

After studying this unit you will be able to

- describe the general characteristics of the alkali metals and their compounds;
- explain the general characteristics of the alkaline earth metals and their compounds;
- describe the manufacture, properties and uses of industrially important sodium and calcium compounds including Portland cement;
- appreciate the biological significance of sodium, potassium, magnesium and calcium.

The s-block elements of the Periodic Table are those in which the last electron enters the outermost s-orbital. As the s-orbital can accommodate only two electrons, two groups (1 & 2) belong to the s-block of the Periodic Table. Group 1 of the Periodic Table consists of the elements: lithium, sodium, potassium, rubidium, cesium and francium. They are collectively known as the alkali metals. These are so called because they form hydroxides on reaction with water which are strongly alkaline in nature. The elements of Group 2 include beryllium, magnesium, calcium, strontium, barium and radium. 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*.

Among the alkali metals sodium and potassium are abundant and lithium, rubidium and caesium have much lower abundances (Table 10.1). Francium is highly radioactive; its longest-lived isotope ^{223}Fr has a half-life of only 21 minutes. Of the alkaline earth metals calcium and magnesium rank fifth and sixth in abundance respectively in the earth's crust. Strontium and barium have much lower abundances. Beryllium is rare and radium is the rarest of all comprising only 10–10 per cent of igneous rocks† (Table 10.2, page 299).

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.

- ❖ The thin, rocky outer layer of the Earth is crust. † A type of rock formed from magma (molten rock) that has cooled and hardened.

Lithium and beryllium, the first elements of Group 1 and Group 2 respectively exhibit some properties which are different from those of the other members of the respective group. In these anomalous properties they resemble the second element of the following group. Thus, lithium shows similarities to magnesium and beryllium to aluminium in many of their properties. This type of diagonal similarity is commonly referred to as diagonal relationship in the periodic table. The diagonal relationship is due to the similarity in ionic sizes and /or charge/radius ratio of the elements. Monovalent sodium and potassium ions and divalent magnesium and calcium ions are

found in large proportions in biological fluids. These ions perform important biological functions such as maintenance of ion balance and nerve impulse conduction.

GROUP 1 ELEMENTS: ALKALI METALS

The alkali metals show regular trends in their physical and chemical properties with the increasing atomic number. The atomic, physical and chemical properties of alkali metals are discussed below.

Electronic Configuration

All the alkali metals have one valence electron, ns^1 (Table 10.1) outside the noble gas core. The loosely held s-electron in the outermost valence shell of these elements makes them the most electropositive metals. They readily lose electron to give monovalent M^+ ions. Hence they are never found in free state in nature.

Element	Symbol	Electronic configuration
Lithium	Li	$1s^2s^1$
Sodium	Na	$1s^22s^22p^63s^1$
Potassium	K	$1s^22s^22p^63s^23p^64s^1$
Rubidium	Rb	$1s^22s^22p^63s^23p^63d^{10}4s^24p^65s^1$
Caesium	Cs	$1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^25p^66s^1$ or [Xe] $6s^1$
Francium	Fr	[Rn] $7s^1$

Atomic and Ionic Radii

$Li > Na > K > Rb > Cs$.

Increase down the group, because value of n (principal quantum number) increases.

Ionization Enthalpy

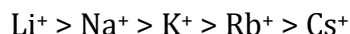
$Li > K > Na > Rb > Cs$.

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.

Hydration Enthalpy

The hydration enthalpies of alkali metal ions decrease with increase in ionic sizes.



Li^+ has maximum degree of hydration and for this reason lithium salts are mostly hydrated, e.g., $\text{LiCl} \cdot 2\text{H}_2\text{O}$

Physical Properties

- (i) All the alkali metals are silvery white, soft and light metals.
- (ii) Because of the large size, these elements have low density which increases down the group from Li to Cs. However, potassium is lighter than sodium.

$$\text{Li} < \text{K} < \text{Na} < \text{Rb} < \text{Cs}.$$
- (iii) The melting and boiling points of the alkali metals are low indicating weak metallic bonding due to the presence of only a single valence electron in them.
- (vi) The alkali metals and their salts impart characteristic colour to an oxidizing flame. This is because the heat from the flame excites the outermost orbital electron to a higher energy level. When the excited electron comes back to the ground state, there is emission of radiation in the visible region as given below:

Metal	Li	Na	K	Rb	Cs
Colour	Crimson	Yellow	Violet	Red violet	Blue
λ/nm	670.8	589.2	766.5	780.0	455.5

- (v) Alkali metals can therefore, be detected by the respective flame tests and can be determined by flame photometry or atomic absorption spectroscopy.
 These elements when irradiated with light, the light energy absorbed may be sufficient to make an atom lose electron.

Table Atomic and Physical Properties of the Alkali Metals

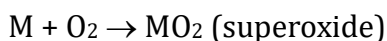
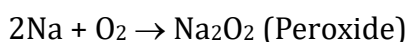
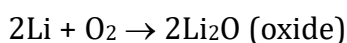
Property	Lithium mLi	Sodium mNa	Potassium mK	Rubidium mRb	Caesium mCs	Francium mFr
Atomic Number	3	11	19	37	55	87
Atomic mass (g mol ⁻¹)	6.94	22.99	39.10	85.47	132.91	(223)
Electronic configuration	[He] 2s ¹	[Ne] 3s ¹	[Ar] 4s ¹	[Kr] 5s ¹	[Xe] 6s ¹	[Rn] 7s ¹
Ionization enthalpy/kJ mol ⁻¹	520	496	419	403	376	375
Hydration enthalpy/kJ mol ⁻¹	-506	-406	-330	-310	-276	-
Metallic radius/pm	152	186	227	248	265	-
Ionic radius M ⁺ /pm	76	102	138	152	167	(180)
m.p./K	454	371	336	312	302	-
b.p./K	1615	1156	1032	961	944	-
Density/gcm ⁻³	0.53	0.97	0.86	1.53	1.90	-
Standard Potentials E ⁻ /V for(M ⁺ /M)	-3.04	-2.714	-2.925	-2.930	-2.927	-
Occurrence in lithosphere	18*	2.27**	1.84**	78-12*	2-6*	10 ⁻¹⁸ *

*ppm (part per million), ** percentage by weight; † Lithosphere: The Earth's outer layer: its crust and part of the upper mantle This property makes caesium and potassium useful as electrodes in photoelectric cells.

Chemical Properties

The alkali metals are highly reactive due to their large size and low ionization enthalpy. The reactivity of these metals increases down the group.

(i) Reactivity towards air: The alkali metals tarnish in dry air due to the formation of their oxides which in turn react with moisture to form hydroxides. They burn vigorously in oxygen forming oxides. Lithium forms monoxide, sodium forms peroxide, the other metals form superoxides. The superoxide O₂⁻ ion is stable only in the presence of large cations such as K, Rb, Cs.



(M = K, Rb, Cs)

In all these oxides the oxidation state of the alkali metal is +1. Lithium shows exceptional behaviour in reacting directly with nitrogen of air to form the nitride, Li_3N as well. Because of their high reacting towards air and water, **alkali metals are normally kept in kerosene oil.**

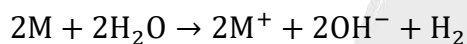
Problem 10.1

What is the oxidation state of K in KO_2 ?

Solution

The superoxide species is represented as O_2^- ; since the compound is neutral, therefore, the oxidation state of potassium is +1.

(ii) Reactivity towards water: The alkali metals react with water to form hydroxide and dihydrogen.



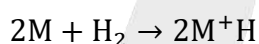
(M = an alkali metal)

It may be noted that although lithium has most negative E^\ominus value (Table 10.1), its reaction with water is less vigorous than that of sodium which has the least negative 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.

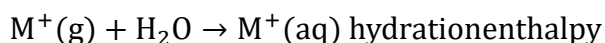
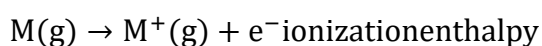
They also react with proton donors such as alcohol, gaseous ammonia and alkynes.

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



(iv) Reactivity towards halogens: The alkali metals readily react vigorously with halogens to form ionic halides, M^+X^- . However, lithium halides are somewhat covalent. It is because of the high polarisation capability of lithium ion (The distortion of electron cloud of the tendency to distort electron cloud around the negative halide ion. Since anion with large size can be easily distorted, among halides, lithium iodide is the most covalent in nature.

(v) Reducing nature: The alkali metals are strong reducing agents, lithium being the most and sodium the least powerful (Table 10.1). The standard electrode potential (E^\ominus) which measures the reducing power represents the overall change :



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.

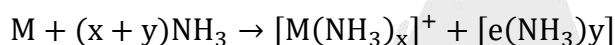
Problem 10.2

The E^\ominus for Cl_2/Cl^- is +1.36, for I_2/I^- is +0.53, for Ag^+/Ag is +0.79, Na^+/Na is -2.71 and for Li^+/Li is -3.04. Arrange the following ionic species in decreasing order of reducing strength : $\text{F}, \text{Ag}, \text{Cl}^-, \text{Li}, \text{Na}$

Solution

The order is $\text{Li} > \text{Na} > \text{I}^- > \text{Ag} > \text{Cl}^-$

(vi) Solutions in liquid ammonia: The alkali metals dissolve in liquid ammonia giving deep blue solutions which are conducting in nature.



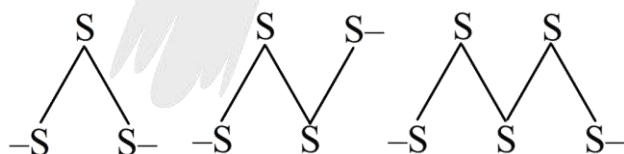
The blue colour of the solution is due to the ammoniated electron which absorbs energy in the visible region of light and thus imparts blue colour to the solution. The solutions are paramagnetic and on standing slowly liberate hydrogen resulting in the formation of amide.

$\text{M}_{(\text{am})}^+ + \text{e}^- + \text{NH}_3(1) \rightarrow \text{MNH}_{2(\text{am})} + 1/2\text{H}_2(\text{g})$ (where 'am' denotes solution in ammonia.) In concentrated solution, the blue colour changes to bronze colour and becomes diamagnetic.

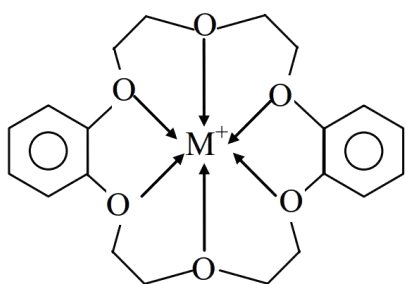
(vi) Reaction with H_2 : They react with H_2 forming metal hydride with formula MH which are of ionic nature. Stability of hydride decreases down the group.

(vii) Reaction with N_2 : Only Lithium reacts with N_2 to form ionic lithium nitride Li_3N . $3\text{Li} + \frac{3}{2}\text{N}_2 \rightarrow \text{Li}_3\text{N}$

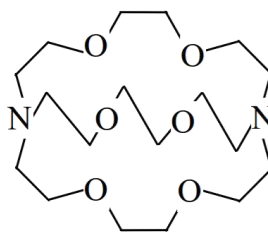
(viii) Sulphides: All metals react with S forming sulphides such as Na_2S and Na_2S_n ($n = 2, 3, 4, 5$ or 6). The polysulphide ions are made from zig-zag chains of sulphur atoms.



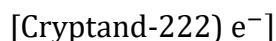
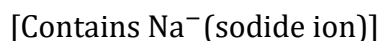
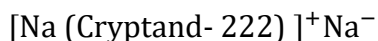
(ix) Crown Ethers and Cryptands:



Dibenzo- 18-Crown-6



Cryptand - 222

**Uses :**

Lithium metal is used to make useful alloys, for example with lead to make 'white metal' bearings for motor engines, with aluminium to make aircraft parts, and with magnesium to make armour plates. It is used in thermonuclear reactions. Lithium is also used to make These organolead compounds were earlier used as anti-knock additives to petrol, but nowadays vehicles use lead-free petrol. Liquid sodium metal is used as a coolant in fast breeder nuclear reactors. Potassium has a vital role in biological systems. Potassium chloride is used as a fertilizer. Potassium hydroxide is used in the manufacture of soft soap. It is also used as an excellent absorbent of carbon dioxide. Caesium is used in devising photoelectric cells.

LEARNER BOX - 1

- Q.1** Cs^+ ions impart violet colour to Bunsen flame. This is due to the fact that the emitted radiations are of
 (A) high energy (B) lower frequencies
 (C) longer wave-lengths (D) zero wave number
- Q.2** The alkali metals which form normal oxide, peroxide as well as super oxides are
 (A) Na, Li (B) K, Li (C) Li, Cs (D) K, Rb
- Q.3** Solution of sodium metal in liquid ammonia is a strong reducing agent due to presence of
 (A) solvated sodium ions (B) solvated hydrogen ions
 (C) sodium atoms or sodium hydroxide (D) solvated electrons
- Q.4** The order of solubility of lithium halides in non-polar solvents follows the order
 (A) $\text{LiI} > \text{LiBr} > \text{LiCl} > \text{LiF}$ (B) $\text{LiF} > \text{LiI} > \text{LiBr} > \text{LiCl}$
 (C) $\text{LiCl} > \text{LiF} > \text{LiI} > \text{LiBr}$ (D) $\text{LiBr} > \text{LiCl} > \text{LiF} > \text{LiI}$
- Q.5** CsBr_3 contains
 (A) Cs-Br covalent bonds (B) Cs^{3+} and Br^- ions
 (C) Cs^+ and Br_3^- ions (D) Cs^{3+} and Br_3^{3-} ions

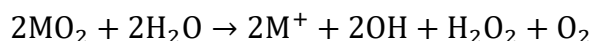
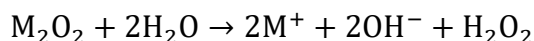
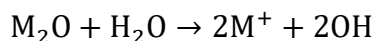
GENERAL CHARACTERISTICS OF THE COMPOUNDS OF THE ALKALI METALS

All the common compounds of the alkali metals are generally ionic in nature. General characteristics of some of their compounds are discussed here.

Oxides and Hydroxides

On combustion in excess of air, lithium forms mainly the oxide, Li_2O , sodium forms the peroxide, Na_2O_2 whilst potassium, rubidium and caesium form the superoxides, MO_2 . Under

appropriate conditions pure compounds M_2O , M_2O_2 and MO_2 may be prepared. The increasing stability of the peroxide or superoxide, as the size of the metal ion increases, is due to the stabilisation of large anions by larger cations through lattice energy effects. These oxides are easily hydrolyzed by water to form the hydroxides according to the following reactions :



The oxides and the peroxides are colourless when pure, but the superoxides are yellow or orange in colour. The superoxides are also paramagnetic. Sodium peroxide is widely used as an oxidizing agent in inorganic chemistry.

Problem

Why is KO_2 paramagnetic?

