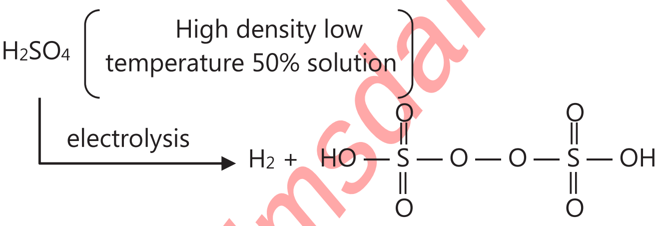
Sol 6: (B) NaCl is soluble salt

∴ It is soft water

Sol 7: (B) H_2O_2 show oxidising as well as reducing properties

∴ H_2O_2 bleaching properties is due to its oxidising nature.

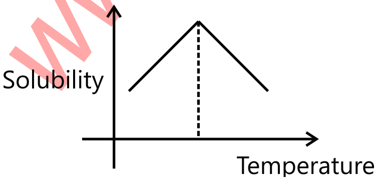
Sol 8: (B)



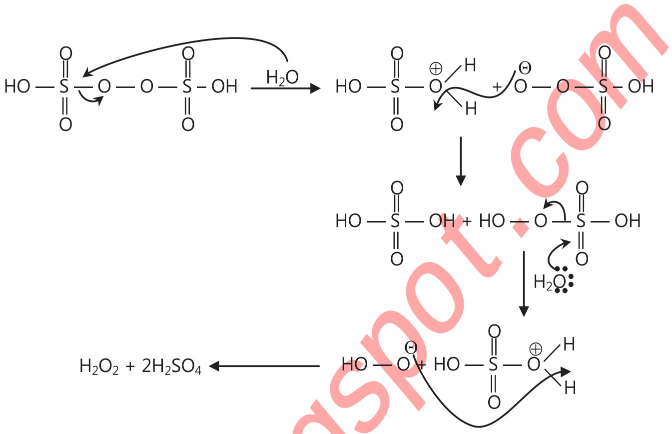
$H_2S_2O_8$

Peroxy disulphuric acid

Sol 9: (B) $CaSO_4$ is a hardness producing salt and its solubility changes with rise in temperature. Its solubility increases till and then decreases when increases temperature beyond that



Sol 10: (C)



Sol 11: (D) $K_2{}^{+6}Cr_2O_7 + 2KOH \longrightarrow 2K_2{}^{+6}CrO_4 + H_2O$

No change in oxidation state and no loss/gain of electron.

∴ Not a redox reaction

Sol 12: (B) Water + sugar + salt $\xrightarrow[\text{resins}]{\text{Organic}}$ organic resins are generally used to soften the water.

When water is passed through it since Na^+, Ca^{2+}, Mg^{2+} can be more attracted. So, resins attract them more and release H^+ in the water.

∴ NaCl can be removed from water and water turns sweet.

Sol 13: (D) (A) $CuSO_4 + Zn \longrightarrow Cu + ZnSO_4$

This reaction takes place in galvanic cell.

(B) E° of this reaction is positive

∴ Reaction is possible.

(C) Hydrides react violently with water providing dihydrogen gas.

(D) Na_2CO_3 is better base than Na_2SO_3

∴ Weak base and acid cannot produce strong base and acid.

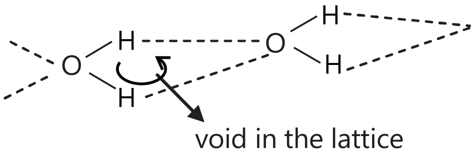
Sol 14: (B) Since bonding vibration of – O – H bond is more than – O – D. Energy required to break the bond is less in – O – H than – O – D

∴ – O – H bond is weaker than – O – D

∴ Biological growth of plant which is fed by H_2O is fast because it requires less energy to break H_2O.

Sol 15: (D) Conceptual fact.

Sol 16: (A) Water molecules in ice are held tight by hydrogen bond attraction



So the H_2O molecules on the border have free O and H-atoms to bond the lattice.

∴ When we press two ice-cube we do sufficient

amount of work to complete the hydrogen bond formation.

∴ These get unit forming ore ice cube.

Sol 17: (A) Washing soda only remove chlorides of Ca, Mg.

E.g. $CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2\ NaCl$

Same as washing soda, related lime cannot remove all the slats from washing soda but soap can precipitate all type of ions by ion-exchange method.

$MgCl_2 + 2C_{17}H_{35}COONa \longrightarrow (C_{17}H_{35}COO)_2\ Mg \downarrow + 2NaCl$

Sol 18: (A) Fenton's Reagent: $H_2O_2 + FeSO_4$

Use to reduce organic compounds.

Sol 19: (D) Liquid H_2 is the best pure fuel because it is not a reactive gas because its bond energy high. But it is inflammable and bonds in air forming water

$2H_2 + O_2 \longrightarrow 2H_2O$

Sol 20: (C) In presence of oxidiser liquid oxygen, liquid hydrogen yields highest specific impulses.

Sol 21: (D) $H_2O \xrightarrow{[o]} O_2$

This reaction is very difficult to do because its E° is highly negative.

∴ Only F_2 which is the strongest reducing agent can give oxygen from water.

Sol 22: (B) H_2O_2 is an oxidising agent so it will oxidise sulphur

$H_2O_2 + PbS \longrightarrow H_2O + PbSO_4$

It will not oxidise $Pb^{2+} \longrightarrow Pb^{4+}$ because Pb^{4+} is not stable and can get easily oxidised due to inert-pair effect.

Sol 23: (A) Fact $2H_2 + O_2 \longrightarrow 2H_2O$

Sol 24: (B) While reacting with Cl_2 H_2O_2 will show its reducing mature.

$H_2O_2 + Cl_2 \longrightarrow 2HCl + O_2$

Sol 25: (A) Ionic Hydrides M^+H^- in which at anode during electrolysis, H^+ gets oxidised and will produce H_2 gas

$H^- \longrightarrow \frac{1}{2}H_2 + e^-$ (Anode Reaction)

$M^+ + e^- \longrightarrow$ M(Cathode Reaction)

Sol 26: (A) CaH_2, NaH are group (I), (II) metal hydrides.

∴ They are ionic in nature.

So NH_3 and B_2H_6 are covalent hydrides because N, B are non-metals.

Sol 27: (C) (A) $Zn + H_2O \longrightarrow Zn(OH)_2 + H_2$

(B)
$$\begin{tikzcd} Zn + NaOH \arrow[r] & Zn(OH)_2 + H_2\uparrow \arrow[d, "(XS)\ NaOH"] \\ & Na_2[Zn(OH)_4] \end{tikzcd}$$

(C) $Zn + conc\ H_2SO_4 \longrightarrow ZnSO_4 + H_2O + SO_2$

(D) $Zn + dil.\ HCl \longrightarrow ZnCl_2 + H_2$

Sol 28: (B) Moles of $MgSO_4$ = 0. 002

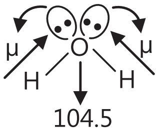
∴ No. of atoms of Mg^{2+} = 0. 002 × 6 × 10^{23}

= 12 × 10^{20}

No. of H_2O particles = $\frac{10^3}{18} \times 6 \times 10^{23} = \frac{10^{26}}{3}$

∴ No. of Mg^{2+} per million H_2O = 200 ppm

Sol 29: (C)



Dipole moment
after calculation = 1.84 D

Sol 30: (C) Blackened oil painting can be restored into original form by the action of H_2O_2 because its a strong oxidising (Bleaching) agent.

Sol 31: (A) Ortho and para hydrogen have similar chemical properties but differ in physical properties like BP, MP.

Sol 32: (B) $CO + H_2 \xrightarrow[X\,(catalyst)]{300°C/300\,atm} CH_3OH$

X → Cr_2O_3 / ZnO Reaction used in production of methanol

Sol 33: (A) $H_2O_2 + HOCl^{+1} \longrightarrow O_2 + Cl_2 + H_2O$

Mn^{2+} is oxidised to Mn^{4+} under alkaline medium.