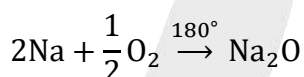
Solution

The superoxide O_2^- is paramagnetic because of one unpaired electron in π^*2p molecular orbital. The hydroxides which are obtained by the reaction of the oxides with water are all white crystalline solids. The alkali metal hydroxides are the strongest of all bases and dissolve freely in water with evolution of much heat on account of intense hydration.

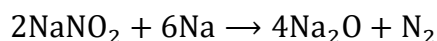
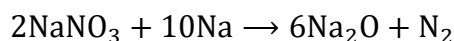
Sodium Oxide (Na_2O) :

Preparation:

- (i) It is obtained by burning sodium at 180°C in a limited supply of air or oxygen and distilling off the excess of sodium in vacuum.

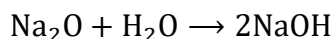


- (ii) By heating sodium peroxide, nitrate or nitrite with sodium.



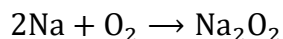
Properties :

- (i) It is white amorphous mass.
- (ii) It decomposes at 400°C into sodium peroxide and sodium $2Na_2O \xrightarrow{400^\circ} Na_2O_2 + 2Na$
- (iii) It dissolves violently in water, yielding caustic soda.

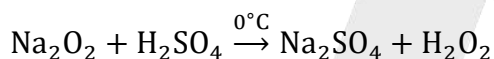
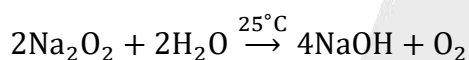
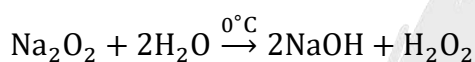


Sodium Peroxides (Na_2O_2) :**Preparation:**

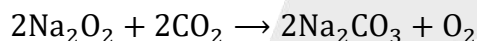
It is formed by heating the metal in excess of air or oxygen at 300° , which is free from moisture and CO_2 .

**Properties:**

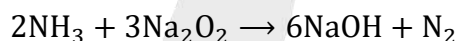
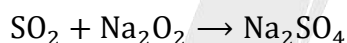
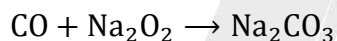
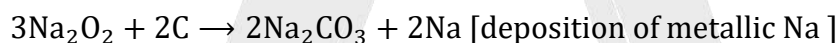
- (i) It is a pale yellow solid, becoming white in air from the formation of a film of NaOH and Na_2CO_3 .
- (ii) In cold water (0°C) produces H_2O_2 but at room temperature produces O_2 . In ice-cold mineral acids also produces H_2O_2 .



- (iii) It reacts with CO_2 , giving sodium carbonate and oxygen and hence its use for purifying air in a confined space e.g. submarine, ill-ventilated room,



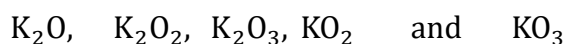
- (iv) It is an oxidising agent and oxidises charcoal, CO , NH_3 , SO_2 .



- (v) It contains peroxide ion $[-\text{O}-\text{O}]^2$

Uses:

- (i) For preparing H_2O_2 , O_2
- (ii) Oxygenating the air in submarines
- (iii) Oxidising agent in the laboratory.

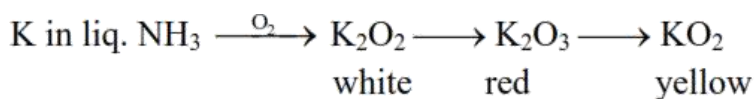
Oxides of Potassium:

Colours: White White Red Bright Yellow Orange Solid

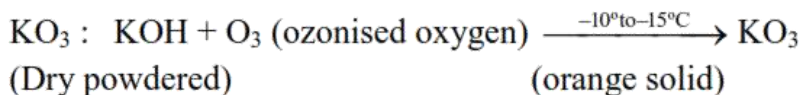
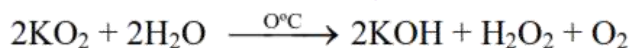
Preparation:

- (i) $2\text{KNO}_3 + 10\text{K} \xrightarrow{\text{heating}} 6\text{K}_2\text{O} + \text{N}_2$

(iii) Passage of O_2 through a blue solution of K in liquid NH_3 yields oxides K_2O_2 (white), K_2O_3 (red) and KO_2 (deep yellow) i.e



** KO_2 reacts with H_2O and produces H_2O_2 and O_2 both



** KO_2 reacts with H_2O and produces H_2O_2 and O_2 both $2KO_2 + 2H_2O \xrightarrow{0^\circ C} 2KOH + H_2O_2 + O_2$
(Dry powdered)
(orange solid)

Halides

The alkali metal halides, MX , ($X = F, Cl, Br, I$) are all high melting, colourless crystalline solids. They can be prepared by the reaction of the appropriate oxide, hydroxide or carbonate with aqueous hydrohalic acid (HX). All of these halides have high negative enthalpies of formation; the $\Delta_f H^\ominus$ values for fluorides become less negative as we go down the group, whilst the reverse is true for $\Delta_f H^\ominus$ for chlorides, bromides and iodides. For a given metal $\Delta_f H^\ominus$ always becomes less negative from fluoride to iodide.

Salts of Oxo-Acids

Oxo-acids are those in which the acidic proton is on a hydroxyl group with an oxo group attached to the same atom e.g., carbonic acid, H_2CO_3 ($OC(OH)_2$); sulphuric acid, H_2SO_4 ($O_2S(OH)_2$). The alkali metals form salts with all the oxo-acids. 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 carbonates and hydrogencarbonates increases. Lithium carbonate is not so stable to heat; lithium being very small in size polarises a large CO_3^{2-} ion leading to the formation of more stable Li_2O and CO_2 . Its hydrogencarbonate does not exist as a solid.

ANOMALOUS PROPERTIES OF LITHIUM

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

Points of Difference between Lithium and other Alkali Metals

- (i) Lithium is much harder. Its m.p. and b.p. are higher than the other alkali metals.
- (ii) Lithium is 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.
- (iii) LiCl is deliquescent and crystallises as a hydrate, $\text{LiCl} \cdot 2\text{H}_2\text{O}$ whereas other alkali metal chlorides do not form hydrates.
- (iv) Lithium hydrogencarbonate is not obtained in the solid form while all other elements form solid hydrogencarbonates.
- (v) Lithium unlike other alkali metals forms no ethynide on reaction with ethyne.
- (vi) Lithium nitrate when heated gives lithium oxide, Li_2O , whereas other alkali metal nitrates decompose to give the corresponding nitrite.

$$4\text{LiNO}_3 \rightarrow 2\text{Li}_2\text{O} + 4\text{NO}_2 + \text{O}_2$$

$$2\text{NaNO}_3 \rightarrow 2\text{NaNO}_2 + \text{O}_2$$
- (vii) LiF and Li_2O are comparatively much less soluble in water than the corresponding compounds of other alkali metals.

Points of Similarities between Lithium and Magnesium

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

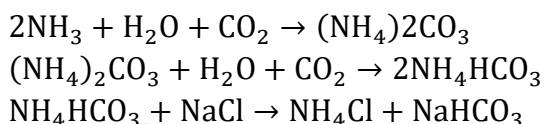
- (i) Both lithium and magnesium are harder and lighter than other elements in the respective groups.
- (ii) Lithium and magnesium react slowly with water. Their oxides and hydroxides are much less soluble and their hydroxides decompose on heating. Both form a nitride, Li_3N and Mg_3N_2 , by
- (iii) The oxides, Li_2O and MgO do not combine with excess oxygen to give any superoxide.
- (iv) 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.
- (v) Both LiCl and MgCl_2 are soluble in ethanol.
- (vi) Both LiCl and MgCl_2 are deliquescent and crystallise from aqueous solution as hydrates, $\text{LiCl} \cdot 2\text{H}_2\text{O}$ and $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$.

SOME IMPORTANT COMPOUNDS OF SODIUM

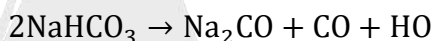
Industrially important compounds of sodium include sodium carbonate, sodium hydroxide, sodium chloride and sodium bicarbonate. The large scale production of these compounds and their uses are described below:

Sodium Carbonate (Washing Soda), $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$

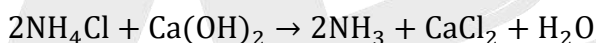
Sodium carbonate is generally prepared by Solvay Process. In this process, advantage is taken of the low solubility of sodium hydrogencarbonate whereby it gets precipitated in the reaction of sodium chloride with ammonium hydrogencarbonate. The latter is prepared by passing CO_2 to a concentrated solution of sodium chloride saturated with ammonia, where ammonium carbonate followed by ammonium hydrogencarbonate are formed. The equations for the complete process may be written as:



Sodium hydrogencarbonate crystal separates. These are heated to give sodium carbonate.



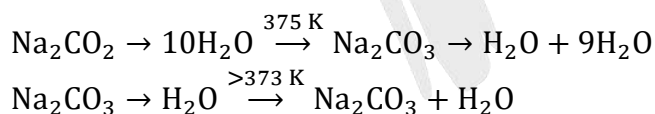
In this process NH_3 is recovered when the solution containing NH_4Cl is treated with $\text{Ca}(\text{OH})_2$. Calcium chloride is obtained as a by-product.



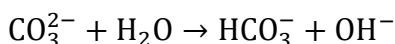
It may be mentioned here that Solvay process cannot be extended to the manufacture of potassium carbonate because potassium hydrogencarbonate is too soluble to be precipitated by the addition of ammonium hydrogencarbonate to a saturated solution of potassium chloride.

Properties :

Sodium carbonate is a white crystalline solid which exists as a decahydrate, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$. This is also called washing soda. It is readily soluble in water. On heating, the decahydrate loses its water of crystallisation to form monohydrate. Above 373 K, the monohydrate becomes completely anhydrous and changes to a white powder called soda ash.



Carbonate part of sodium carbonate gets hydrolysed by water to form an alkaline solution.



Uses:

- (i) It is used in water softening, laundering and cleaning.
- (ii) It is used in the manufacture of glass, soap, borax and caustic soda.
- (iii) It is used in paper, paints and textile industries.
- (iv) It is an important laboratory reagent both in qualitative and quantitative analysis.

Note: K_2CO_3 cannot be prepared by Solvey process because $KHCO_3$ is soluble in water and cannot be separated from NH_4Cl .

Sodium Chloride, NaCl

The most abundant source of sodium chloride is sea water which contains 2.7 to 2.9% by mass of the salt. In tropical countries like India, common salt is generally obtained by evaporation of sea water. Approximately 50 lac tons of salt are produced annually in India by solar evaporation. Crude sodium chloride, generally obtained by crystallisation of brine solution, contains sodium sulphate, calcium sulphate, calcium chloride and magnesium chloride as impurities. Calcium chloride, $CaCl_2$, and magnesium chloride, $MgCl_2$ are impurities because they are deliquescent (absorb moisture easily from the atmosphere). To obtain pure sodium chloride, the crude salt is dissolved in minimum amount of water and filtered to remove insoluble impurities. The solution is then saturated with hydrogen chloride gas. Crystals of pure sodium chloride separate out. Calcium and magnesium chloride, being more soluble than sodium chloride, remain in solution.

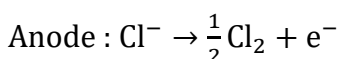
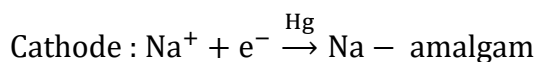
Sodium chloride melts at 1081 K. It has a solubility of 36.0 g in 100 g of water at 273 K. The solubility does not increase appreciably with increase in temperature.

Uses :

- (i) It is used as a common salt or table salt for domestic purpose.
- (ii) It is used for the preparation of Na_2O_2 , $NaOH$ and Na_2CO_3 .
- (iii) It is used to prepare freezing mixture in laboratory [Ice-common salt mixture is called freezing mixture and temperature goes down to $-23^\circ C$.]
- (iv) For melting ice and snow on road.

Sodium Hydroxide (Caustic Soda), NaOH

Sodium hydroxide is generally prepared commercially by the electrolysis of sodium chloride in Castner-Kellner cell. A brine solution is electrolysed using a mercury cathode and a carbon anode. Sodium metal discharged at the cathode combines with mercury to form sodium amalgam. Chlorine gas is evolved at the anode.



The amalgam is treated with water to give sodium hydroxide and hydrogen gas. $2Na\text{-amalgam} + 2H_2O \rightarrow 2NaOH + 2Hg + H_2$

Sodium hydroxide is a white, translucent solid. It melts at 591 K. It is readily soluble in water to give a

strong alkaline solution. Crystals of sodium hydroxide are deliquescent. The sodium hydroxide solution at the surface reacts with the CO_2 in the atmosphere to form Na_2CO_3 .

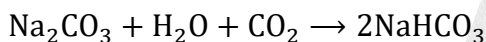
Uses

It is used in (i) the manufacture of soap, paper, artificial silk and a number of chemicals, (ii) in petroleum refining, (iii) in the purification of bauxite, (iv) in the textile industries for mercerizing cotton fabrics, (v) for the preparation of pure fats and oils, and (vi) as a laboratory reagent.

Sodium Hydrogencarbonate (Baking Soda), NaHCO_3

Sodium hydrogencarbonate is known as baking soda because it decomposes on heating to generate bubbles of carbon dioxide (leaving holes in cakes or pastries and making them light and fluffy).

Sodium hydrogencarbonate is made by saturating a solution of sodium carbonate with carbon dioxide. The white crystalline powder of sodium hydrogencarbonate, being less soluble, gets separated out.



Sodium hydrogencarbonate is a mild antiseptic for skin infections. It is used in fire extinguishers.

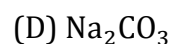
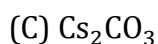
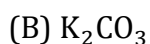
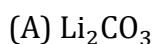
BIOLOGICAL IMPORTANCE OF SODIUM AND POTASSIUM

A typical 70 kg man contains about 90 g of Na and 170 g of K compared with only 5 g of iron and 0.06 g of copper. Sodium ions are found primarily on the outside of cells, being located in blood plasma and in the interstitial fluid which surrounds the cells. These ions participate in the transmission of nerve signals, in regulating the flow of water across cell membranes and in the transport of sugars and amino acids into cells. Sodium and potassium, although so similar chemically, differ quantitatively in their ability to penetrate cell membranes, in their transport mechanisms and in their efficiency to activate enzymes. Thus, potassium ions are the most abundant cations within cell fluids, where they activate many enzymes, participate in the oxidation of glucose to produce ATP and, with sodium, are responsible for the transmission of nerve signals.

There is a very considerable variation in the concentration of sodium and potassium ions found on the opposite sides of cell membranes. As a typical example, in blood plasma, sodium is present to the extent of 143mmolL^{-1} , whereas the potassium level is only 5mmolL^{-1} within the red blood cells. These concentrations change to $10\text{mmolL}^{-1}(\text{Na}^+)$ and $105\text{mmolL}^{-1}(\text{K}^+)$. These ionic gradients demonstrate that a discriminatory mechanism, called the sodiumpotassium pump, operates across the cell membranes which consumes more than one-third of the ATP used by a resting animal and about 15 kg per 24 h in a resting human.

LEARNER BOX - 2

Q.1 Which of the following carbonate of alkali metals has the least thermal stability?



- Q.2** The pair of compounds, which cannot exist together in a solution is
 (A) NaHCO_3 and NaOH (B) Na_2CO_3 and NaOH
 (C) NaHCO_3 and Na_2CO_3 (D) NaHCO_3 and H_2O
- Q.3** $\text{aq. NaOH} + \text{P}_4 \text{ (white)} \rightarrow \text{PH}_3 + \text{X}$; compound X is
 (A) NaH_2PO_2 (B) NaHPO_4
 (C) Na_2CO_3 (D) NaHCO_3
- Q.4** The correct order of solubility is
 (A) $\text{CaCO}_3 < \text{KHCO}_3 < \text{NaHCO}_3$ (B) $\text{KHCO}_3 < \text{CaCO}_3 < \text{NaHCO}_3$
 (C) $\text{NaHCO}_3 < \text{CaCO}_3 < \text{KHCO}_3$ (D) $\text{CaCO}_3 < \text{NaHCO}_3 < \text{KHCO}_3$

GROUP 2 ELEMENTS : ALKALINE EARTH METALS

The group 2 elements comprise beryllium, magnesium, calcium, strontium, barium and radium. They follow alkali metals in the periodic table. These (except beryllium) are known as alkaline earth metals. The first element beryllium differs from the rest of the members and shows diagonal relationship to aluminium. The atomic and physical properties of the alkaline earth metals are shown in Table 10.2.

Electronic Configuration

These elements have two electrons in the s-orbital of the valence shell (Table 10.2). Their general electronic configuration may be represented as [noble gas] ns^2 . Like alkali metals, the compounds of these elements are also predominantly ionic.

Element	Symbol	Electronic configuration
Beryllium	Be	$1s^2 2s^2$
Magnesium	Mg	$1s^2 2s^2 2p^6 3s^2$
Calcium	Ca	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
Strontium	Sr	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2$
Barium	Ba	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6 6s^2$ or $[\text{Xe}] 6s^2$
Radium	Ra	$[\text{Rn}] 7s^2$

Atomic and Ionic Radii

The atomic and ionic radii of the alkaline earth metals are smaller than those of the

Table 10.2 Atomic and Physical Properties of the Alkaline Earth Metals

(Inorganic Chemistry)

s-BLOCK ELEMENTS

Property	Beryllium Be	Magnesium Mg	Calcium Ca	Strontium Sr	Barium Ba	Radium Ra
Atomic Number	4	12	20	38	56	88
Atomic mass (g mol ⁻¹)	9.01	24.31	40.08	87.62	137.33	222.03
Electronic configuration	[He] 2s ²	[Ne] 3s ²	[Ar] 4s ²	[Kr] 5s ²	[Xe] 6s ²	[Rn] 7s ²
Ionization enthalpy (I)/kJ mol ⁻¹	899	737	590	549	503	509
Hydration enthalpy (II)/kJ mol ⁻¹	-2494	-1921	-1577	-1443	-1305	-
Metallic radius/pm	111	160	197	215	222	-
Ionic radius M ⁺ /pm	31	72	100	118	135	148
m.p./K	1560	924	1124	1062	1002	973
b.p./K	2745	1363	1767	1655	2078	(1973)
Density/gcm ⁻³	1.84	1.74	1.55	2.63	3.59	(5.5)
Standard Potentials E ⁻ /V for (M ⁺ /M)	-1.97	-2.36	-2.84	-2.89	-2.92	-2.92
Occurrence in lithosphere	2*	2.76**	4.6**	384*	390*	10 ⁻⁶ *

*ppm (part per million); ** percentage by weight

corresponding alkali metals in the same periods. This is due to the increased nuclear charge in these elements. Within the group, the atomic and ionic radii increase with increase in atomic number.

Ionization Enthalpies**Ionization Enthalpy**

Be > Mg > Ca > Sr > Ba

Down the group IE decreases due to increase in size

Q. IE₁ of AM < IE₁ of AEM

IE₂ of AM > IE₂ of AEM

[where AM = Alkali metal, AEM = Alkaline earth metal]

Reason : IE₁ of AEM is large due to increased nuclear charge in AEM as compared to AM but IE₂ of AM is large because second electron in AM is to be removed from cation which has already acquired noble gas configuration.

Hydration Enthalpies

Like alkali metal ions, the hydration enthalpies of alkaline earth metal ions decrease with increase in

ionic size down the group. $\text{Be}^{2+} > \text{Mg}^{2+} > \text{Ca}^{2+} > \text{Sr}^{2+} > \text{Ba}^{2+}$

The hydration enthalpies of alkaline earth metal ions are larger than those of alkali metal ions. Thus, compounds of alkaline earth metals are more extensively hydrated than those of alkali metals, e.g., MgCl_2 and CaCl_2 exist as $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ and $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$ while NaCl and KCl do not form such hydrates.

Physical Properties

- (i) The alkaline earth metals, in general, are silvery white, lustrous and relatively soft but harder than the alkali metals. Beryllium and magnesium appear to be somewhat grayish.
- (ii) The melting and boiling points of these metals are higher than the corresponding alkali metals due to smaller sizes. The trend is, however, not systematic.
- (iii) Because of the low ionisation enthalpies, they are strongly electropositive in nature. The electropositive character increases down the group from Be to Ba.
- (iv) Calcium, strontium and barium impart characteristic brick red, crimson and apple green colours respectively to the flame. In flame the electrons are excited to higher energy levels and when they drop back to the ground state, energy is emitted in the form of visible light. The electrons in beryllium and magnesium are too strongly bound to get excited by flame. Hence, these elements do not impart any colour to the flame. The flame test for Ca, Sr and Ba is helpful in their detection in qualitative analysis and estimation by flame photometry.
- (v) The alkaline earth metals like those of alkali metals have high electrical and thermal conductivities which are typical characteristics of metals.

Chemical Properties

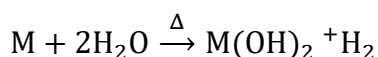
The alkaline earth metals are less reactive than the alkali metals. The reactivity of these elements increases on going down the group.

- (i) Reactivity towards air : Beryllium and magnesium are kinetically 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 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.

- (ii) Reactivity towards water.

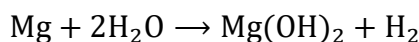
Reaction with H_2O

AEM have lesser tendency to react with water as compared to AM. They form hydroxides and liberate H_2 on reaction with H_2O



- Be is inert towards water.

- Magnesium react as

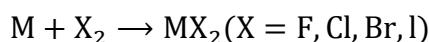


MgO forms protective layer, that is why it does not react readily unless layer is removed amalgamating with Hg.

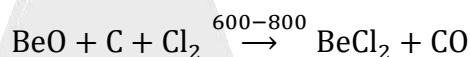
Other metals react quite readily (Ca, Sr, Ba).

Note: Be(OH)₂ is amphoteric but other hydroxides are basic in nature.

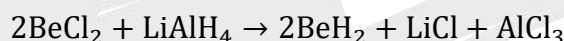
- (iii) Reactivity towards the halogens:** All the alkaline earth metals combine with halogen at elevated temperatures forming their halides.



Thermal decomposition of (NH₄)₂BeF₄ is the best route for the preparation of BeF₂, and BeCl₂ is conveniently made from the oxide.



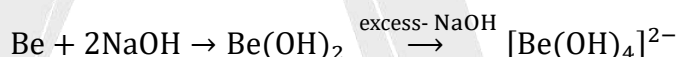
- (iv) Reactivity towards hydrogen:** All the elements except beryllium combine with hydrogen upon heating to form their hydrides, MH₂. BeH₂, however, can be prepared by the reaction of BeCl₂ with LiAlH₄.



- (v) Reactivity towards acids:** AEM react with acids & liberate H₂



Be is amphoteric as it also react with NaOH, other metals do not react as they are purely basic.



- (vi) Reducing nature:** Like alkali metals, the alkaline earth metals are strong reducing agents. This is indicated by large negative values of their reduction potentials (Table 10.2). However their reducing power is less than those of their corresponding alkali metals. Beryllium has less negative value compared to other alkaline earth metals. However, its reducing nature is due to large hydration energy associated with the small size of Be²⁺ ion and relatively large value of the atomization enthalpy of the metal.

- (vii) Solutions in liquid ammonia:** Like alkali metals, the alkaline earth metals dissolve in liquid ammonia to give deep blue black solutions forming ammoniated ions.



From these solutions, the ammoniates, [M(NH₃)₆]²⁺ can be recovered.

Uses

Be : Beryllium is used in the manufacture of alloys. Copper-beryllium alloys are used in the

preparation of high strength springs. Metallic beryllium is used for making windows of X-ray tubes.

Mg: Magnesium forms alloys with aluminium, zinc, manganese and tin. Magnesiumaluminium alloys being light in mass are used in air-craft construction. Magnesium (powder and ribbon) is used in flash powders and bulbs, incendiary bombs and signals. A suspension of magnesium hydroxide in water (called milk of magnesia) is used as antacid in medicine. Magnesium carbonate is an ingredient of toothpaste.

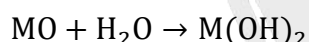
Ca : Calcium is used in the extraction of metals from oxides which are difficult to reduce with carbon. Calcium and barium metals, owing to their reactivity with oxygen and nitrogen at elevated temperatures, have often been used to remove air from vacuum tubes.

Ra : Radium salts are used in radiotherapy, for example, in the treatment of cancer.

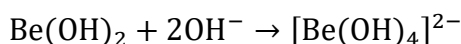
GENERAL CHARACTERISTICS OF COMPOUNDS OF THE ALKALINE EARTH METALS

The dipositive oxidation state (M^{2+}) is the predominant valence of Group 2 elements. The alkaline earth metals form compounds which are predominantly ionic but less ionic than the corresponding compounds of alkali metals. This is due to increased nuclear charge and smaller size. The oxides and other compounds of beryllium and magnesium are more covalent than those formed by the heavier and large sized members (Ca, Sr, Ba). The general characteristics of some of the compounds of alkali earth metals are described below.

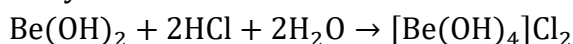
(i) Oxides and Hydroxides: The alkaline earth metals burn in oxygen to form the monoxide, MO which, except for BeO, have rock-salt structure. The BeO is essentially covalent in nature. The enthalpies of formation of these oxides are quite high and consequently they are very stable to heat. BeO is amphoteric 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.



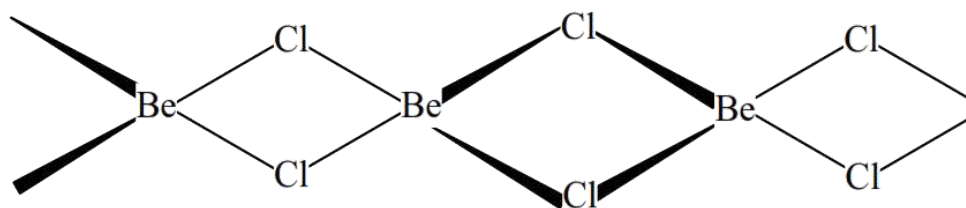
The solubility, thermal stability and the basic character of these hydroxides increase with increasing atomic number from $Mg(OH)_2$ to $Ba(OH)_2$. The alkaline earth metal hydroxides are, however, less basic and less stable than alkali metal hydroxides. Beryllium hydroxide is amphoteric in nature as it reacts with acid and alkali both.



Beryllate ion



(ii) Halides: Except for beryllium halides, all other halides of alkaline earth metals are ionic in nature. Beryllium halides are essentially covalent and soluble in organic solvents. Beryllium chloride has a chain structure in the solid state as shown below:



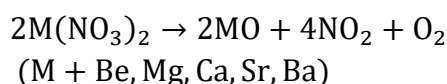
In the vapour phase BeCl_2 tends to form a chloro-bridged dimer which dissociates into the linear monomer at high temperatures of the order of 1200 K. The tendency to form halide hydrates gradually decreases (for example, $\text{MgCl}_2 \cdot 8\text{H}_2\text{O}$, $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$, $\text{SrCl}_2 \cdot 6\text{H}_2\text{O}$ and $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$) 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.

(iii) **Salts of Oxoacids:** The alkaline earth metals also form salts of oxoacids. Some of these are :

Carbonates: Carbonates of alkaline earth metals are insoluble in water and can be precipitated by 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 the 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.

Sulphates: The sulphates of the alkaline earth metals are all white solids and 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.

Nitrates: The nitrates are made by dissolution of the carbonates in dilute nitric acid. Magnesium nitrate crystallises with six molecules of water, whereas barium nitrate crystallises 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 the oxide like lithium nitrate.



Problem

Why does the solubility of alkaline earth metal hydroxides in water increase down the group?

Solution

Among alkaline earth metal hydroxides, the anion being common the cationic radius will influence the lattice enthalpy. Since lattice enthalpy decreases much more than the hydration enthalpy with

increasing ionic size, the solubility increases as we go down the group.

Problem 10.5

Why does the solubility of alkaline earth metal carbonates and sulphates in water decrease down the group?

Solution

The size of anions being much larger compared to cations, the lattice enthalpy will remain almost constant within a particular group. Since the hydration enthalpies decrease down the group, solubility will decrease as found for alkaline earth metal carbonates and sulphates.

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. Further, it shows diagonal relationship to aluminium which is discussed subsequently.

- (i) Beryllium has exceptionally small atomic and ionic sizes and thus does not compare well with other members of the group. Because of high ionisation enthalpy and small size it forms compounds which are largely covalent and get easily hydrolysed.
- (ii) Beryllium does not exhibit 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.
- (iii) The oxide and hydroxide of beryllium, unlike the hydroxides of other elements in the group, are amphoteric in nature.

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:

- (i) Like aluminium, beryllium is not readily attacked by acids because of the presence of an oxide film on the surface of the metal.
- (ii) Beryllium hydroxide dissolves in excess of alkali to give a beryllate ion, $[\text{Be}(\text{OH})_4]^{2-}$ just as aluminium hydroxide gives aluminate ion, $[\text{Al}(\text{OH})_4]^-$.
- (iii) The chlorides of both beryllium and aluminium have Cl^- -bridged chloride structure in vapour phase. Both the chlorides are soluble in organic solvents and are strong Lewis acids. They are used as Friedel Craft catalysts.
- (iv) Beryllium and aluminium ions have strong tendency to form complexes, BeF_4^{2-} , AlF_6^{3-} .