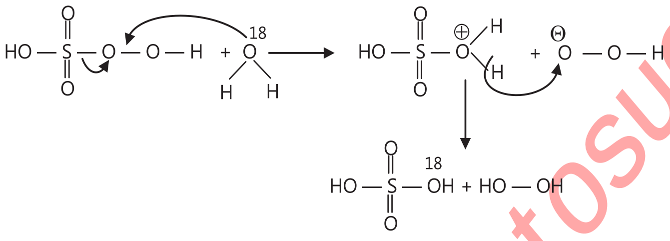
Sol 34: (B) Washing soda is used to remove permanent hardness but $Ca(OH)_2$ can be used to remove temporary hardness.

$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 + 2H_2O$

Sol 35: (C) Polysulphates of Ca^{2+}, Mg^{2+} etc. are soluble in water. Polysulphates are used as water softening agent because they form soluble complexes with cationic species.

Sol 36: (B) Ortho form increases with increase in temperature.

Sol 37: (C) $H_2SO_5 + H_2O^{18}$



Sol 38: (D) Conceptual fact

Previous Years' Questions

Sol 1: (C) Polyphosphates

(Sodium hexametaphosphates, sodium tripolyphosphate or STPP) form soluble complexes with Ca^{+2}, Mg^{+2} present in hard water.

Sol 2: (C) $Ca_3P_2 + 6H_2O \rightarrow 2PH_3 + 3Ca(OH)_2$

Cal. phosphide   Phosphine

(1 mole)   (2 moles)

Sol 3: (D) H_2 will not reduce heated Al_2O_3

Sol 4: (C) $BaO_2 + 2HCl \rightarrow BaCl_2 + H_2O_2$.

Sol 5: (A) Cu and dil. HCl will not produce H_2

Sol 6: (B) Strength = Normality × Eq. mass

= 1.5 × 17 (eq. mass of H_2O_2)

= 25. 5 gL^{-1}

Sol 7: (B) $Mn + 2HNO_3(dil.) \rightarrow Mn(NO_3)_2 + H_2$

Sol 8: (A) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

Correct Reason: H_2O_2 is a strong reducing agent.

Sol 9: (C) Assertion is correct but Reason is not the correct explanation of Assertion.

Sol 10: (C) H_2^{2+} and H_2 does not exist.

Sol 11: (B) $H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$

$H_2O_2 + 2OH^- \rightarrow O_2 + 2H_2O + 2e^-$

Sol 12: (A) It can acts as an oxidising as well as reducing agent.

JEE Advanced/Boards

Exercise 1

Sol 1: The process of converting CO into by passing the gases obtained by steam and hydrocarbons or coke over iron oxide as catalyst at 673 K resulting in the generation of more is called water gas shift reaction.

$$C(s) + H_2O(g) \longrightarrow CO(g) + H_2(g)$$

$$CO + H_2O \xrightarrow{673K} CO_2 + H_2$$

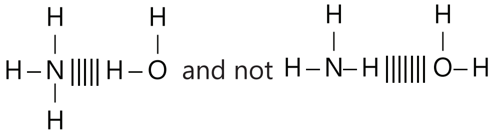
Sol 2: Reaction of Zn and HCl gives nascent hydrogen which is more powerful reducing agent than ordinary hydrogen and thus ferric chloride solution is reduced.

Sol 3: $r_H = -\log P_{H_2}$,

P_{H_2} = pressure of H_2 in atmosphere

Sol 4: Scattreing thermal neutrons (0.1 ev or 9.6 kJ/mol) is roughly similar for all nuclei regardless of atomic number where scattering of X-rays depends upon electron density and is lowest for hydrogen.

Sol 5:



$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{N}}\text{|||||}H-\overset{\overset{H}{|}}{O} \quad \text{and not} \quad H-\overset{\overset{H}{|}}{N}-H\text{|||||||}\overset{\overset{H}{|}}{O}-H$$

Sol 6: Water used during the reaction reacts with Na_2O_2 to form NaOH which tends to decompose H_2O_2.

$$Na_2O_2 + 2H_2O \longrightarrow H_2O_2 + 2NaOH$$
$$2H_2O_2 \xrightarrow{NaOH} 2H_2O + O_2$$

Sol 7: $2H_2O_2 \longrightarrow 2H_2O + O_2$

Sol 8: Moles of $MgSO_4$ = 0.001

$\therefore$ Mole of $CaCO_3$ = 0.001

($\because$ Mg and Ca both are bivalent)

$\therefore$ Wt. of $CaCO_3$ = 0.001 × 100 = 0.1 g

$\therefore$ 10^3 mL water contains 0.1 g $CaCO_3$

$\therefore$ 10^3 mL water contains $\dfrac{0.1\times10^6}{10^3} = 100$ ppm

Sol 9: $CaO + Ca(HCO_3)_2 \longrightarrow 2CaCO_3 + H_2O$

For one litre water

Meq. of CaO = Meq. of $Ca(HCO_3)_2$

$$\frac{w\times1000}{56/2} = \frac{1.62\times1000}{162/2}$$

$\therefore w_{CaO} = 0.56\,g$

Thus CaO required for 10^3 litre

H_2O = 0.56 × 10^3 = 560 g

Sol 10: Meq. of $CaCO_3$ = Meq. of $Ca(HCO_3)_2$ = Meq. of HCl

$$\frac{w}{100/2}\times1000 = \frac{1}{50}\times30$$

$$w_{CaCO_3} = \frac{3\times100}{5\times2000} = 0.03\text{ g}$$

$\therefore$ 100 mL of HO contains = 0.03 g

$\therefore$ 10^6 mL H_2O contains $\dfrac{0.03\times10^6}{100} = 300$ ppm

Sol 11: $CaCrO_4.XH_2O \xrightarrow{\Delta} CaCrO_4 + XH_2O$

$$\frac{\text{Moles of } CaCrO_4}{\text{Moles of } H_2O} = \frac{1}{X}$$

$$\therefore X = \frac{\text{Moles of } H_2O}{\text{Moles of } CaCrO_4} = \frac{\dfrac{1.823-1.479}{18}}{\dfrac{1.479}{156.1}} = 2.02 = 2$$

$\therefore$ Hydrate is $CaCrO_4.2H_2O$

Sol 12: (i) Chromium hydroxide is converted into soluble yellow sodium chromate.

$$\left[H_2O_2 \longrightarrow H_2O + [O]\right]\times3$$
$$2Cr(OH)_3 + 4NaOH + 3[O] \longrightarrow 2Na_2CrO_4 + 5H_2O$$
$$\overline{2Cr(OH)_3 + 4NaOH + 3H_2O_2 \longrightarrow 2Na_2CrO_4 + 8H_2O}$$

(ii) Zinc dissolves in caustic potash solution evolving hydrogen.

$$Zn + 2KOH \longrightarrow \underset{\text{Pot. zincate}}{K_2ZnO_2} + H_2\uparrow$$

(iii) Hydrolysis of CaH_2 occurs with evolution of H_2

$$CaH_2 + 2H_2O \longrightarrow Ca(OH)_2 + 2H_2\uparrow$$

(iv) Deuterometahne is evolved.

$$Al_4C_3 + \underset{\text{Heavy water}}{12D_2O} \longrightarrow 4Al(OD)_3 + \underset{\text{Deuteromethane}}{3CD_4}$$

Sol 13: It is clear from point (iv) that (X) is H_2O_2.

$$Ti(SO_4)_2 + 2H_2O + \underset{(X)}{H_2O_2} \longrightarrow \underset{\substack{\text{Pertitanic acid}\\\text{(Yellow)}}}{H_2TiO_4} + 2H_2SO_4$$

(i) $2KMnO_4 + 2KOH \longrightarrow 2K_2MnO_4 + H_2O + O$

$\underset{(X)}{H_2O_2} + O \longrightarrow H_2O + O_2$ Or

$$2KMnO_4 + 2KOH + \underset{(X)}{H_2O_2} \longrightarrow 2K_2MnO_4 + 2H_2O + O_2$$

$$2K_2MnO_4 + 2H_2O \longrightarrow \underset{\text{(Brown ppt.)}}{2MnO_2} + O_2 + 4KOH$$

(ii) $\underset{(X)}{H_2O_2} + Cl_2 \longrightarrow 2HCl + O_2$

(iii) $\underset{(X)}{H_2O_2} + 2KI + H_2SO_4 \longrightarrow K_2SO_4 + 2H_2O + I_2\uparrow$

Hence (X) is H_2O_2.