LEARNER BOX - 3

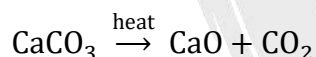
- Q.1** The compound(s) of alkaline earth metals, which are amphoteric in nature is/are
 (A) BeO (B) MgO (C) Be(OH)₂ (D) Mg(OH)₂
- Q.2** An alkaline earth metal (M) gives a salt with chlorine, which is soluble in water at room temperature. It also forms an insoluble sulphate whose mixture with a sulphide of a transition metal is called 'lithopone' -a white pigment. Metal M is
 (A) Ca (B) Mg (C) Ba (D) Sr
- Q.3** $\text{Mg}_2\text{C}_3 + \text{H}_2\text{O} \rightarrow \text{X}$ (organic compound). Compound X is
 (A) C₂H₂ (B) CH₄ (C) propyne (D) ethene
- Q.4** The hydration energy of Mg²⁺ is
 (A) more than that of Mg³⁺ ion (B) more than that of Na⁻⁴ ion
 (C) more than that of Al³⁺ ion (D) more than that of Be²⁺ ion
- Q.5** A pair of substances which gives the same products on reaction with water is
 (A) Mg and MgO (B) Sr and SrO
 (C) Ca and CaH₂ (D) Be and BeO

SOME IMPORTANT COMPOUNDS OF CALCIUM

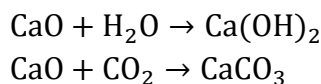
Important compounds of calcium are calcium oxide, calcium hydroxide, calcium sulphate, calcium carbonate and cement. These are industrially important compounds. The large scale preparation of these compounds and their uses are described below.

Calcium Oxide or Quick Lime, CaO

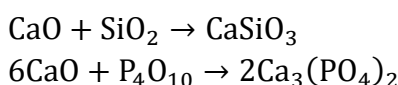
It is prepared on a commercial scale by heating limestone (CaCO₃) in a rotary kiln at 1070-1270 K.



The carbon dioxide is removed as soon as it is produced to enable the reaction to proceed to completion. Calcium oxide is a white amorphous solid. It has a melting point of 2870 K. On exposure to atmosphere, it absorbs moisture and carbon dioxide.



The addition of limited amount of water breaks the lump of lime. This process is called slaking of lime. Quick lime slaked with soda gives solid sodalime. Being a basic oxide, it combines with acidic oxides at high temperature.



Uses:

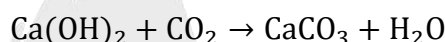
- (i) It is an important primary material for manufacturing cement and is the cheapest form of alkali.
- (ii) It is used in the manufacture of sodium carbonate from caustic soda.
- (iii) It is employed in the purification of sugar and in the manufacture of dye stuffs.

Calcium Hydroxide (Slaked lime), Ca(OH)_2

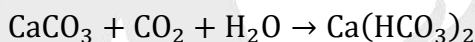
Calcium hydroxide is prepared by adding water to quick lime, CaO .

It is a white amorphous powder. It is sparingly soluble in water. The aqueous solution is known as lime water and a suspension of slaked lime in water is known as milk of lime.

When carbon dioxide is passed through lime water it turns milky due to the formation of calcium carbonate.



On passing excess of carbon dioxide, the precipitate dissolves to form calcium hydrogencarbonate.



Milk of lime reacts with chlorine to form hypochlorite, a constituent of bleaching powder.

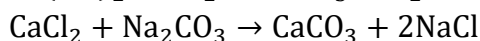
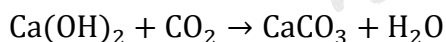


Uses:

- (i) It is used in the preparation of mortar, a building material.
- (ii) It is used in white wash due to its disinfectant nature.
- (iii) It is used in glass making, in tanning industry, for the preparation of bleaching powder and for purification of sugar.

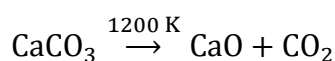
Calcium Carbonate, CaCO_3

Calcium carbonate occurs in nature in several forms like limestone, chalk, marble etc. It can be prepared by passing carbon dioxide through slaked lime or by the addition of sodium carbonate to calcium chloride.

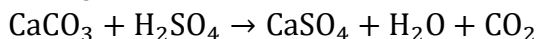
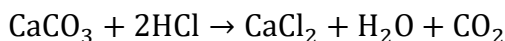


Excess of carbon dioxide should be avoided since this leads to the formation of water soluble calcium hydrogencarbonate.

Calcium carbonate is a white fluffy powder. It is almost insoluble in water. When heated to 1200 K, it decomposes to evolve carbon dioxide.



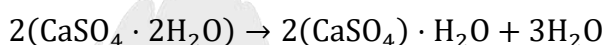
It reacts with dilute acid to liberate carbon dioxide.

**Uses:**

It is used as a building material in the form of marble and in the manufacture of quick lime. Calcium carbonate along with magnesium carbonate is used as a flux in the extraction of metals such as iron. Specially precipitated CaCO_3 is extensively used in the manufacture of high quality paper. It is also used as an antacid, mild abrasive in tooth paste, a constituent of chewing gum, and a filler in cosmetics.

Calcium Sulphate (Plaster of Paris), $\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$

It is a hemihydrate of calcium sulphate. It is obtained when gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, is heated to 393 K.



Above 393 K, no water of crystallisation is left and anhydrous calcium sulphate, CaSO_4 is formed.

This is known as 'dead burnt plaster'.

It has a remarkable property of setting with water. On mixing with an adequate quantity of water it forms a plastic mass that gets into a hard solid in 5 to 15 minutes.

Uses:

The largest use of Plaster of Paris is in the building industry as well as plasters. It is used for immobilising the affected part of organ where there is a bone fracture or sprain. It is also employed in dentistry, in ornamental work and for making casts of statues and busts.

Cement: Cement is an important building material. It was first introduced in England in 1824 by Joseph Aspdin. It is also called Portland cement because it resembles with the natural limestone quarried in the Isle of Portland, England. Cement is a product obtained by combining a material rich in lime, CaO with other material such as clay which contains silica, SiO_2 along with the oxides of aluminium, iron and magnesium. The average composition of Portland cement is :

CaO , 50 – 60%; SiO_2 , 20 – 25%; Al_2O_3 , 5 – 10%; MgO , 2 – 3%; Fe_2O_3 , 1 – 2% and SO_3 , 1 – 2%. For a good quality cement, the ratio of silica (SiO_2) to alumina (Al_2O_3) should be between 2.5 and 4 and the ratio of lime (CaO) to the total of the oxides of silicon (SiO_2) aluminium (Al_2O_3) and iron (Fe_2O_3) should be as close as possible to 2 .

The raw materials for the manufacture of cement are limestone and clay. When clay and lime are strongly heated together they fuse and react to form 'cement clinker'. This clinker is mixed with 2- 3% by weight of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) to form cement. Thus important ingredients present in Portland cement are dicalcium silicate (Ca_2SiO_4) 26%, tricalcium silicate (Ca_3SiO_5) 51% and tricalcium aluminate ($\text{Ca}_3\text{Al}_2\text{O}_6$) 11%.

Setting of Cement

When mixed with water, the setting of cement takes place to give a hard mass. This is due to the hydration of the molecules of the constituents and their rearrangement. The purpose of adding gypsum is only to slow down the process of setting of the cement so that it gets sufficiently hardened.

Uses: Cement has become a commodity of national necessity for any country next to iron and steel. It is used in concrete and reinforced concrete, in plastering and in the construction of bridges, dams and buildings.

BIOLOGICAL IMPORTANCE OF MAGNESIUM AND CALCIUM

An adult body contains about 25 g of Mg and 1200 g of Ca compared with only 5 g of iron and 0.06 g of copper. The daily requirement in the human body has been estimated to be 200 – 300 mg. All enzymes that utilise ATP in phosphate transfer require magnesium as the cofactor. The main pigment for the absorption of light in plants is chlorophyll which contains magnesium. About 99% of body calcium is present in bones and teeth. It also plays important roles in neuromuscular function, interneuronal transmission, cell membrane integrity and blood coagulation. The calcium concentration in plasma is regulated at about 100mgL^{-1} . It is maintained by two hormones: calcitonin and parathyroid hormone. Do you know that bone is not an inert and unchanging substance but is continuously being solubilised and redeposited to the extent of 400mg per day in man? All this calcium passes through the plasma.

LEARNER BOX – 4

- Q.1** The incorrect statement is/are
- (A) BeCl_2 is a ionic compound
 - (B) BeCl_2 is an electron deficient molecule
 - (C) BeCl_2 can form dimer
 - (D) the hybrid state of Be in BeCl_2 is sp^2 in its dimer
- Q.2** Fire extinguishers contain
- (A) conc. H_2SO_4 solution
 - (B) H_2SO_4 and NaHCO_3 solutions
 - (C) NaHCO_3 solution
 - (D) CaCO_3 solution
- Q.3** The correct order of second ionisation potentials (IP) of Ca, Ba and K is
- (A) $\text{K} > \text{Ca} > \text{Ba}$
 - (B) $\text{Ba} > \text{Ca} > \text{K}$
 - (C) $\text{K} > \text{Ba} > \text{Ca}$
 - (D) $\text{K} = \text{Ba} = \text{Ca}$
- Q.4** Weakest base among KOH , NaOH , $\text{Ca}(\text{OH})_2$ and $\text{Zn}(\text{OH})_2$ is
- (A) $\text{Ca}(\text{OH})_2$
 - (B) KOH
 - (C) NaOH
 - (D) $\text{Zn}(\text{OH})_2$

Q.5 If X and Y are the second ionisation potentials of alkali and alkaline earth metals of same period, then

- (A) $X > Y$ (B) $X < Y$
(C) $X = Y$ (D) $X \ll Y$

FEW IMPORTANT POINTS

- (i) Magnesium Peroxide (MgO_2) and Calcium Peroxide (CaO_2) are obtained by passing H_2O_2 in a suspension of $\text{Mg}(\text{OH})_2$ and $\text{Ca}(\text{OH})_2$.
- (ii) MgO_2 is used as an antiseptic in tooth paste and as a bleaching agent.
- (iii) Preparation of NaOH : Caustication of Na_2CO_3 (Gossage's method):

$$\text{Na}_2\text{CO}_3 + \text{Ca}(\text{OH})_2 \rightarrow 2\text{NaOH} + \text{CaCO}_3 \downarrow$$
 (suspension)
 Since the $K_{\text{sp}}(\text{CaCO}_3) < K_{\text{sp}}(\text{Ca}(\text{OH})_2)$, the reaction shifts towards right.
- (iv) As a reagent KOH is less frequently used but in absorption of CO_2 , KOH is preferably used compared to NaOH . Because KHCO_3 formed is soluble whereas NaHCO_3 is sparingly soluble and may therefore choke the tubes of apparatus used.
- (v) Calcium hydroxide is used as a mortar.
 [Mortar is a mixture of slaked lime (1 Part) and sand (3 Parts) made into paste with water.]
- (vi) NaCl is used to prepare freezing mixture in laboratory [Ice-common salt mixture is called freezing mixture and temperature goes down to -23°C .]
- (vii) On heating $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ undergoes hydrolysis as follows:

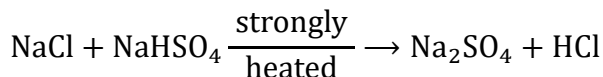
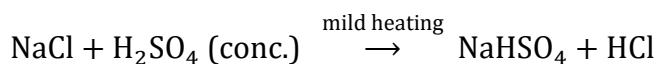
$$\text{MgCl}_2 \cdot 6\text{H}_2\text{O} \xrightarrow{\Delta} \text{Mg}(\text{OH})\text{Cl} + \text{HCl} + 5\text{H}_2\text{O}$$

$$\text{Mg}(\text{OH})\text{Cl} \rightarrow \text{MgO} + \text{HCl}$$
 ** Hence, Anhydrous MgCl_2 cannot be prepared by heating this hydrate.
 ** Because of the formation of HCl , sea water cannot be used in marine boilers which corrodes the iron body.
- (viii) Anhydrous MgCl_2 can be prepared by heating a double salt like $\text{MgCl}_2 \cdot \text{NH}_4\text{Cl} \cdot 6\text{H}_2\text{O}$ as follows:

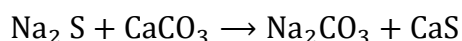
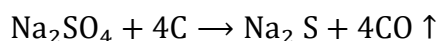
$$\text{MgCl}_2 \cdot \text{NH}_4\text{Cl} \cdot 6\text{H}_2\text{O} \xrightarrow[-10^\circ]{\Delta} \text{MgCl}_2 \cdot \text{NH}_4\text{Cl} \xrightarrow[\text{strong}]{\Delta} \text{MgCl}_2 + \text{NH}_3 + \text{HCl}$$
- (ix) Sorel Cement is a mixture of $\text{MgO} \cdot \text{CaO} \cdot \text{MgCl}_2$ (paste like) which set to hard mass on standing, this is used in dental filling, flooring etc.
- (x) Anhydrous CaCl_2 is used in drying gases and organic compounds but not NH_3 or alcohol due to the formation of $\text{CaCl}_2 \cdot 8\text{NH}_3$ and $\text{CaCl}_2 \cdot 4\text{C}_2\text{H}_5\text{OH}$.

(xi) One interesting feature of the solubility of glauber's salt is; when crystallised at below 32.4°C , then $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ is obtained but above 32.4°C , Na_2SO_4 (anh.) comes out.

(xii) Leblanc Process (Preparation of Na_2CO_3) :



(Salt Cake)



SUMMARY

The s-Block of the periodic table constitutes Group 1 (alkali metals) and Group 2 (alkaline earth metals). They are so called because their oxides and hydroxides are alkaline in nature. The alkali metals are characterised by one s-electron and the alkaline earth metals by two s-electrons in the valence shell of their atoms. These are highly reactive metals forming monovalent (M^+) and divalent (M^{2+}) ions respectively.

There is a regular trend in the physical and chemical properties of the alkali metal with increasing atomic numbers. The atomic and ionic sizes increase and the ionization enthalpies decrease systematically down the group. Somewhat similar trends are observed among the properties of the alkaline earth metals.

The first element in each of these groups, lithium in Group 1 and beryllium in Group 2 shows similarities in properties to the second member of the next group. Such similarities are termed as the 'diagonal relationship' in the periodic table. As such these elements are anomalous as far as their group characteristics are concerned.

The alkali metals are silvery white, soft and low melting. They are highly reactive. The compounds of alkali metals are predominantly ionic. Their oxides and hydroxides are soluble in water forming strong alkalis. Important compounds of sodium include sodium carbonate, sodium chloride, sodium hydroxide and sodium hydrogencarbonate. Sodium hydroxide is manufactured by Castner-Kellner process and sodium carbonate by Solvay process. The chemistry of alkaline earth metals is very much like that of the alkali metals. However, some differences arise because of reduced atomic and ionic sizes and increased cationic charges in case of alkaline earth metals. Their oxides and hydroxides are less basic than the alkali metal oxides and hydroxides. Industrially important compounds of calcium include calcium oxide (lime), calcium hydroxide (slaked lime), calcium sulphate (Plaster of Paris),

calcium carbonate (limestone) and cement. Portland cement is an important constructional material. It is manufactured by heating a pulverised mixture of limestone and clay in a rotary kiln. The clinker thus obtained is mixed with some gypsum (2-3%) to give a fine powder of cement. All these substances find variety of uses in different areas.

Monovalent sodium and potassium ions and divalent magnesium and calcium ions are found in large proportions in biological fluids. These ions perform important biological functions such as maintenance of ion balance and nerve impulse conduction.



EXERCISE - I

Question Bank on s-block elements

- Q.1** The reaction of an element A with water produces combustible gas B and an aqueous solution of C. When another substance D reacts with this solution C also produces the same gas B. D also produces the same gas even on reaction with dilute H_2SO_4 at room temperature. Element A imparts golden yellow colour to Bunsen flame. Then, A, B, C and D may be identified as
- (A) Na, H_2 , NaOH and Zn
 (B) K, H_2 , KOH and Zn
 (C) K, H_2 , NaOH and Zn
 (D) Ca, H_2 , CaCO_3 and Zn
- Q.2** The hydroxide of alkaline earth metal, which has the lowest value of solubility product (K_{sp}) at normal temperature (25°C) is
- (A) $\text{Ca}(\text{OH})_2$
 (B) $\text{Mg}(\text{OH})_2$
 (C) $\text{Sr}(\text{OH})_2$
 (D) $\text{Be}(\text{OH})_2$ If X gives green flame test. Then, X is
- Q.3** (Yellow ppt) T $\xleftarrow{\text{K}_2\text{CrO}_4/\text{H}^+}$ X $\xrightarrow{\text{dil. HCl}}$ Y (Yellow ppt) + Z \uparrow (pungent smelling gas) If X gives green flame test. Then, X is
- (A) MgSO_4 (B) BaSO_4 (C) CuSO_4 (D) PbSO_4
- Q.4** The 'milk of magnesia' used as an antacid is chemically
- (A) $\text{Mg}(\text{OH})_2$ (B) MgO (C) MgCl_2 (D) $\text{MgO} + \text{MgCl}_2$
- Q.5** The golden yellow colour associated with NaCl to Bunsen flame can be explained on the basis of
- (A) low ionisation potential of sodium
 (B) emission spectrum
 (C) photosensitivity of sodium
 (D) sublimation of metallic sodium of yellow vapours
- Q.6** The salt which finds uses in qualitative inorganic analysis is
- (A) $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ or $\text{ZnSO}_4 \cdot 5\text{H}_2\text{O}$ (B) $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$
 (C) $\text{Na}(\text{NH}_4)\text{HPO}_4 \cdot 4\text{H}_2\text{O}$ (D) $\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$
- Q.7** The compound(s) which have - O-O- bond(s) is/are
- (A) BaO_2 (B) Na_2O_2
 (C) CrO_5 (D) Fe_2O_3

- Q.8** EDTA is used in the estimation of
 (A) Mg^{2+} ions (B) Ca^{2+} ions
 (C) both Ca^{2+} and Mg^{2+} ions (D) Mg^{2+} ions but not Ca^{2+} ions
- Q.9** Highly pure dilute solution of sodium in ammonia
 (A) shows blue colouration due to solvated electrons
 (B) shows electrical conductivity due to both solvated electrons as well as solvated sodium ions
 (C) shows red colouration due to solvated electrons but a bad conductor of electricity
 (D) produces hydrogen gas or carbonate
- Q.10** The complex formation tendency of alkaline earth metals decreases down the group because
 (A) atomic size increases
 (B) availability of empty d and f-orbitals increases
 (C) nuclear charge to volume ratio increases
 (D) all the above
- Q.11** The alkaline earth metals, which do not impart any colour to Bunsen flame are
 (A) Be and Mg (B) Mg and Ca
 (C) Be and Ca (D) Be and Ba
- Q.12** $\text{Y} \xleftarrow{\Delta, 205^\circ\text{C}} \text{CaSO}_4 \cdot 2\text{H}_2\text{O} \xrightarrow{\Delta, 120^\circ\text{C}} \text{X}$. X and Y are respectively
 (A) plaster of paris, dead burnt plaster (B) dead burnt plaster, plaster of paris
 (C) CaO and plaster of paris (D) plaster of paris, mixture of gases
- Q.13** A metal M readily forms water soluble sulphate, and water insoluble hydroxide $\text{M}(\text{OH})_2$. Its oxide MO is amphoteric, hard and having high melting point. The alkaline earth metal M must be
 (A) Mg (B) Be (C) Ca (D) Sr
- Q.14** When K_2O is added to water, the solution becomes basic in nature because it contains a significant concentration of
 (A) K^+ (B) O^{2-} (C) OH^- (D) O_2^{2-}
- Q.15** An aqueous solution of an halogen salt of potassium reacts with same halogen X_2 to give KX_3 , a brown coloured solution, in which halogen exists as X_3^- ion, X_2 as a Lewis acid and X^- as a Lewis base, halogen X is
 (A) chlorine (B) bromine (C) iodine (D) fluorine
- Q.16** The correct order of basic-strength of oxides of alkaline earth metals is
 (A) $\text{BeO} > \text{MgO} > \text{CaO} > \text{SrO}$ (B) $\text{SrO} > \text{CaO} > \text{MgO} > \text{BeO}$
 (C) $\text{BeO} > \text{CaO} > \text{MgO} > \text{SrO}$ (D) $\text{SrO} > \text{MgO} > \text{CaO} > \text{BeO}$

(Inorganic Chemistry)

s-BLOCK ELEMENTS

Q.17 $X \xrightarrow{N_2, \Delta} Y \xrightarrow{H_2O} Z(\text{colour gas}) \xrightarrow{CuSO_4} T(\text{blue colour})$ Then, substances Y and T are

- (A) $Y = Mg_3 N_2$ and $T = CuSO_4 \cdot 5H_2O$ (B) $Y = Mg_3 N_2$ and $T = CuSO_4 \cdot 4NH_3$
 (C) $Y = Mg(NO_3)_2$ and $T = CuO$ (D) $Y = MgO$ and $T = CuSO_4 \cdot 4NH_3$

Q.18 The aqueous solutions of lithium salts are poor conductor of electricity rather than other alkali metals because of

- (A) high ionisation energy
 (B) high electronegativity
 (C) lower ability of Li^+ ions to polarize water molecules
 (D) higher degree of hydration of Li^+ ions

Q.19 Which of the following substance(s) is/are used in laboratory for drying purposes?

- (A) anhydrous P_2O_5 (B) graphite
 (C) anhydrous $CaCl_2$ (D) Na_3PO_4

Q.20 In $LiAlH_4$, metal Al is present in

- (A) anionic part (B) cationic part
 (C) in both anionic and cationic part (D) neither in cationic nor in anionic part

Q.21 $X \xrightarrow{CoCl_2} CaCl_2 + Y \uparrow$; the effective ingredient of X is

- (A) OCi^- (B) Cl^- (C) OCi^+ (D) OCi_2

Q.22 Crown ethers and cryptands form

- (A) complexes with alkali metals
 (B) salts of alkali metals
 (C) hydroxides of alkali metals used for inorganic quantitative analysis
 (D) organic salts of alkali metals

Q.23 White heavy precipitates are formed when $BaCl_2$ is added to a clear solution of compound A. Precipitates are insoluble in dilute HCl. Then, the compound A is

- (A) a bicarbonate (B) a carbonate
 (C) a sulphate (D) a chloride

Q.24 $X + C + Cl_2 \xrightarrow{\text{High temperature}} Y + 2H_2O \rightarrow Z + 2HCl$

Compound Y is found in polymeric chain structure and is an electron deficient molecule. Y must be

- (A) BeO (B) $BeCl_2$ (C) BeH_2 (D) $AlCl_3$

Q.25 $BeCl_2 + LiAlH_4 \rightarrow X + LiCl + AlCl_3$

- (A) X is LiH (B) X is BeH_2 (C) X is $BeCl_2 \cdot 2H_2O$ (D) None

- Q.26** The order of thermal stability of carbonates of IIA group is
(A) $\text{BaCO}_3 > \text{SrCO}_3 > \text{CaCO}_3 > \text{MgCO}_3$ (B) $\text{MgCO}_3 > \text{CaCO}_3 > \text{SrCO}_3 > \text{BaCO}_3$
(C) $\text{CaCO}_3 > \text{SrCO}_3 > \text{BaCO}_3 > \text{MgCO}_3$ (D) $\text{MgCO}_3 = \text{CaCO}_3 > \text{SrCO}_3 = \text{BaCO}_3$
- Q.27** Na_2SO_4 is water soluble but BaSO_4 is insoluble because
(A) the hydration energy of Na_2SO_4 is higher than that of its lattice energy
(B) the hydration energy of Na_2SO_4 is less than that of its lattice energy
(C) the hydration energy of BaSO_4 is less than that of its lattice energy
(D) the hydration energy of BaSO_4 is higher than that of its lattice energy
- Q.28** The commercial method of preparation of potassium by reduction of molten KCl with metallic sodium at 850°C is based on the fact that
(A) potassium is solid and sodium distils off at 850°C
(B) potassium being more volatile and distils off thus shifting the reaction forward
(C) sodium is more reactive than potassium at 850°C
(D) sodium has less affinity to chloride ions in the presence of potassium ion
- Q.29** MgBr_2 and MgI_2 are soluble in acetone because of
(A) Their ionic nature
(B) Their coordinate nature
(C) Their metallic nature
(D) Their covalent nature
- Q.30** Which of the following is not the characteristic of barium?
(A) It emits electrons on exposure to light
(B) It is a silvery white metal
(C) It forms $\text{Ba}(\text{NO}_3)_2$ which is used in preparation of green fire
(D) All of these

Question No. 31 to 38

Questions given below consist of two statements each printed as Assertion (A) and Reason (R); while answering these questions you are required to choose any one of the following four responses:

- (A) if both (A) and (R) are true and (R) is the correct explanation of (A)
(B) if both (A) and (R) are true but (R) is not correct explanation of (A)
(C) if (A) is true but (R) is false
(D) if (A) is false and (R) is true

- Q.31** Assertion : Beryllium does not impart any characteristic colour to the bunsen flame.
Reason : Due to its very high ionization energy, beryllium requires a large amount of energy for excitation of the electrons.
- Q.32** Assertion : In fused state, calcium chloride cannot be used to dry alcohol or NH_3 .
Reason : Anhyd. CaCl_2 is not a good desiccant.
- Q.33** Assertion : Diagonal relationship is shown between Be and Al.
Reason : Ionization potential of Be is almost the same as that of Al.
- Q.34** **Assertion :** Beryllium halides dissolve in organic solvents.
Reason : Beryllium halides are ionic in character.
- Q.35** Assertion : BeCl_2 fumes in moist air.
Reason : BeCl_2 reacts with moisture to form HCl gas.
- Q.36** Assertion : Calcium carbide on hydrolysis gives methane.
Reason : Calcium carbide contains C_2^{2-} anion.
- Q.37** Assertion : When CO_2 is passed through lime water, it first turns milky and then the solution becomes clear when the passage of CO_2 is continued.
Reason : The milkiness is due to the formation of insoluble CaCO_3 which then changes to soluble $\text{Ca}(\text{HCO}_3)_2$ when excess of CO_2 is present.
- Q.38** Assertion : MgCO_3 is soluble in water when a current of CO_2 is passed.
Reason : The solubility of MgCO_3 is due to the formation of $\text{Mg}(\text{HCO}_3)_2$.

IIT JEE ASKED QUESTION

- Q.40** The compound(s) formed upon combustion of sodium metal in excess air is (are) [JEE 2009]
(A) Na_2O_2 (B) Na_2O (C) NaO_2 (D) NaOH

EXERCISE – II

PREVIOUS YEAR QUESTIONS (JEE MAIN)

1. KO_2 (potassium super oxide) is used in oxygen cylinders in space and submarines because it:
[AIEEE-2002]
(A) Absorbs CO_2 and increases O_2 contents
(B) Eliminates moisture
(C) Absorbs CO_2
(D) Produces ozone
2. A metal M readily forms water soluble sulphate MSO_4 , water insoluble hydroxide $\text{M}(\text{OH})_2$ and oxide MO which becomes inert on heating. The hydroxide is soluble in NaOH . The M is :
[AIEEE-2002]
(A) Be (B) Mg (C) Ca (D) Sr
3. In curing cement plasters, water is sprinkled from-time to time. This helps in:
[AIEEE-2003]
(A) developing interlocking needle like crystals of hydrate silicates
(B) hydrated sand gravel mixed with cement
(C) converting sand into silicic acid
(D) keeping it cool.
4. The substance not likely to contain CaCO_3 is:
[AIEEE-2003]
(A) calcined gypsum (B) sea shells
(C) dolomite (D) a marble statue
5. The solubilities of carbonates decrease down the magnesium group due to a decrease in:
[AIEEE-2003]
(A) hydration energies of cations (B) inter ionic interaction
(C) entropy of solution formation (D) lattice energies of solids.
6. Several blocks of magnesium are fixed to the bottom of a ship to :
[AIEEE-2003]
(A) make the ship lighter (B) prevent action of water and salt
(C) prevent puncturing by under-sea rocks (D) keep away the sharks.
7. One mole of magnesium nitride on the reaction with an excess of water gives:
[AIEEE-2004]

- (A) one mole of ammonia (B) one mole of nitric acid
(C) two moles of ammonia (D) two moles of nitric acid.
8. Beryllium and aluminium exhibit many properties which are similar. But, the two elements differ in
- [AIEEE-2004]
- (A) Exhibiting maximum covalency in compounds
(B) Forming polymeric hydrides
(C) Forming covalent halides
(D) Exhibiting amphoteric nature in their oxides.
9. Following statements regarding the periodic trends of chemical reactivity of the alkali metals and the halogens are given. Which of these statements gives the correct picture? [AIEEE-2006]
- (A) The reactivity decreases in the alkali metals but increases in the halogens with increase in atomic number down the group.
(B) In both the alkali metals and the halogens the chemical reactivity decreases with increase in atomic number down the group.
(C) Chemical reactivity increases with increase in atomic number down the group in both the alkali metals and halogens.
(D) In alkali metals the reactivity increases but in the halogens it decreases with increase in atomic number down the group.
10. The ionic mobility of alkali metal ions in aqueous solution is maximum for:
- [AIEEE-2006]
- (A) K^+ (B) Rb^+ (C) Li^+ (D) Na^+
11. Which one of the following orders presents the correct sequence of the increasing basic nature of the given oxides?
- [AIEEE-2011]
- (A) $Al_2O_3 < MgO < Na_2O < K_2O$ (B) $MgO < K_2O < Al_2O_3 < Na_2O$
(C) $Na_2O < K_2O < MgO < Al_2O_3$ (D) $K_2O < Na_2O < Al_2O_3 < MgO$
12. The products obtained on heating $LiNO_3$ will be :
- [AIEEE-2011]
- (A) $Li_2O + NO_2 + O_2$ (B) $LiN + O_2$
(C) $Li_2O + NO + O_2$ (D) $LiNO_3 + O_2$
13. Which of the following on thermal decomposition yields a basic as well as acidic oxide?
- [AIEEE-2011]

(Inorganic Chemistry)

s-BLOCK ELEMENTS

- (A) NaNO_3 (B) KClO_3 (C) CaCO_3 (D) NH_4NO_3

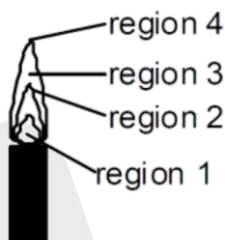
14. Which one of the following alkaline earth metal sulphates has its hydration enthalpy greater than its lattice enthalpy?