Sol 14: (i) 20 vol. H_2O_2 means 1 mL of H_2O_2 solution gives 20 mL O_2.

$$\begin{array}{lcl} 2H_2O_2 & \longrightarrow & 2H_2O + O_2 \\ 2\text{ mole} & & 1\text{ mole} \\ = 68\text{ g} & & 22400\text{ mL at NTP} \end{array}$$

$\therefore$ 22400 mL of O_2 is obtained by 68 g H_2O_2

$\therefore$ 20 mL of O_2 is obtained by

$$\frac{68\times20}{22400} = 0.0607\text{ g of } H_2O_2$$

Or 1 mL of H_2O_2 solution = 0.0607 g

$\therefore$ 100 mL of H_2O_2 solution $= 0.0607\times100 = 6.07\%$

(ii) 6.8% strength H_2O_2 solution means 6.8 g H_2O_2 is present in 100 mL H_2O_2

$$\therefore 6.8\text{ g } H_2O_2 \text{ gives } \frac{22400\times6.8}{68} = 2240\text{ mL } O_2$$

$$\therefore \text{Volume strength of } H_2O_2 \text{ gives} = \frac{2240}{100} = 22.4\ \text{Volume}$$

Sol 15: 1 molar H_2O_2 solution means 1 mole (or 34 g H_2O_2) is present in 10^3 mL solution.

$\therefore$ 68 g H_2O_2 gives 22400 mL O_2

$$\therefore 34\text{ g } H_2O_2 \text{ gives } \frac{22400\times34}{78} = 11200\text{ mL } O_2$$

$$\therefore \text{Volume strength} = \frac{11200}{10^3} = 11.2$$

Sol 16: Volume strength of H_2O_2 = 5.6 × N

$$\therefore 10\text{ vol. } H_2O_2 = \frac{10}{5.6} NH_2O_2$$

$$15\text{ vol. } H_2O_2 = \frac{15}{5.6} NH_2O_2$$

$$20\text{ vol. } H_2O_2 = \frac{20}{5.6} NH_2O_2$$

Let 500 mL of each is mixed then total volume of mixture = 1500 mL; Also this is diluted to double its volume i.e., 3000 m

$$N\times3000 = \frac{10\times500}{5.6} + \frac{15\times500}{5.6} + \frac{20\times500}{5.6}$$

$$\text{Or } N_{H_2O_2}\text{ mixture} = \frac{500\times45}{5.6\times3000} = 1.339$$

$\therefore$ Vol. strength of H_2O_2 = 1.339 × 5.6 = 7.5

Sol 17: The given reaction is:

$$2KMnO_4 + 5H_2O_2 + 4H_2SO_4$$
$$\longrightarrow 2KHSO_4 + 2MnSO_4 + 8H_2O + 5O_2$$

Meq. of O_2 = Meq. of H_2O_2 = Meq. of $KMnO_4$

$$N\times10 = 25\times\frac{1}{20}$$

$$\therefore N_{H_2O} = \frac{25}{200} = 0.125$$

$$\therefore N_{O_2} = 0.125$$

$$\text{Or } w_{O_2} = 0.125\times16 = 2\text{ g / litre}$$

Sol 18: $O_2^- + 2e \longrightarrow 2O^{2-}$

$2I^- \longrightarrow I_2 + 2e$

$2\left(S^{2+}\right)_2 \longrightarrow \left(S^{5/2+}\right)_4 + 2e;$

$I_2 + 2e \longrightarrow 2I^-$

Meq. of H_2O_2 = Meq. of I_2 = Meq. of $Na_2S_2O_3$ = 20 × 0.1

$$\frac{w\times1000}{34/2} = 2$$

$$\therefore w_{H_2O_2} = 0.034\text{ g per 25 mL}$$

$$\therefore N_{H_2O_2} = \frac{0.034\times1000}{34/2\times25} = 0.08$$

Also, Volume strength = 5.6 × 0.08 = 0.448

$$\%\text{ strength} = \frac{17}{56}\times5.6\times0.08 = 0.136\%$$

Sol 19: Meq. of KI = Meq. of H_2O_2 in 50 mL

= Meq of $Na_2S_2O_3$

$$\frac{w\times1000}{34/2} = 20\times0.1$$

$\therefore w_{H_2O_2}$ in 50 mL

$$= \frac{20 \times 0.1 \times 34}{2000} = 0.034$$

$$\therefore w_{H_2O_2} \text{ in 1000 mL } = \frac{0.034 \times 1000}{50} = 0.68\,g$$

Sol 20: For 20 mL H_2O_2;

Meq. of O_2 = Meq of H_2O_2 = Meq. of $KMnO_4$

$$\frac{w \times 1000}{34/2} = \frac{1}{2} \times 30$$

$$\therefore w_{H_2O_2} = 0.255\ g/20\ mL$$

$$\therefore N_{H_2O_2} = \frac{0.255}{34/2} \times \frac{1000}{20} = 0.75$$

Strength = 0.75 × 17 = 12.75 g / litre

Sol 21: (i) Potassium ferricyanide is reduced to potassium ferrocyanide.

$$2K_3[Fe(CN)_6] + 2KOH \longrightarrow 2K_4[Fe(CN)_6] + H_2O + [O]$$

$$H_2O_2 + [O] \longrightarrow H_2O + O_2$$

$$2K_3[Fe(CN)_6] + 2KOH + H_2O_2 \longrightarrow 2K_4[Fe(CN)_6] + 2H_2O + O_2$$

(ii) Potassium permanganate is decolourised due to reduction.

$$2KMnO_4 + 3H_2SO_4 \longrightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5[O]$$

$$[H_2O_2 + [O] \longrightarrow H_2O + O_2] \times 5$$

$$2KMnO_4 + 3H_2SO_4 + 5H_2O_2 \longrightarrow K_2SO_4 + 2MnSO_4 + 2MnSO_4 + 8H_2O + 5O_2$$

(iii) Ferrous ammonium sulphate is oxidised to ferric salt.

$$H_2O_2 \longrightarrow H_2O + [O]$$

$$2FeSO_4 + H_2SO_4 + [O] \longrightarrow Fe_2(SO_4)_3 + H_2O$$

$$2FeSO_4 + H_2SO_4 + H_2O_2 \longrightarrow Fe_2(SO_4)_3 + 2H_2O$$

Exercise 2

Single Correct Choice Type

Sol 1: (A) $H_2 \longrightarrow 2H$ + energy

So, we can say nascent hydrogen consists of Hydrogen atoms with excess energy.

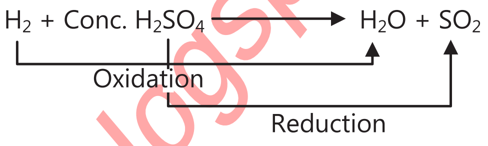
Sol 2: (C) Volume strength of H_2O_2 is determined by its O_2 giving ability.

So volume H_2O_2 means 1 cm^3 of the solution liberate 10 cm^3 of O_2 at STP.