[JEE(Main)-2015]

- (A) CaSO_4 (B) BeSO_4 (C) BaSO_4 (D) SrSO_4

15. The hottest region of Bunsen flame shown in the figure below is

[JEE(Main)-2016]



- (A) region 2 (B) region 3 (C) region 4 (D) region 1

16. Lithium aluminium hydride reacts with silicon tetrachloride to form:

[Main-2018(Online)]

- (A) LiCl , AlH_3 and SiH_4 (B) LiCl , AlCl_3 and SiH_4
 (C) LiH , AlCl_3 and SiCl_2 (D) LiH , AlH_3 and SiH_4

17. The alkaline earth metal nitrate that does not crystallise with water molecules is :

[2019]

- (A) $\text{Sr}(\text{NO}_3)_2$ (B) $\text{Mg}(\text{NO}_3)_2$
 (C) $\text{Ca}(\text{NO}_3)_2$ (D) $\text{Ba}(\text{NO}_3)_2$

18. The metal that forms nitride by reacting directly with N_2 of air is :

[2019]

- (A) Li (B) Cs (C) Rb (D) K

19. The metal used for making X-ray tube window is :

[2019]

- (A) Ca (B) Na (C) Mg (D) Be

20. Sodium metal on dissolution in liquid ammonia gives a deep blue solution due to the formation of:

[2019]

- (A) ammoniated electrons
 (B) sodamide
 (C) sodium ion-ammonia complex
 (D) sodium-ammonia complex

21. NaH is an example of : [2019]
 (A) Metallic hydride
 (B) Saline hydride
 (C) Molecular hydride
 (D) Electron-rich hydride

22. The amphoteric hydroxide is: [2019]
 (A) $\text{Ca}(\text{OH})_2$ (B) $\text{Mg}(\text{OH})_2$ (C) $\text{Be}(\text{OH})_2$ (D) $\text{Sr}(\text{OH})_2$

23. Match the following items in column I with the corresponding items in column II.

Column I

(i) $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ (ii) $\text{Mg}(\text{HCO}_3)_2$

(iii) NaOH

(iv) $\text{Ca}_3\text{Al}_2\text{O}_6$

Column II

(P) Portland cement ingredient

(Q) Castner-Kellner process

(R) Solvay process

(S) Temporary hardness

(A) (i) – (Q); (ii) – (R); (iii) – (P); (iv) – (S)

(B) (i) – (S); (ii) – (P); (iii) – (Q); (iv) – (R)

(C) (i) – (R); (ii) – (Q); (iii) – (S); (iv) – (P)

(D) (i) – (R); (ii) – (S); (iii) – (Q); (iv) – (P)

24. A metal on combustion in excess air forms X, X upon hydrolysis with water yields H_2O_2 and O_2 along with another product. The metal is : [2019]

(A) Li (B) Rb (C) Na (D) Mg

25. The correct order of hydration enthalpies of alkali metal ions is : [2019]

(A) $\text{Li}^+ > \text{Na}^+ > \text{K}^+ > \text{Cs}^+ > \text{Rb}^+$ (B) $\text{Na}^+ > \text{Li}^+ > \text{K}^+ > \text{Rb}^+ > \text{Cs}^+$ (C) $\text{Na}^+ > \text{Li}^+ > \text{K}^+ > \text{Cs}^+ > \text{Rb}^+$ (D) $\text{Li}^+ > \text{Na}^+ > \text{K}^+ > \text{Rb}^+ > \text{Cs}^+$

26. A hydrated solid X on heating initially gives a monohydrated compound Y. Y upon heating above 373 K leads to an anhydrous white powder Z. X and Z, respectively, are : [2019]

(A) Washing soda and soda ash
 (B) Baking soda and dead burnt plaster.
 (C) Washing soda and dead burnt plaster.
 (D) Baking soda and soda ash.

27. The INCORRECT statement is : [2019]
(A) Lithium is the strongest reducing agent among the alkali metals.
(B) Lithium is least reactive with water among the alkali metals.
(C) LiNO_3 decomposes on heating to give LiNO_2 and O_2 .
(D) LiCl crystallises from aqueous solution as $\text{LiCl} \cdot 2\text{H}_2\text{O}$.
28. $\text{NaOH} + \text{Cl}_2 \rightarrow \text{A} + \text{other products}$ Hot & conc. [2020]
 $\text{Ca(OH)}_2 + \text{Cl}_2 \rightarrow \text{B} + \text{other products}$ Cold & dil.
A & B are respectively
(A) NaClO_3 , Ca(OCl)_2
(B) NaClO_3 , $\text{Ca(ClO}_3)_2$
(C) NaCl , $\text{Ca(ClO}_3)_2$
(D) NaClO , $\text{Ca(ClO}_3)_2$
29. Two elements A and B have similar chemical properties. They don't form solid hydrogen carbonates, but react with nitrogen to form nitrides. A and B, respectively, are [2020]
(A) Li and Mg
(B) Cs and Ba
(C) Na and Rb
(D) Na and Ca
30. Among the statements (a) – (d), the correct ones are : [2020]
(a) Lithium has the highest hydration enthalpy among the alkali metals.
(b) Lithium chloride is insoluble in pyridine.
(c) Lithium cannot form ethynide upon its reaction with ethyne.
(d) Both lithium and magnesium react slowly with H_2O .
(A) (a), (b) and (d) only
(B) (b) and (c) only
(C) (a) and (d) only
(D) (a), (c) and (d) only

31. Among the sulphates of alkaline earth metals, the solubilities of BeSO_4 and MgSO_4 in water, respectively, are [2020]

(A) poor and poor (B) poor and high
(C) high and poor (D) high and high

32. Match List-I with List-II [2021]

List-I

List-II

(Salt)

(Flame colour wavelength)

(a) LiCl

(i) 455.5 nm

(b) NaCl

(ii) 970.8 nm

(c) RbCl

(iii) 780.0 nm

(d) CsCl

(iv) 589.2 nm

Choose the correct answer from the options given below :

(A) (a) - (ii), (b) - (i), (c) - (iv), (d) - (iii)

(B) (a) - (ii), (b) - (iv), (c) - (iii), (d) - (i)

(C) (a) - (iv), (b) - (ii), (c) - (iii), (d) - (i)

(D) (a) - (i), (b) - (iv), (c) - (ii), (d) - (iii)

33. The Correct set from the following in which both pairs are in correct order of melting point is [2021]

(A) $\text{LiF} > \text{LiCl}$; $\text{NaCl} > \text{MgO}$ (B) $\text{LiF} > \text{LiCl}$; $\text{MgO} > \text{NaCl}$ (C) $\text{LiCl} > \text{LiF}$; $\text{NaCl} > \text{MgO}$ (D) $\text{LiCl} > \text{LiF}$; $\text{MgO} > \text{NaCl}$

34. Given below are two statements: [2021]

One is labelled as Assertion A and the other labelled as reason R

Assertion A : During the boiling of water having temporary hardness, $\text{Mg}(\text{HCO}_3)_2$ is converted to MgCO

Reason R : The solubility product of $\text{Mg}(\text{OH})_2$ is greater than that of MgCO_3 . In the light of the above statements, choose the most appropriate answer from the options given below:

(A) Both A and R are true but R is not the correct explanation of A

(B) A is true but R is false

(C) Both A and R are true and R is the correct explanation of A

(D) A is false and R is also false

35. Match list-I with list-II :

[2021]

List-I

List-II

(a) Be

(i) Treatment of cancer

(b) Mg

(ii) Extraction of metals

(c) Ca

(iii) Incendiary bombs and signals

(d) Ra

(iv) Windows of X-ray tubes

(v) Bearings for motor engines.

Choose the most appropriate answer the option given below:

(A) a - iv, b-iii, c-i, d - ii

(B) a - iv, b - iii, c - ii, d - i

(C) a - iii, b - iv, c - v, d - ii

(D) a - iii, b - iv, c - ii, d - v

36. A s-block element (M) reacts with oxygen to form an oxide of the formula MO_2 . The oxide is pale yellow in colour and paramagnetic. The element (M) is:

[2021]

(A) Mg

(B) Na

(C) Ca

(D) K

37. Given below are two statements

[2021]

Statement I : None of the alkaline earth metal hydroxides dissolve in alkali.

Statement II : Solubility of alkaline earth metal hydroxides in water increases down the group.

In the light of the above statements, choose the most appropriate answer from the options given below

(A) Statement I is correct but Statement II is incorrect.

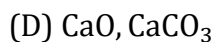
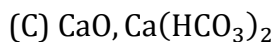
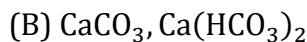
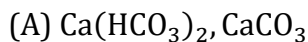
(B) Statement I is incorrect but Statement II is correct.

(C) Statement I and Statement II both are incorrect.

(D) Statement I and Statement II both are correct.

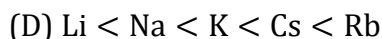
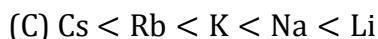
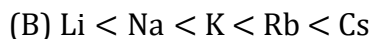
38. What are the products formed in sequence when excess of CO_2 is passed in slaked lime?

[2021]



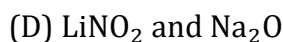
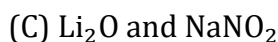
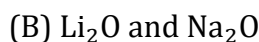
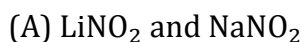
39. Choose the correct order of density of the alkali metals :

[2022]



40. Lithium nitrate and sodium nitrate, when heated separately, respectively, give :

[2022]



41. Which of the following statement is incorrect?

[2022]

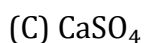
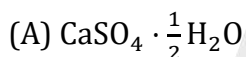
(A) Low solubility of LiF in water is due to its small hydration enthalpy.(B) KO_2 is paramagnetic.

(C) Solution of sodium in liquid ammonia is conducting in nature.

(D) Sodium metal has higher density than potassium metal

42. Portland cement contains 'X' to enhance the setting time. What is 'X'?

[2022]



43. Match List I with List II

[2023]

List I		List II	
Elements		Colour imparted to the flame	
A	K	I	Brick Red
B	Ca	II	Violet
C	Sr	III	Apple Green
D	Ba	IV	Crimson Red

Choose the correct answer from the options given below:

(A) A-II, B-I, C-III, D-IV

(B) A-II, B-IV, C-I, D-III

(C) A-II, B-I, C-IV. D-III

(D) A-IV, B-III, C-II. D-I

44. Which one among the following metals is the weakest reducing agent ? [2023]

(A) K

(B) Rb

(C) Na

(D) Li

45. The correct order of hydration enthalpies is [2023]

(I) K^+ (II) Rb^+ (III) Mg^{2+} (IV) Cs^+ (V) Ca^{2+}

Choose the correct answer from the options given below:

(A) $III > I > V > II > IV$ (B) $V > III > I > II > IV$ (C) $III > V > I > IV > II$ (D) $III > V > I > II > III$

46. The magnetic behaviour of Li_2O , Na_2O_2 and KO_2 , respectively, are [2023]

(A) diamagnetic, paramagnetic and diamagnetic

(B) paramagnetic, paramagnetic and diamagnetic

(C) paramagnetic, diamagnetic and paramagnetic

(D) diamagnetic, diamagnetic and paramagnetic

47. Which of the following reaction is correct? [2023]

(A) $2LiNO_3 \xrightarrow{\Delta} 2LiNO_2 + O_2$ (B) $4LiNO_3 \xrightarrow{\Delta} 2Li_2O + 2N_2O_4 + O_2$ (C) $4LiNO_3 \xrightarrow{\Delta} 2Li_2O + 4NO_2 + O_2$ (D) $2LiNO_3 \xrightarrow{\Delta} 2Li + 2NO_2 + O_2$

48. Choose the correct statement(s): [2023]

I. Beryllium oxide is purely acidic in nature.

II. Beryllium carbonate is kept in the atmosphere of CO_2 .

III. Beryllium sulphate is readily soluble in water.

IV. Beryllium shows anomalous behavior.

Choose the correct answer from the options given below:

(A) I, II and III only

(B) II, III and IV only

(C) I and II only

(D) I only

EXERCISE - III

PREVIOUS YEAR QUESTIONS (JEE ADVANCED)

1. Property of the alkaline earth metals that increases with their atomic number is :

[JEE-1997(Cancelled), 2/200]

- (A) ionisation energy (B) solubility of their hydroxides
(C) solubility of their sulphates (D) electronegativity

2. Highly pure dilute solution of sodium in liquid ammonia:

[JEE-1998, 1/200]

- (A) shows blue colour (B) exhibits electrical conductivity.
(C) produces sodium amide. (D) produces hydrogen gas.

3. Sodium nitrate decomposes above 800°C to give:

[JEE-1998, 1/200]

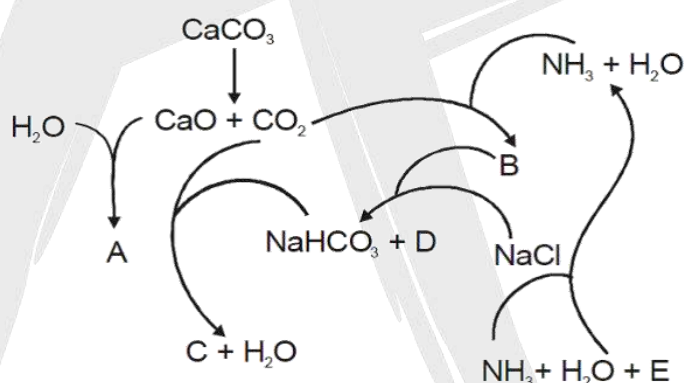
- (A) N_2 (B) O_2 (C) NO_2 (D) Na_2O

4. Beryllium chloride shows acidic nature in water or why BeCl_2 is easily hydrolysed ?

[JEE-1999, 2/200]

5. The Haber's process can be represented by the following scheme : Identify A, B, C, D and E.

[JEE - 1999, 5/200]



6. 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.

[JEE-1999, 4/200]

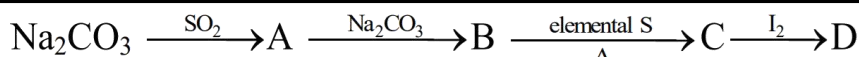
- (i) Identify the substances and explain with balanced equation.
(ii) Explain what would happen to the red litmus if the white solid were the other compound

7. The set representing the correct order of first ionization potential is:

[JEE - 2001, 1/35]

- (A) $\text{K} > \text{Na} > \text{Li}$ (B) $\text{Be} > \text{Mg} > \text{Ca}$
(C) $\text{B} > \text{C} > \text{N}$ (D) $\text{Ge} > \text{Si} > \text{C}$

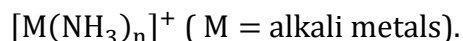
8. Identify the following :



Also mention the oxidation state of S in all the compounds.

9. **Statement-1:** Alkali metals dissolve in liquid ammonia to give blue solutions.

Statement-2: Alkali metals in liquid ammonia give solvated species of the type



[JEE-2007]

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.

(C) Statement-1 is True, Statement-2 is False.

(D) Statement-1 is False, Statement-2 is True.

10. The compound(s) formed upon combustion of sodium metal in excess air is(are):

[JEE-2009]

(A) Na_2O_2

(B) Na_2O

(C) NaO_2

(D) NaOH

11. The pair(s) of reagents that yield paramagnetic species is / are :

[2014]

(A) Na and excess of NH_3

(B) K and excess of O_2

(C) Cu and dilute HNO_3

(D) O_2 and 2-ethylantraquinol

12. Hydrogen peroxide in its reaction with KIO_4 and NH_2OH respectively, is acting as a

[JEE Adv, 2014]

(A) reducing agent, oxidising agent

(B) reducing agent, reducing agent

(C) oxidising agent, oxidising agent

(D) oxidising agent, reducing agent

13. Which of the following liberates O_2 upon hydrolysis?

[JEE Adv. 2020]

(A) Pb_3O_4

(B) KO_2

(C) Na_2O_2

(D) Li_2O_2

14. LIST-I contains compounds and LIST-II contains reactions

LIST-I

LIST-II

(I) H_2O_2

(P) $\text{Mg}(\text{HCO}_3)_2 + \text{Ca}(\text{OH})_2 \rightarrow$

(II) $\text{Mg}(\text{OH})_2$

(Q) $\text{BaO}_2 + \text{H}_2\text{SO}_4 \rightarrow$

(III) BaCl_2

(R) $\text{Ca}(\text{OH})_2 + \text{MgCl}_2 \rightarrow$

(IV) CaCO_3

(S) $\text{BaO}_2 + \text{HCl} \rightarrow$

(T) $\text{Ca}(\text{HCO}_3)_2 + \text{Ca}(\text{OH})_2 \rightarrow$

Match each compound in LIST-I with its formation reaction(s) in LIST-II, and choose the correct

option

[JEE Adv. 2022]

(A) I \rightarrow Q; II \rightarrow P; II \rightarrow S; IV \rightarrow R

(B) I \rightarrow T; II \rightarrow P; II \rightarrow Q; IV \rightarrow R

(C) I \rightarrow T; II \rightarrow R; III \rightarrow Q; IV \rightarrow P

(D) I \rightarrow Q; II \rightarrow R; III \rightarrow S; IV \rightarrow P

A

NCERT EXEMPLAR

- The alkali metals are low melting. Which of the following alkali metal is expected to melt if the room temperature rises to 30°C ?
(A) Na (B) K (C) Rb (D) Cs
- Alkali metals react with water vigorously to form hydroxides and dihydrogen. Which of the following alkali metals reacts with water least vigorously?
(A) Li (B) Na (C) K (D) Cs
- The reducing power of a metal depends on various factors. Suggest the factor which makes Li, the strongest reducing agent in aqueous solution.
(A) Sublimation enthalpy (B) Ionisation enthalpy
(C) Hydration enthalpy (D) Electron-gain enthalpy
- Metal carbonates decompose on heating to give metal oxide and carbon dioxide. Which of the metal carbonates is most stable thermally?
(A) MgCO_3 (B) CaCO_3 (C) SrCO_3 (D) BaCO_3
- Which of the carbonates given below is unstable in air and is kept in CO_2 atmosphere to avoid decomposition.
(A) BeCO_3 (B) MgCO_3 (C) CaCO_3 (D) BaCO_3
- Metals form basic hydroxides. Which of the following metal hydroxide is the least basic ?
(A) $\text{Mg}(\text{OH})_2$ (B) $\text{Ca}(\text{OH})_2$ (C) $\text{Sr}(\text{OH})_2$ (D) $\text{Ba}(\text{OH})_2$
- Some of the Group 2 metal halides are covalent and soluble in organic solvents. Among the following metal halides, the one which is soluble in ethanol is
(A) BeCl_2 (B) MgCl_2 (C) CaCl_2 (D) SrCl_2
- The order of decreasing ionisation enthalpy in alkali metals is
(A) $\text{Na} > \text{Li} > \text{K} > \text{Rb}$ (B) $\text{Rb} < \text{Na} < \text{K} < \text{Li}$
(C) $\text{Li} > \text{Na} > \text{K} > \text{Rb}$ (D) $\text{K} < \text{Li} < \text{Na} < \text{Rb}$
- The solubility of metal halides depends on their nature, lattice enthalpy and hydration enthalpy of the individual ions. Amongst fluorides of alkali metals, the lowest solubility of LiF in water is due to
(A) Ionic nature of lithium fluoride
(B) High lattice enthalpy
(C) High hydration enthalpy for lithium ion.
(D) Low ionisation enthalpy of lithium atom

10. Amphoteric hydroxides react with both alkalies and acids. Which of the following Group 2 metal hydroxides is soluble in sodium hydroxide?
(A) $\text{Be}(\text{OH})_2$ (B) $\text{Mg}(\text{OH})_2$ (C) $\text{Ca}(\text{OH})_2$ (D) $\text{Ba}(\text{OH})_2$
11. In the synthesis of sodium carbonate, the recovery of ammonia is done by treating NH_4Cl with $\text{Ca}(\text{OH})_2$. The by-product obtained in this process is
(A) CaCl_2 (B) NaCl (C) NaOH (D) NaHCO_3
12. When sodium is dissolved in liquid ammonia, a solution of deep blue colour is obtained. The colour of the solution is due to
(A) ammoniated electron (B) sodium ion
(C) sodium amide (D) ammoniated sodium ion
13. By adding gypsum to cement
(A) setting time of cement becomes less.
(B) setting time of cement increases.
(C) colour of cement becomes light.
(D) shining surface is obtained.
14. Dead burnt plaster is
(A) CaSO_4 (B) $\text{CaSO}_4 \cdot 4\text{H}_2\text{O}$
(C) $\text{CaSO}_4 \cdot \text{H}_2\text{O}$ (D) $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
15. Suspension of slaked lime in water is known as.
(A) lime water (B) quick lime
(C) milk of lime (D) aqueous solution of slaked lime
16. Which of the following elements does not form hydride by direct heating with dihydrogen?
(A) Be (B) Mg (C) Sr (D) Ba
17. The formula of soda ash is
(A) $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ (B) $\text{Na}_2\text{CO}_3 \cdot 2\text{H}_2\text{O}$
(C) $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$ (D) Na_2CO_3
18. A substance which gives brick red flame and breaks down on heating to give oxygen and a brown gas is
(A) Magnesium nitrate (B) Calcium nitrate
(C) Barium nitrate (D) Strontium nitrate
19. Which of the following statements is true about $\text{Ca}(\text{OH})_2$?
(A) It is used in the preparation of bleaching powder
(B) It is a light blue solid

- (C) It does not possess disinfectant property.
(D) It is used in the manufacture of cement.
20. A chemical A is used for the preparation of washing soda to recover ammonia. When CO_2 is bubbled through an aqueous solution of A, the solution turns milky. It is used in white washing due to disinfectant nature. What is the chemical formula of A ?
(A) $\text{Ca}(\text{HCO}_3)_2$ (B) CaO (C) $\text{Ca}(\text{OH})_2$ (D) CaCO_3
21. Dehydration of hydrates of halides of calcium, barium and strontium i.e., $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$, $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$, $\text{SrCl}_2 \cdot 2\text{H}_2\text{O}$, can be achieved by heating. These become wet on keeping in air. Which of the following statements is correct about these halides?
(A) act as dehydrating agent
(B) can absorb moisture from air
(C) Tendency to form hydrate decreases from calcium to barium
(D) All of the above

II. Multiple Choice Questions (Type-II)

In the following questions two or more options may be correct.

22. Metallic elements are described by their standard electrode potential, fusion enthalpy, atomic size, etc. The alkali metals are characterised by which of the following properties?
(A) High boiling point
(B) High negative standard electrode potential
(C) High density
(D) Large atomic size
23. Several sodium compounds find use in industries. Which of the following compounds are used for textile industry?
(A) Na_2CO_3 (B) NaHCO_3 (C) NaOH (D) NaCl
24. Which of the following compounds are readily soluble in water?
(A) BeSO_4 (B) MgSO_4 (C) BaSO_4 (D) SrSO_4
25. When Zeolite, which is hydrated sodium aluminium silicate is treated with hard water, the sodium ions are exchanged with which of the following ion(s)?
(A) H^+ ions (B) Mg^{2+} ions (C) Ca^{2+} ions (D) SO_4^{2-} ions
26. Identify the correct formula of halides of alkaline earth metals from the following.
(A) $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ (B) $\text{BaCl}_2 \cdot 4\text{H}_2\text{O}$ (C) $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$ (D) $\text{SrCl}_2 \cdot 4\text{H}_2\text{O}$
27. Choose the correct statements from the following.
(A) Beryllium is not readily attacked by acids because of the presence of an oxide film on the

surface of the metal.

(B) Beryllium sulphate is readily soluble in water as the greater hydration enthalpy of Be^{2+} overcomes the lattice enthalpy factor.

(C) Beryllium exhibits coordination number more than four.

(D) Beryllium oxide is purely acidic in nature.

28. Which of the following are the correct reasons for anomalous behaviour of lithium?

(A) Exceptionally small size of its atom

(B) Its high polarising power

(C) It has high degree of hydration

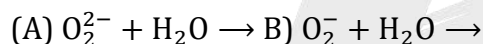
(D) Exceptionally low ionisation enthalpy

III. Short Answer Type

29. How do you account for the strong reducing power of lithium in aqueous solution?

30. When heated in air, the alkali metals form various oxides. Mention the oxides formed by Li, Na and K.

31. Complete the following reactions



32. Lithium resembles magnesium in some of its properties. Mention two such properties and give reasons for this resemblance.

33. Name an element from Group 2 which forms an amphoteric oxide and a water soluble sulphate.

34. Discuss the trend of the following:

(A) Thermal stability of carbonates of Group 2 elements.

(B) The solubility and the nature of oxides of Group 2 elements.

35. Why are BeSO_4 and MgSO_4 readily soluble in water while SrSO_4 and BaSO_4 are insoluble?

36. All compounds of alkali metals are easily soluble in water but lithium compounds are more soluble in organic solvents. Explain.

37. In the Solvay process, can we obtain sodium carbonate directly by treating the solution containing $(\text{NH}_4)_2\text{CO}_3$ with sodium chloride? Explain.

38. Write Lewis structure of O_2^- ion and find out oxidation state of each oxygen atom? What is the average oxidation state of oxygen in this ion?

39. Why do beryllium and magnesium not impart colour to the flame in the flame test?

40. What is the structure of BeCl_2 molecule in gaseous and solid state?

IV. Matching Type

In the following questions more than one option of column I and II may be correlated.

41. Match the elements given in Column I with the properties mentioned in Column II.

Column I

(A) Li

(B) Na

(C) Ca

(D) Ba

Column II

(a) Insoluble sulphate

(b) Strongest monoacidic base among these

(c) Most negative E^0 value among alkali metals.

(d) Insoluble oxalate

(e) $6s^2$ outer electronic configuration

42. Match the compounds given in Column I with their uses mentioned in Column II.

Column I(A) CaCO_3 (B) Ca(OH)_2

(C) CaO

(D) CaSO_4 **Column II**

(a) Dentistry, ornamental work

(b) Manufacture of sodium carbonate from caustic soda

(c) Manufacture of high quality paper

(d) Used in white washing

43. Match the elements given in Column I with the colour they impart to the flame given in

Column I

(A) Cs

(B) Na

(C) K

(D) Ca

(E) Sr

(F) Ba

Column II

(a) Apple green

(b) Violet

(c) Brick red

(d) Yellow

(e) Crimson red

(f) Blue

V. Assertion and Reason Type

In the following questions a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

44. **Assertion (A):** The carbonate of lithium decomposes easily on heating to form lithium oxide and CO_2 .

Reason (R): Lithium being very small in size polarises large carbonate ion leading to the formation of more stable Li_2O and CO_2 .

(A) Both A and R are correct and R is the correct explanation of A.

(B) Both A and R are correct but R is not the correct explanation of A.

- (C) Both A and R are not correct
(D) A is not correct but R is correct.

45. **Assertion (A):** Beryllium carbonate is kept in the atmosphere of carbon dioxide.

Reason (R): Beryllium carbonate is unstable and decomposes to give beryllium oxide and carbon dioxide.

- (A) Both A and R are correct and R is the correct explanation of A.
(B) Both A and R are correct but R is not the correct explanation of A.
(C) Both A and R are not correct.
(D) A is not correct but R is correct.

VI. Long Answer Type

46. The s-block elements are characterised by their larger atomic sizes, lower ionisation enthalpies, invariable +1 oxidation state and solubilities of their oxosalts. In the light of these features describe the nature of their oxides, halides and oxosalts.
47. Present a comparative account of the alkali and alkaline earth metals with respect to the following characteristics:
- (A) Tendency to form ionic / covalent compounds
(B) Nature of oxides and their solubility in water
(C) Formation of oxosalts
(D) Solubility of oxosalts
(E) Thermal stability of oxosalts
48. When a metal of group 1 was dissolved in liquid ammonia, the following observations were obtained:
- (A) Blue solution was obtained initially.
(B) On concentrating the solution, blue colour changed to bronze colour. How do you account for the blue colour of the solution? Give the name of the product formed on keeping the solution for some time.
48. The stability of peroxide and superoxide of alkali metals increase as we go down the group. Explain giving reason.
49. When water is added to compound (A) of calcium, solution of compound (B) is formed. When carbon dioxide is passed into the solution, it turns milky due to the formation of compound (C). If excess of carbon dioxide is passed into the solution milkiness disappears due to the formation of compound (D). Identify the compounds A, B, C and D. Explain why the milkiness disappears in the last step.

50. Lithium hydride can be used to prepare other useful hydrides. Beryllium hydride is one of them. Suggest a route for the preparation of beryllium hydride starting from lithium hydride. Write chemical equations involved in the process.
51. An element of group 2 forms covalent oxide which is amphoteric in nature and dissolves in water to give an amphoteric hydroxide. Identify the element and write chemical reactions of the hydroxide of the element with an alkali and an acid.
52. Ions of an element of group 1 participate in the transmission of nerve signals and transport of sugars and amino acids into cells. This element imparts yellow colour to the flame in flame test and forms an oxide and a peroxide with oxygen. Identify the element and write chemical reaction to show the formation of its peroxide. Why does the element impart colour to the flame?
53. Ions of an element of group 1 participate in the transmission of nerve signals and transport of sugars and amino acids into cells. This element imparts yellow colour to the flame in flame test and forms an oxide and a peroxide with oxygen. Identify the element and write chemical reaction to show the formation of its peroxide. Why does the element impart colour to the flame?