Sol 3: (B) Molarity = $\frac{\text{no. of moles}}{\text{volume}} \times 1000$

$$= \frac{\frac{5.1}{34}}{100} \times 1000 = 1.5\ M$$

Sol 4: (C)

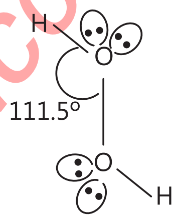


$$H_2 + \text{Conc. } H_2SO_4 \longrightarrow H_2O + SO_2$$

Sol 5: (D) Nature of H_2O_2 is weakly acidic because

$H_2O_2 \rightleftharpoons H-O-O^{\ominus} + H^+$ this equilibrium exist and its equilibrium constant K > 1

Sol 6: (B) Structure of H_2O_2 is open book line structure in gas phase



Sol 7: (C) $H_2 + K_2O \longrightarrow 2K + H_2O$;$E^o < 0$

∴ Reduction of K^+ is not possible by H_2 gas

So 8: (B) $Mg/Mn + \underset{(dil)}{HNO_3} \longrightarrow MgO + H_2O + H_2$

Sol 9: (B) H_2O_2 act as a reducing agent with acidified $KMnO_4$, because it is a better reducing agent than $KMnO_4$

$5H_2O_2 + 2KMnO_4 + 3H_2SO_4 \longrightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$

Sol 10: (B) (A) $Cu + H_2SO_4 \longrightarrow$ No reaction if dilute

(B) $HCOO^- Na^+ \longrightarrow H_2 + Na_2CO_3 + H_2O$

(C) $Na_2C_2O_4 \longrightarrow Na_2CO_3 + CO_2 + CO + H_2O$

Sol 11: (D) H_2O_2 do not show this property.

Sol 12: (D) (A) Temporary hardness of water can be removed by calgon but it only reacts with sulphate/ bicarbonates of Ca^{2+}/Mg^{2+} etc.

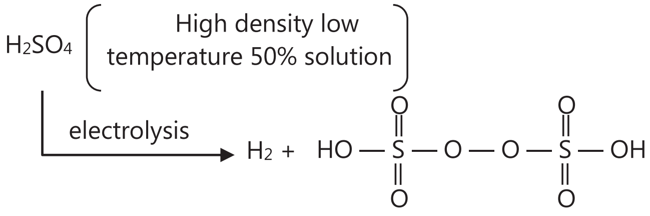
(D) Boiling of water can decompose calcium bicarbonate into calcium carbonate and CO_2 molecules. So, this is a method to remove temporary hardness of water.

Sol 13: (B) Pb^{2+} is soluble in H_2O only. So, it will poison only soft water but not hard water. In hard water, it will precipitate as insoluble salt.

Sol 14: (A) In laboratory, H_2O_2 is prepared by passing a current of CO_2 through a cold pasty solution of BaO_2 in water

$BaO_2 + CO_2 + H_2O \longrightarrow H_2O_2 + BaCO_3$

Sol 15: (B)

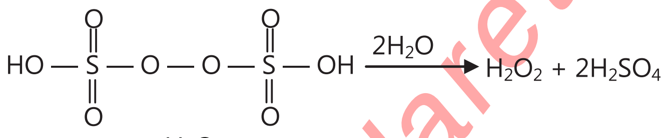


$H_2S_2O_8$

Peroxy disulphuric acid

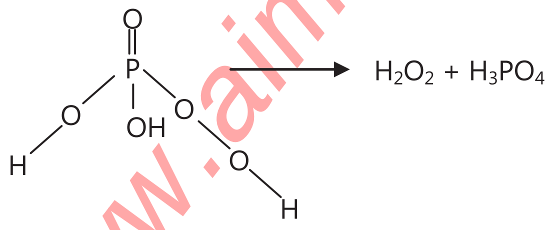
Multiple Correct Choice Type

Sol 16: (A, B, C)

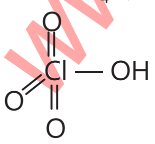


(B) $H_2SO_4 \xrightarrow{H_2O} H_2O_2 + 2H_2SO_4$

(C) H_3PO_5



(D) $HClO_4$



Sol 17: (B, D) Na^+ is exchanged with Ca^{2+} and Mg^{2+} because Ca^{2+} and Mg^{2+} have higher charge density so anions of silicate will attract them by releasing Na^+

Sol 18: (B, D) Group (I), (II) match violently reacts with water giving hydroxides and hydrogen gas.

$CaH + H_2O \longrightarrow Ca(OH)_2 + H_2$

$Ca + H_2O \longrightarrow Ca(OH)_2 + H_2$

Sol 19: (C, D) Ice forms cage like structure due to hydrogen bonding. Its density is less than water.

Sol 20: (A, B, D) $Zn + \text{dil. HCl} \longrightarrow ZnCl_2 + H_2$ $Zn + \text{Hot NaOH} \longrightarrow Zn(OH)_2 + H_2$

(Solution)

$ZN + \text{Conc. Sulphuric} \longrightarrow ZnSO_4 + H_2O + SO_2$

(Acid)

$Zn + \text{Cold water} \longrightarrow Zn(OH)_2 + H_2$

Assertion Reasoning Type

Sol 21: (C) Since ZrH_2 is a non-stoichiometric hydride, the composition of ZrH_2 will be different than its chemical formula.

Sol 22: (A) Molecular weight of D_2 is more than H_2 So, there will be less bond vibration in D_2 because deuterium atom is heavier than H_2

$\therefore$ D_2 is more stable than H_2

Sol 23: (A) Acetanilide form stable complex with H_2O_2 because of which stability of H_2O_2 increases and in its decomposition reaction, it acts as an inhibitor / negative catalyst.

Sol 24: (A) Statement-II is correct explanation of 1 gets decomposed in reactions.

Sol 25: (A) H_2O_2 is a very unstable compounds by any onzymic / catalytic activity it decomposes producing O_2 gas.

$\therefore$ When H_2O_2 is injected in blood it decomposes producing O_2 bubbles seriously.

Sol 26: (A) Statement-II is the correct reason for statement-I

Comprehension Type

Sol 27: (A)

(A) $$\underbrace{\overset{+4}{PbO_2} + H_2\overset{-1}{O_2} \longrightarrow \overset{+2}{PbO}}_{\text{Reduction}} + H_2O + O_2$$

(B) $$\underbrace{\overset{+4}{Na_2SO_3} + H_2O_2 \longrightarrow \overset{+6}{Na_2SO_4}}_{\text{Oxidation}} + H_2O$$

(C) $$\underbrace{2\overset{-1}{KI} + H_2O_2 \longrightarrow 2KOH + \overset{0}{I_2}}_{\text{Oxidation}}$$

(D) $$\underbrace{\overset{+3}{KNO_2} + H_2O_2 \longrightarrow \overset{+5}{KNO_3}}_{\text{Oxidation}} + H_2O$$

Sol 28: (B) $$\underbrace{H_2\overset{-1}{O_2} + \overset{0}{Cl_2} \longrightarrow H_2\overset{+2}{O}}_{\text{Reduction}} + H\overset{-1}{Cl}$$

Sol 29: (D) Z = 43 Technetium. It do not form hydride.

Sol 30: (D) ZrH_2 is most metallic hydride

∴ It has highest electrical conductance.

Sol 31: (C) Interstitial hydride do not give hydrogen ion to get oxidised.

∴ It cannot be used as rocket propellant.

Sol 32: (B) (A) $PbO_2 \longrightarrow Pb^{4+} + 2O^{2-}$

(B) $SrO_2 \longrightarrow Sr^{2+} + O^{-}—O^{-} \xrightarrow{H^+} HO—OH$

(C) $MnO_2 \longrightarrow Mn^{4+} + 2O^{2-}$

(D) $TiO_2 \longrightarrow Ti^{4+} + 2O^{2-}$

Sol 33: (B) H_2O_2 is more acidic than H_2O because the anion is more stable.

∴ $H_2O < H_2O_2 < CO_2$

Because carbonic acid is stronger acid than H_2O_2

Sol 34: (B) Anhydrous

$Na_2O_2 + H_2O \longrightarrow H_2O_2 + NaOH$

$$\therefore \frac{\text{volume strength}}{5.6} = \text{Normality}$$

Sol 35: (A) 30 Volume H_2O_2

$$H_2O_2 \longrightarrow H_2O + \frac{1}{2}O_2$$

$$\text{Normality} = \frac{VS}{5.6} = \frac{30}{5.6} = 5.35$$

Sol 36: (D) $xK_2Cr_2O_7 + yH_2SO_4 + 2H_2O_2 \longrightarrow K_2SO_4 + Cr_2(SO_4)_3 + COH_2O + iO_2$

By balancing it with exchange of electrons,

x = 1; y = 4; z = 3

Sol37: (A)

$$\underset{\big\downarrow}{H_2O_2} + Na\overset{+3}{As}O_3 \longrightarrow Na_3AsO_4 + H_2O$$

Will show its oxidising nature

Sol 38: (B) $H_2O_2 \longrightarrow H_2O + \frac{1}{2}O_2$

This reaction is feasible.

∴ ΔG= -ve at room temperature

Sol 39: (C) Heavy water D_2O is more heavier than H_2O because of which vibration of bond is less and it is more stable so it can be used as moderator as well as coolant to absorb the high kinetic energy value neutrons, which get evolved in nuclear fission.

Sol 40: (B) Fact.

Sol 41: (B) D_2O is more acidic than H_2O so its neutral point will shift towards right and will be (> 7)

Sol 42: (C) D_2O freezes at higher temperature than H_2O.

Match the Columns

Sol 43: A → s; B → s; C → r; D → p

(A) $BaO_2.8H_2O \xrightarrow{H_2SO_4} BaSO_4 + H_2O_2$

(B) $Na_2O_2 \xrightarrow{H_2SO_4} H_2O_2 + 2NaOH$

(C) $H_2SO_4 \xrightarrow{\text{electrolysis}} H_2O + H_2S_2O_8$

$\downarrow$ Hydrolysis

$H_2O_2 + 2H_2SO_4$

(D) – S

Sol 44: A → p, s; B → q, r; C → q, r; D → q, r

(A) Perhydrol is a dilute solution of H_2O_2 and is used as an antiseptic and germicide.

(B) Water gas CO + H_2, gives H_2

(C) Bosch's process is used for the manufacture of H_2

$CO(g) + H_2O(g) \longrightarrow CO_2(g) + H_2(g)$

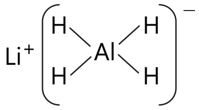
(D) $CH_4 + H_2O \longrightarrow CO + H_2$

It is used to manufacture H_2 gas.

It is called water gas (CO + H_2)

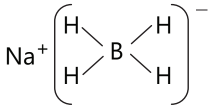
Sol 45: A → q, r, s; B → q, r; C → p, q; D → p, q

(A) $LiAlH_4$



Complex hydride

(B) $NaBH_4$



Complex hydride

(C) $CaH_2 \longrightarrow Ca^{2+} + \enclose{circle}{2H^-}$ Reducing agent

(D) $LiH \longrightarrow Li^+ + \enclose{circle}{H^-}$ Reducing agent

Sol 46: A→r, B→p, C→q, D→s

(A) Heavy water: D_2O

(B) Temporary hard water: $Mg(HCO_3)_2$; $Ca(HCO_3)_2$

(C) Soft water: only H_2O

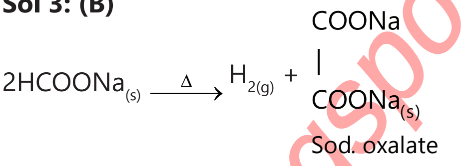
(D) Permanent hard water: Sulphate and chloride of Mg^{2+} / Ca^{2+}

Previous Years' Questions

Sol 1: (B) NaCl does not make water hard.

Sol 2: (A) Pure para form can be obtained at low temperature (20K) but pure orthoform is very difficult to obtain.

Sol 3: (B)



$$2HCOONa_{(s)} \xrightarrow{\Delta} H_{2(g)} + \begin{array}{c} COONa \\ | \\ COONa_{(s)} \end{array}$$

Sod. oxalate

Sol 4: (B) Presence of CO_3^{2-} and SO_4^{2-} ions in water reduces the tendency of dissolution of Pb in water as $Pb(OH)_2$

Sol 5: (C, D) Critical temperature of water is higher than O_2 because H_2O molecule has dipole moment, which is due to its V-shape.

Sol 6: (B, D) Both Ca^{2+} and Mg^{2+} ions present in hard water are exchanged by Na^+ ions present in zeolite.

Sol 7: (B, C) (b) $HCO_3^- + OH^- \rightarrow H_2O + CO_3^{2-}$ and $CaCO_3$ will get precipitated.

(C) $CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3$

(White)

precipitate

Sol 8: (A) As H_2O_2 is loosing electrons, it acts as a reducing agent.

Sol 9: (A) The structure of H_2O_2 is open book like.

Sol 10: (C) This is due to the formation of CrO_5.

$K_2Cr_2O_7 + H_2SO_4\ 4H_2O_2 \rightarrow K_2SO_4 + 2CrO_5 + 5H_2O$

Sol 11: (A)

$$KIO_4 + \overset{\text{R.A.}}{H_2O_2} \longrightarrow KIO_3 + H_2O + O_2$$

$$NH_2OH + \underset{\text{O.A.}}{H_2O_2} \longrightarrow H_2O + N_2O_3$$

JEE Main/Boards

Exercise 1

s-Block Elements

Sol 1: For metal to be obtained by chemical reduction, we need another element which is more electropositive (or have affinity towards oxygen) for reduction. All alkali & alkaline earth metals are the most electropositive elements of the periodic table. So, they cannot be obtained by chemical reduction methods.

Sol 2: During the electrolysis of NaCl solution, water molecules are reduced at cathode to form OH^- ions & H_2 gas. The obtained OH^- ions react with Na^+ ions to form NaOH. So, we cannot produce Na through electrolysis of NaCl solution.

Sol 3: Sodium has a higher melting point because of strong metallic bonds compound to potassium. It is because of low distance between nucleus & delocalised electrons in Na compare to K.

Sol 4: (i) $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2\uparrow$

(ii) $2Ca(OH)_2 + 2Cl_2 \rightarrow Ca(OCl)_2 + CaCl_2 + 2H_2O$

(iii) $Be(OH)_2 + 2NaOH \rightarrow Na_2Be(OH)_4$ (or Na_2BeO_2)

(iv) $BaO_2 + H_2SO_4 \rightarrow BaSO_4\downarrow + H_2O_2$

white ppt

Sol 5: Quick lime → CaO powder (grains)

Slaked lime → Water added to quick lime i.e. $Ca(OH)_2$. Its dry, light-coloured power.

Lime water → It's a saturated solution of $Ca(OH)_2$ in water.

Sol 6: The more the difference of electonegativities, the more is the ionic character.

∴ Covalent character of

MI > MBr > MCl > MF

Sol 7: Ionisation enthalpy is the energy required to remove the outermost electron from an atom. If we go down the group, the distance between nucleus and the outer electrons increase. So, I.E. will decrease.

Sol 8: (i) Li^+ forms an oxide due to its small size. It can polarise the peroxide ion. And lattice energy of Li_2O is high.

(ii) Na_2CO_3 is formed from NaOH & H_2CO_3, NaOH is a very strong base & H_2CO_3 is a weak acid. ∴ resulting solution is alkaline in nature.

(iii) Na can't be prepared by chemical reduction, because of it's high electropositivity. We need an element with more electropositivity to reduce it chemically.

Sol 9: LiI is more soluble than KI because of very high hydration energy of Li^+ ion. Due to its small size, Li^+ has a high hydration energy. So, LiI is more soluble.

Sol 10: $Na_2CO_3 \xrightarrow{SO_2} \overset{+4}{NaHSO_3} \xrightarrow{Na_2CO_3} \overset{+4}{Na_2SO_3}$

$\xrightarrow{\text{Elemental S}} \overset{+2}{Na_2S_2O_3} \xrightarrow{I_2} Na_2S_4O_6$

Sol 11: Sodium metal is highly reactive in the presence of oxidising chemicals whereas kerosene is chemically inactive. So, Na is stored in kerosene.

Sol 12: Gypsum $\rightarrow CaSO_4 \cdot 2H_2O$

$$\Big\downarrow \Delta$$

$$CaSO_4 \cdot \frac{1}{2}H_2O$$

Plaster of Paris

Sol 13: Dead burnt plaster is obtained on strong heating of POP

$$CaSO_4 \cdot \frac{1}{2}H_2O \xrightarrow{\Delta} CaSO_4$$

Plaster of Paris Dead burnt plaster

Sol 14: Super oxide → MO_2

i.e. M^+, O_2^-

O_2^- contain 17 electrons i.e. odd no. of electrons, So, atleast 1 e^- will be unpaired, so its paramagnetic. Normal oxide ions are O^{2-}. It's complete filled octet with no unpaired e^-. So, it's diamagnetic.

Sol 15: The main reason behind adding gypsum to cement is to control the rate of hardening of cement.

The cement will set immediately after mixing of water leaving no time for concrete placing.

Sol 16: Cs, K act as cathode in photoelectric cells. Cathodes must easily give e^-, Cs, K have low ionisation potentials but Li has relatively high IP, So, it is not preferred.

Sol 17: (i) Alkali metals are not in free form in nature because of their high reactivity. They either react with oxidising agents or these metals reduce other compounds.

(ii) Alkali metals are good reducing agents because they are the most electropositive elements. They have very low IP. So, they can lose an e^- very easily.

Sol 18: (i) As we go down a group, the strength of metallic bonds decrease due to increase in size between nucleus and delocalised electrons. So, their melting points decrease down the group, So, the softness increases down the group.

(ii) Lithium salts have greater covalent character because Li^+ is a small ion. So, it has high polarising power. So, covalent character increases.

Sol 19: (i) In the electrolysis of alkali salt solutions, the obtained M^+ ions react with OH^- ion at cathode to produce hydroxides.

(ii) $CaCl_2$ helps in reducing the melting point of the mixture and it acts as a flux.

(iii) $NaOH \xrightarrow{CO_2} Na_2CO_3 \xrightarrow{H_2O(g)} Na_2CO_3$ in moist form. After becoming crystals, it slowly loses water of crystallisation and becomes powder.

(iv) In Solvay's process, we get $NaHCO_3$ ppt as an intermediate, we obtain Na_2CO_3 from that precipitate. But, in case of potassium $KHCO_3$, it is soluble. So, getting K_2CO_3 is an expensive & difficult process.

(v) On adding excess of NaOH, all of the iodine becomes I^- & loses its colour.

Sol 20: (i) $2KO_2 + 2H_2O \rightarrow 2KOH + O_2 + H_2O_2$

(ii) $PbO_2 + \underset{\text{(Conc.)}}{2NaOH} \xrightarrow{\Delta} Na_2PbO_3 + H_2O$

(iii) $2KI + H_2SO_4 + H_2O_2 \rightarrow I_2 + K_2SO_4 + 2H_2O$

(iv) $6NaOH + 3I_2 \rightarrow 5Na + NaIO_3 + 3H_2O$

Sol 21: (i) Black Ash :- It is the impure form of Na_2CO_3. Its produced in Leblanc process

(ii) Action of NaOH of ammonium salts gives a sodium salt with liberation of NH_3 (Ammonia)

(iii) Washing soda :- $Na_2CO_3 . 10H_2O$

Sol 22: (i) $6NaOH + 3I_2 \rightarrow 5NaI + NaIO_3 + 3H_2O$

(ii) $P_4 + 3NaOH + 3H_2O \rightarrow 3NaH_2PO_2 + PH_3$

(iii) $ZnSO_4 + 2NaOH \rightarrow Zn(OH)_2 + Na_2SO_4$

(iv) $AlCl_3 + 3NaOH \rightarrow 3NaCl + Al(OH)_3$

$$\Big\downarrow \text{NaOH}$$

$$NaAlO_2 + 2H_2O$$

(v) $10\,K + 2KNO_3 \rightarrow 6K_2O + N_2$

(vi) $2Na + O_2 \xrightarrow{\Delta} Na_2O_2$

$$\Big\downarrow H_2SO_4$$

$$H_2O_2 + Na_2SO_4$$

Sol 23: (i) $Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2O$

(ii) $2AgNO_3 + 2NaOH \rightarrow 2NaNO_3 +$

$$\underbrace{Ag_2O + H_2O}$$

$$\Big\downarrow$$

$$2AgOH$$

(iii) $3NaOH + P_4 + 3H_2O \rightarrow 3NaH_2PO_2 + PH_3$

Disproportionation (Phosphine)

Sol 24: (i) NH_4Cl & KCl

Reaction with NaOH

NH_4Cl liberates NH_3

No effect of KCl

(ii) Na_2SO_3 and Na_2SO_4

Na_2SO_3 on action with a strong acid produce SO_2 gas

(iii) NaCl, KCl

Flame test

Gives different colours for different metals. Most of the chemical tests will fail to differentiate between them.

Sol 25: (i) KOH > NaOH > LiOH

because of Ionic character)

(ii) $LiHCO_3 < NaHCO_3 < KHCO_3$

(iii) $Li_2(CO_3) < Na_2CO_3 < K_2CO_3$

(iv) $Li^+ > Na^+ > K^+ > Rb^+ > Cs^+$

It is because of high positive charge density in smaller ions. So, it gets hydrated for more layers.

Sol 26: (i) $MgCl_2\,2H_2O \xrightarrow{\Delta} MgCl_2\,H_2O \xrightarrow{\Delta}$

$$\begin{tikzcd} Mg(OH)Cl \arrow[d] \\ \underbrace{MgO}_{} + HCl + H_2O \arrow[d] \\ \text{High lattice energy} \end{tikzcd}$$

(ii) $\underset{\text{Gypsum}}{CaSO_4.2H_2O} \xrightarrow[120°C]{\Delta} \underset{\text{Plasterof paris}}{CaSO_4.\frac{1}{2}H_2O}$

$$\begin{tikzcd} \xrightarrow[170°C]{\Delta} CaSO_4 \arrow[d, "\Delta"] \\ CaO + SO_2 + \frac{1}{2}O_2 \end{tikzcd}$$

Even $CaSO_4$ can be the final product.

(iii) $M(HCO_3)_2 \xrightarrow{\Delta} MCO_3+H_2O+CO_2$

(iv) $\underset{\text{Epsom salt}}{MgSO_4.7H_2O} \xrightarrow{\Delta} MgSO_4.H_2O$

$$\begin{tikzcd} \xrightarrow{\Delta} MgSO_4 \arrow[d, "\Delta"] \\ MgO + SO_2\uparrow + \frac{1}{2}O_2\uparrow \end{tikzcd}$$

Even here, $MgSO_4$ can be the last product.

(v) $Ba(NO_3)_2 \xrightarrow{\Delta} BaO + NO_2 + O_2$

Sol 27: (i) BeO is insoluble due to its high covalent nature. Be^{2+} has high polarising power and O^{2-} has high polarisability.

(ii) The covalent character of $BaSO_4$ is greater than that of BaO. It's because both of Be^{2+} and SO_4^{2-} are similar in size.

Sol 28: (i) The energy of the flame causes an excitation of the outer most electron which on return on its original position gives out energy released increases in accordance with the formula E = hν. The frequency of light is minimum in lithium which corresponds to red light.

(ii) Sodium is highly electropositive and hence is very reactive. It readily combines with oxygen, moisture and CO_2 of the atmosphere. Hence it is always kept in kerosene as to prevent the action of atmosphere.

(iii) Because of low ionization potentials, potassium and caesium are used in photoelectric cells. The low energy photons (light) can eject electrons from their metal surface.

Sol 29: (i) The dense charge of Li^+ attracts several layers of water molecules around it, i.e., Li^+ has maximum degree of hydration. Thus, the size of the hydrated metal ions which affects its movement in solution.

(ii) The small size of both the Li^+ and F^- ions leads to a very large lattice energy and thus, the crystal is very hard to break apart.

(iii) The salts of Li^+ with small anions have high lattice energy and thus very stable while with large anion, the lattice energy decreases and the salts become less stable.

Sol 30: (i) Sodium Bicarbonate;

(ii) Lithium Chloride;

(iii) Calcium Chloride;

(iv) Sodium Formate

Exercise 2

Single Correct Choice Type

Sol 1: (A) $2NaNO_3 \xrightarrow{\Delta} 2NaNO_2 + O_2\uparrow$

Sol 2: (A) In Downs process, we take fused NaCl for electrolysis so, we get Na in that Down's process.

Sol 3: (C) $MgCl_2\,.\,2H_2O \xrightarrow{\Delta} MgCl_2\,.H_2O \xrightarrow{\Delta}$ Mg(OH)Cl

Sol 4: (D) $2Mg + O_2 \rightarrow MgO$ ......(i)

$3Mg + N_2 \rightarrow Mg_3N_2$ ......(ii)

Sol 5: (D) Magnesite ore → $MgCO_3$ (It can have impurities of iron carbonate)

Sol 6: (A) $CaSO_4.\frac{1}{2}H_2O \xrightarrow{\text{Water}} \underset{\text{Gypsum}}{CaSO_4.2H_2O}$

Sol 7: (D) For 1A metals, $M(HCO_3)$ solubilities increase down the group. They are greater that NCO_3 where N is a alkali earth metal. (because of more covalent character and lattice energy)

$\therefore CaCO_3 < NaHCO_3 < KHCO_3$

Sol 8: (A) Nitrolium $\rightarrow CaCN_2 + C$ obtained by

$$\underset{\text{Calcium carbide}}{CaC_2} + \underset{\text{Nitrogen}}{N_2} \longrightarrow CaCN_2 + C$$

Sol 9: (A) Sodium sulphate is soluble because, it's hydration energy > lattice energy it is reverse for Barium sulphate.

Sol 10: (C) For alkali metals, electrolysis of molten salt is the most suitable method because of their high reactivities (in other methods, they give different compounds).

Sol 11: (D) Anhydrone :- $Mg(ClO_4)_2$

Sol 12: (A) The smallest alkali metal cation is Li^+.

Sol 13: (C) Due to more covalent character, LiCl is less soluble then NaCl in water.

Sol 14: (C) Li^+ have very high hydration energy due to high charge density. So, Li can act as reducing agent in solution state.

Sol 15: (C) Na → Intense yellow

K → Lilac

Li → Crimson (bright red)

Cs → Blue violet

Sol 16: (C) The blue colour is due to the presence of dissolved e^- in NH_3 solution. The e^- are from metal ions.

Sol 17: (A) LiF → because of small size of ions.

Sol 18: (C) $2Na + 2NH_3 \xrightarrow{\text{dry}} \underset{\text{Sodum amide}}{2NaNH_2} + H_2$

Sol 19: (A) $NaHCO_3$ and NaOH can't exist together in a solution as NaOH is a base and $NaHCO_3$ has an acidic hydrogen we will get Na_2CO_3

Sol 20: (D) Due to high hydration of Li^+, it's size increases drastically, decreasing it's mobility. So, it's a poor conductor.

Sol 21: (D) Polarity $\propto$ electronegativity difference

CsF > KCl > CaO > MgO

Sol 22: (D) It is clearly wrong as group elements have only 1 unpaired e^- in its outer shell. So, group IA elements are more electropositive than group IIA.

Sol 23: (D) In their unipositive state, they have 1 unpaired e^-. It's not stable. Thus, loses another e^- very easily. M^{2+} configuration is stable as it has filled orbitals. They have more lattice energy.

Sol 24: (A) As Mg, P, Al are in a period & electropositivity decrease, if we go right in a period.

So $EP_{mg} > EP_{Al} > EP_P$

& down a group, EP increases

So $EP_{Mg} > EP_{Be}$

$\therefore$ Mg has maximum EP in the given elements.

Sol 25: (C) For an ionic compound to be soluble in water, it's hydration energy must be greater than lattice energy. For alkaline earth metals, Be^{2+} has very low size. So, it's hydration energy is very high. So, its soluble.

Sol 26: (C) As HNO_3 is a strong oxidising agent, it oxidizes the surface of Be, Al. As BeO & Al_2O_3 have high lattice energies, the oxides acts as a protective layer and prevents the inner part of metal from undergoing reaction.

Sol 27: (A) (a) Epsom salt $\rightarrow MgSO_4 \cdot 7H_2O$

(b) Gypsum $\rightarrow CaSO_4 \cdot 2H_2O$

(c) $BaSO_4 \cdot H_2O$

Sol 28: (B) Blue john is a fluorite mixture (CaF_2).

Sol 29: (B) Ionic character & Electronegativity difference

$\therefore$ Greatest → RbCl

Least → $BeCl_2$

Sol 30: (D) $Zn(OH)_2$ because Zn is from d-block. It's amphoteric and not as electropositive as s-block elements.

Sol 31: (A) 2nd IP of IA metals will be very high as they will have inert gas configuration

2nd IP of IIA metals will be low as they will have s' configuration

∴ K > Ca > Ba

Previous Years' Questions

Sol 1: (B) $Na_2S_2O_3 + 4Cl_2 + 5H_2O \rightarrow 2NaHSO_4 + 8HCl$

Sol 2: (B)

$$NaCl + H_2O + CO_2 + NH_3 \longrightarrow NaHCO_3 + NH_4Cl$$

$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$$

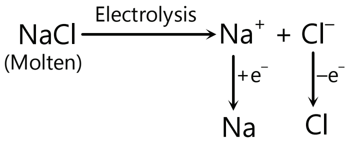
Sol 3: (A) $2I^- + 4H^+ + 2NO_2^- \rightarrow 2NO + I_2 + 2H_2O$

Sol 4: (B) $2Na + 2H_2O \rightarrow 2NaOH + H_2$

Sol 5: (A) $2Na + 2H_2O \rightarrow 2NaOH + H_2\uparrow$

$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$



$$\underset{\text{(Molten)}}{NaCl} \xrightarrow{\text{Electrolysis}} \begin{array}{ccc} Na^+ & + & Cl^- \\ \downarrow{\scriptstyle +e^-} & & \downarrow{\scriptstyle -e^-} \\ Na & & Cl \end{array}$$

Sol 6: (B) $Na_2SO_3 + S \xrightarrow{NaOH} \underset{\text{Sod. thiosulphate}}{Na_2S_2O_3}$

Sol 7: (D) Both assertion and reason are false. Radium is the rarest of all s-block elements comprising only 10^{-10} percent of igneous rocks. Francium (s-block member) is radioactive; its long lived isotope ^{223}Fr has a half life of only 21 minutes.

Sol 8: (C) Assertion is true but reason is false.

Due to high polarizing power of Li^+, LiCl is a covalent compound.

Sol 9: (C) Assertion is true but reason is false.

Be has fully filled $2s^2$-orbital which gives a relatively more stable electronic configuration.

Sol 10: (A) Both assertion and reason are true and reason is the correct explanation of assertion.

Sol 11: (A) Both assertion and reason are true and reason is the correct explanation of assertion.

Sol 12: (B) Factual.

Sol 13: (B) $BaSO_4$ is least soluble.

$BeSO_4$ is most soluble.

JEE Advanced/Boards

Exercise 1

Sol 1: (D) For alkali metals, the no. of shells go on increasing as we go down the group.

Sol 2: (A) Li is one of the elements coming as an exceptional case where in the bonding shows a covalent nature rather than ionic.

Sol 3: (B) Bigger atomic sizes.

Sol 4: (C) Readily absorbs moisture & carbon dioxide from air; reacts with CO_2 to form sodium carbonate.

Sol 5: (A) It's crystal lattice is quite rigid, has a very high enthalpy change of solution.

Sol 6: (A)

$$Ca(NH_2)_2 \underrightarrow{H_2O} Ca(OH)_2 + \underset{(B)}{NH_3}$$

$$\underset{(B)}{NH_3} + CaCl(OCl) \rightarrow CaCl_2 + H_2O + \underset{(C)}{N_2}$$

$$N_2 + Mg \rightarrow \underset{(D)}{Mg_3N_2}$$

$$Mg_3N_2 + H_2O \rightarrow Mg(OH)_2 + \underset{(B)}{NH_3}$$

Sol 7: (C) Fluorine being the halogen, its smallest atomic size & higher electronegativity accounts for the high lattice energy.

Sol 8: (B) Stability factor.

Solution for Q.9: (C), Q.10: (A) and **Q.11: (A)**

$$Sr + H_2O \rightarrow \underset{(C)}{Sr(OH)_2} + \underset{(B)}{H_2} \xrightarrow{Li} \underset{(D)}{LiH} + H_2O \rightarrow \underset{(E)}{Li(OH)}$$

$$Sr(OH)_2 + CO_2 \rightarrow \underset{\substack{\text{white ppt} \\ (F)}}{Sr(CO_3)_2} \xrightarrow{CO_2} \underset{(Cl)}{Sr(HCO_3)_2}$$

Sol 12: (D) Self explanatory.

Sol 13: (B) The only existing one.

Sol 14: (B) $KO_2 + H_2O \rightarrow KOH + O_2$

Sol 15: (A) Lattice energy.

Exercise 2

Single Correct Choice Type

Sol 1: (C) At one electrode

$2Cl^- \rightarrow Cl_2 + 2e^-$

At another

$Na^+ + H_2O \rightarrow NaOH + H^+$

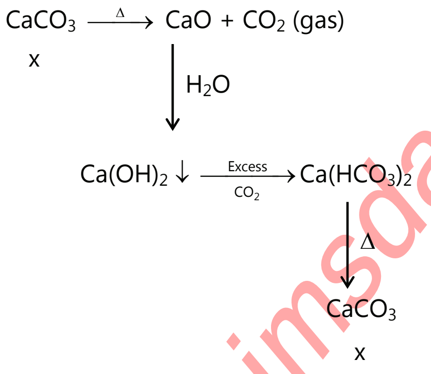
$\therefore Cl^-$ & H^-

Sol 2: (B) Iron (see the setup of Castner - Kelner cell)

Sol 3: (B) Electrolysis of aq. NaOH gives Cl_2, NaOH, H_2 If NaOH and Cl_2 get in contact, they react again to give NaCl.

Sol 4: (D) Generally on passing excess of CO_2, we get bicarbonates and bicarbonates give carbonates.

So, x must be carbonate and heating Na_2CO_3 doesn't give CO_2 easily



Sol 5: (C) As potassium has less BP & MP, it's more volatile and distils off at that temperature, moving the reaction in the forward direction.

Sol 6: (C) If the lattice energy is high, then solubility decreases.

$\therefore$ MgS is least soluble in water.

Sol 7: (D) Mg is more electropositive than C

$\therefore 2Mg + CO_2 \rightarrow 2MgO + C.$

Sol 8: (B) Solubility of hydroxides increases down the group in IIA metals.

$\therefore Sr(OH)_2$ is most soluble

Sol 9: (C) For sulphates & carbonates, hydration energy factor wins over lattice energy because of large anion size

$\therefore Be > Mg > Ca > Sr > Ba$

Sol 10: (C) $BaCO_3 \xrightarrow{H_2SO_4} \underset{\text{White ppt}}{BaSO_4 \downarrow}$

and barium chromate is yellow.

Sol 11: (D) Strontium decompose water readily than Be because of high electropositivity.

MP of $BaCO_3 > CaCO_3$

$Ba(OH)_2$ is more basic than $Be(OH)_2$

Sol 12: (B) Pungent smelting gas is of the barium salt,which is yellow in colour

Ba → green on flame test

$\therefore$ Salt is BaS_2O_3

Multiple Correct Choice Type

Sol 13: (A, B) Refer features of Bronsted acid /base.

Sol 14: (C, D) Aluminium alloys one used in aircraft.

Sol 15: (A, B, C) Properties of group-II elements.

Sol 16: (A, B, D) Diagonal Relationships.

Comprehension Type

Sol 17: (A) Lattice of MgO > CaO

because size of $Mg^{2+} < Ca^{2+}$

So, MgO is more stable.

Sol 18: (D) In cation and anion are of similar size then the resultant salt will be quite stable.

Sol 19: (A) $Na_2CO_3 \xrightarrow{\Delta} Na_2O + CO_2(g)$

Sol 20: (B) Li_2O

$Li - \ddot{\underset{\cdot\cdot}{O}} - Li$

Sol 21: (C) BH_4^- is a covalent hydride

$BH_4^- \longrightarrow OH^-$ Ions.

Sol 22: (B) We need H^- ions to react with $AlCl_3$ to get AlH_3. LiH is suitable.

Sol 23: (B) We get H_2 and metal. So, it will be highly basic.

Sol 24: (A) LiH → because of high lattice energy

Sol 25: (C) In ionic hydrides, H^- acts as a strong reducing agent.

Assertion Reasoning Type

Sol 26: (D) Assertion is wrong as Li^+ is highly hydrated compared to Na^+. So, size of hydrated Li^+ > hydrated Na^+. Even reaction is false as hydration energy of $Li^+ > Na^+$.

Sol 27: (D) $MnO_3 \xrightarrow{\Delta} MnO_2 + \frac{1}{2}O_2 \uparrow$ in case of alkali metals.

So, both A and R are false.

Sol 28: (A) $CaCO_3 \rightarrow$ nearly 840°C

$MgCO_3 \rightarrow$ nearly 660°C

though the lattice energy of $MgCO_3$ is more than $CaCO_3$, the temperature depends also on the lattice energy of obtained products i.e. MgO, CaO and difference in lattice energies of MgO & CaO is pretty high.

Sol 29: (A) K_3N is not possible because of high polarising power of N^{-3}

Li_3N is covalent with stable p bonds

So, R is correct explanation of A

Sol 30: (A) Li cannot be stored in kerosene because of its low density (i.e. more volatility) So, it floats in kerosene and has a probability of getting in contact in air. This may lead to an explosive reaction.

Previous Years' Questions

Sol 1: (B) Thermal stability of salts with common anion depends on polarizing power of cation. Greater the polarizing power, lower will be the thermal stability. Hence, $BeCO_3$ (IV) < $MgCO_3$ (II) < $CaCO_3$ (III) < K_2CO_3 (I)

Sol 2: (A) Electrolysis of aqueous Na_2SO_4 gives H_2 (g) at cathode and O_2(g)at anode.

Sol 3: (B) $Mg(HCO_3)_2$ on boiling decomposes to give white precipitate of $MgCO_3$ as

$Mg(HCO_3)_{2(aq)} \xrightarrow{\text{Heat}} MgCO_3\downarrow + H_2O + CO_2\uparrow$

Sol 4: (A, B) When sodium metal is burnt in excess of air, mainly sodium peroxide (Na_2O_2) with little sodium oxide (Na_2O) are formed.

Sol 5: (B, C, D) $Ca(OH)_2 + Ca(HCO_3)_2 \rightarrow 2CaCO_3\downarrow + 2H_2O$

(Clark's method)

$NaOCl + H_2 \rightarrow NaOH + HOCl$

$HO^- + HCO_3^- \rightarrow CO_3^{2-} + H_2O$

$Ca(HCO_3)_2 + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2NaHCO_3$

Sol 6: Heating $MgCl_2 .6H_2O$ brings about partial dehydration as

$MgCl_2.6H_2O \xrightarrow{\Delta} Mg(OHCl) + HCl + 5H_2O$

Sol 7: Sodium when burnt in excess of oxygen, gives sodium peroxide as major product

$Na + O_2 \xrightarrow{\Delta} \underset{\text{major}}{Na_2O_2} + \underset{\text{minor}}{Na_2O}$

Sol 8: The substance is Na_2O_2.When Na_2O_2 is dissolved in water, it forms NaOH and H_2O_2.In this case, NaOH is a strong base while H_2O_2 is a weak acid.

(i) $Na_2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_2$

H_2O_2 decolourises red litmus paper due to its bleaching action which is due to its oxidizing character.

$H_2O_2 \rightarrow H_2O + \underset{\substack{\text{bleaches colour}\\ \text{of red litmus}}}{[O]}$

(ii) If the compound is Na_2O, it will hydrolyse to form NaOH.

$Na_2O + H_2O \rightarrow 2NaOH$

NaOH solution formed above will change colour of red litmus paper into blue.

Sol 9: Be in $BeCl_2$ is electron deficient, short of two lone pair of electrons from stable octet. H_2O has lone pair of electrons, reacts with $BeCl_2$

Sol 10: $BaCO_3 + H_2SO_4 \rightarrow BaSO_4 + H_2O + CO_2$ $C = C^{14}$

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