ANSWER KEY

Learner Box-1	1	2	3	4	5
Ans.	A	D	D	A	C

Learner Box-2	1	2	3	4
Ans.	A	A	A	D

Learner Box-3	1	2	3	4	5
Ans.	A,C	C	C	B	C

Learner Box-4	1	2	3	4	5
Ans.	A	B	A	D	A

ANSWER KEY

EXERCISE - I

1. (A) 2. (D) 3. (B) 4. (A) 5. (A) 6. (C) 7. (A,B,C)
 8. (C) 9. (A,B) 10. (A) 11. (A) 12. (A) 13. (B) 14. (C)
 15. (C) 16. (B) 17. (B) 18. (D) 19. (A,C) 20. (A) 21. (A)
 22. (A) 23. (C) 24. (B) 25. (B) 26. (A) 27. (A,C) 28. (B)
 29. (D) 30. (A) 31. (A) 32. (C) 33. (A) 34. (C) 35. (A)
 36. (D) 37. (A) 38. (A) 39. (A,B)

EXERCISE - II (JEE MAIN)

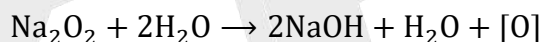
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|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1. | (1) | 2. | (1) | 3. | (1) | 4. | (1) | 5. | (1) | 6. | (2) | 7. | (3) |
| 8. | (1) | 9. | (4) | 10. | (2) | 11. | (1) | 12. | (1) | 13. | (3) | 14. | (2) |
| 15. | (1) | 16. | (2) | 17. | (4) | 18. | (1) | 19. | (4) | 20. | (1) | 21. | (2) |
| 22. | (3) | 23. | (4) | 24. | (2) | 25. | (D) | 26. | (A) | 27. | (C) | 28. | (A) |
| 29. | (A) | 30. | (D) | 31. | (D) | 32. | (B) | 33. | (B) | 34. | (D) | 35. | (B) |
| 36. | (D) | 37. | (B) | 38. | (B) | 39. | (A) | 40. | (C) | 41. | (A) | 42. | (B) |
| 43. | (C) | 44. | (C) | 45. | (D) | 46. | (D) | 47. | (C) | 48. | (B) | | |

EXERCISE - III (JEE-ADVANCE)

1. (B) 2. (A) 3. (A)
4. (i) Beryllium chloride is acidic, when dissolved in water because the hydrated ion hydrolysed producing H_3O^+ . This happens because the Be – O bond is very strong, and so in the hydrated ion this weakens the O – H bonds, and hence there is tendency to lose protons.

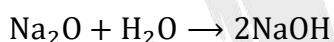


5. A = $\text{Ca}(\text{OH})_2$, B = NH_4HCO_3 , C = Na_2CO_3 , D = NH_4Cl , E = CaCl_2
6. (i) Na_2O_2 is powerful oxidant and bleaching agent and bleaches red litmus paper to white in aqueous solution according to the following reaction,



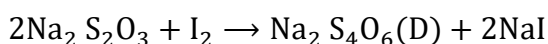
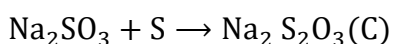
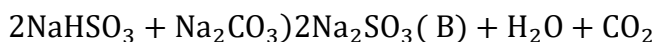
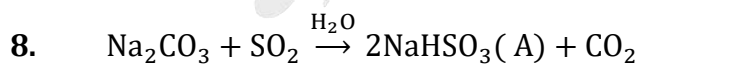
$[\text{O}] + \text{Litmus} \rightarrow \text{White (bleaching)}$

(ii) The other compound Na_2O will give NaOH on dissolution in water according to the following reaction.



The red litmus will turn to blue due to stronger alkaline nature of NaOH .

7. (B)



Oxidation states of S + 4 in NaHSO_3 [$1 + 1 + x + 3(-2) = 0$] and

+4 in Na_2SO_3 [$2 + x + 3(-2) = 0$]

+6 and – 2 (or an average + 2) in $\text{Na}_2\text{S}_2\text{O}_3$ and + 5 and 0 (or an average + 5

/2) in $\text{Na}_2\text{S}_4\text{O}_6$.

9. (B)

10. (A, B)
11. (A, B, C)/(B, C)
12. (A)
13. (B)
14. (D)

NCERT EXEMPLAR

I. Multiple Choice Questions (Type-I)

1. (D) 2. (A) 3. (C) 4. (D) 5. (A) 6. (A) 7. (A)
8. (C) 9. (B) 10. (A) 11. (A) 12. (A) 13. (B) 14. (A)
15. (C) 16. (A) 17. (D) 18. (B) 19. (A) 20. (C) 21. (D)

II. Multiple Choice Questions (Type-II)

22. (B),(D) 23. (A), (C) 24. (A), (B) 25. (B), (C) 26. (A),(C)
27. (A), (B) 28. (A), (B)

III. Short Answer Type

31. (A) $\text{O}_2^{2-} + 2\text{H}_2\text{O} \rightarrow 2\text{OH}^- + \text{H}_2\text{O}_2$
(B) $2\text{O}_2^- + 2\text{H}_2\text{O} \rightarrow 2\text{OH}^- + \text{H}_2\text{O}_2 + \text{O}_2$

IV. Matching Type

41. (A) \rightarrow (c) ; (B) \rightarrow (b) ; (C) \rightarrow (a), (d), (e) ; (D) \rightarrow (a), (d), (e)
42. (A) \rightarrow (c) ; (B) \rightarrow (d) ; (C) \rightarrow (b) ; (D) \rightarrow (a)
43. (A) \rightarrow (f); (B) \rightarrow (d); (C) \rightarrow (b) ; (D) \rightarrow (c); (E) \rightarrow (e); (F) \rightarrow (a)

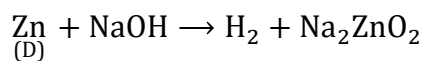
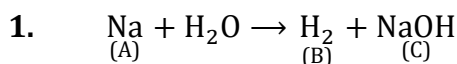
V. Assertion and Reason Type

44. (A) 45. (A)

VI. Long Answer Type

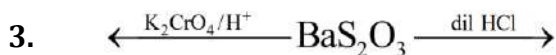
50. Compound : A: CaO ; B: Ca(OH)_2 ; C: CaCO_3 ; D: $\text{Ca(HCO}_3)_2$
 $\text{Ca(HCO}_3)_2$ is soluble in water. Hence, milkiness of solution disappears on passing excess carbon dioxide into the solution of compound B.
51. $8\text{LiH} + \text{Al}_2\text{Cl}_6 \rightarrow 2\text{LiAlH}_4 + 6\text{LiCl}$
 $\text{LiAlH}_4 + 2\text{BeCl}_2 \rightarrow 2\text{BeH}_2 + \text{LiCl} + \text{AlCl}_3$
52. The element is beryllium
53. The element is sodium.

SOLUTION



Sodium imparts golden yellow colour to Bunsen flame.

2. K_{sp} of the hydroxide of alkaline earth metal increase down the group. $\Rightarrow \text{Be}(\text{OH})_2$ has lowest value of solubility product.



4. $\text{Mg}(\text{OH})_2$ is known as milk of magnesia.

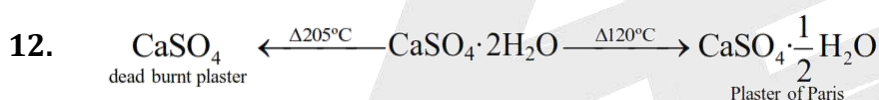
5. Due to low ionisation potential sodium imparts golden yellow colour to Bunsen flame.

6. BaO_2 , Na_2O_2 & CrO_5 have the peroxide linkages.

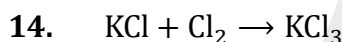
7. EDTA is used in the estimation of both Ca^{+2} and Mg^{2+} ions.

8. Due to high ionization, Be & Mg do not import any colour to Bunsen flame test.

11. Due to high ionization, Be&Mg do not import any colour to Bunsen flame test.

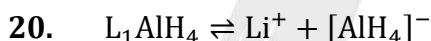
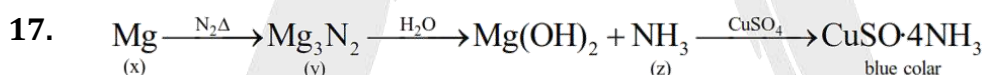


13. BeO is amphoteric in nature among oxide of given metal.

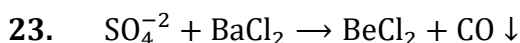


15. Basic strength of oxides of alkaline earth metal increases down the group.

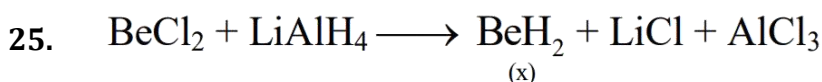
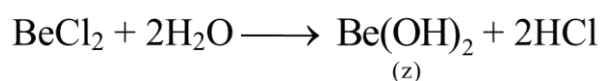
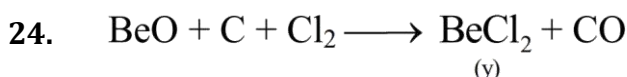
16. Basic strength of oxides of alkaline earth metal increases down the group.



The effective ingradient of x is OCl^-



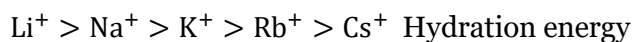
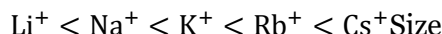
(insoluble in dil HCl)



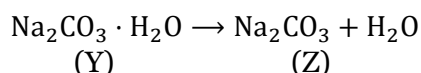
26. The order of thermal stability of carbonates of IIA group increases down the group.

JEE MAINS

25. Hydration energy is inversely proportional to the size of ion.



26. $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O} \rightarrow \text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O} + 9\text{H}_2\text{O}$
(X) (Y)



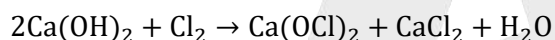
X = Washing soda

Z = Soda ash

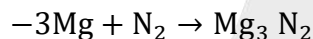
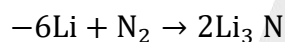
27. Lithium nitrate decomposes into its oxide on heating.



28. $6\text{NaOH} + 3\text{Cl}_2 \rightarrow 5\text{NaCl} + \text{NaClO}_3 + 3\text{H}_2\text{O}$



29. Solid hydrogen carbonates are not formed by lithium and magnesium.



31. BeSO_4 and MgSO_4 are readily soluble in water.

Reason \rightarrow The greater hydration enthalpies of Be^{2+} and Mg^{2+} ions dominate over their lattice enthalpies and the refore their sulphates are highly soluble.

32. Range of visible region :

390 nm – 760 nm

VIBGYOR

Violet Red

LiCl Crimson Red

NaCl Golden yellow

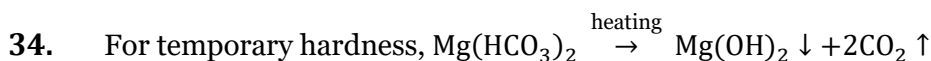
RbCl Violet

CsCl Blue

So Lid Which is crimson have wave length closed to red in the spectrum of visible region which is as per given data is.

33. Generally

$$\text{M.P.} \propto \text{Lattice energy} = \frac{kQ_1Q_2}{r^+ + r^-} \propto (\text{packing efficiency})$$



Assertion is false. MgCO_3 has high solubility product than $\text{Mg}(\text{OH})_2$

According to data of NCERT table 7.9 (Equilibrium chapter), the solubility product of magnesium carbonate is

3.5×10^{-8} and solubility product of $\text{Mg}(\text{OH})_2$ is 1.8×10^{-11} Hence Reason is incorrect.

35. (a) Be \rightarrow it is used in the Windows of X-ray tubes

(b) Mg \rightarrow it is used in the Incendiary bombs and signals

(c) Ca \rightarrow it is used in the Extraction of metals

(d) Ra \rightarrow it is used in the Treatment of cancer

36. (A) $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$ (Diamagnetic)

(B) $2\text{Na} + \text{O}_2 \rightarrow \text{Na}_2\text{O}$ (Diamagnetic)

$2\text{Na} + \text{O}_2 \xrightarrow{\text{(excess)}} \text{Na}_2\text{O}_2$ (Diamagnetic)

(C) $2\text{Ca} + \text{O}_2 \rightarrow 2\text{CaO}$ (Diamagnetic)

$\text{Ca} + \text{O}_2 \rightarrow \text{CaO}_2$ (Diamagnetic)

(D) $\text{K} + \text{O}_2 \xrightarrow{\text{(excess)}} \text{KO}_2$ (Paramagnetic)

37. Statement-I is incorrect

$\text{Be}(\text{OH})_2$ dissolve in alkali due to it's amphoteric nature.

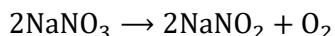
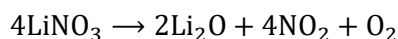
Statement-II is correct Solubility of alkaline earth metal hydroxide in water increases down the group due to rapid decreases in lattice energy as compared to hydration energy.

38. $\text{Ca}(\text{OH})_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 \downarrow + \text{H}_2\text{O}$

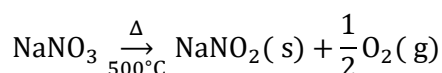
$\text{CaCO}_3 \downarrow + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{Ca}(\text{HCO}_3)_2$

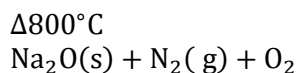
40. $\text{Li}_2\text{O}, \text{NaNO}_2$

As per NCERT Lithium nitrate when heated gives lithium oxide, Li_2O , whereas other alkali metal nitrates decompose to give the corresponding nitrite.



However, the decomposition product of NaNO_3 are temperature dependent process as shown in the below reaction.





41. Low solubility of LiF in water is due to high lattice enthalpy
42. Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is used to enhance setting time in portland cement.
- 43.

Element	Colour in flame test
K	Violet
Ca	Brick red
Sr	Crimson red
Ba	Apple green

44. Sodium have lowest oxidation potential in alkali metals. Hence it is weakest reducing agent among alkali metals.
45. Hydration enthalpies:
 (i) $\text{K}^+ > \text{Rb}^+ > \text{Cs}^+$: (I) > (II) > (IV)
 (ii) $\text{Mg}^{+2} > \text{Ca}^{+2}$: (III) > (V)
 Option (IV)
 (III) > (V) > (I) > (II) > (IV)
46. $\text{Li}_2\text{O} \rightarrow \text{O}^{2-} \rightarrow$ diamagnetic
 $\text{Na}_2\text{O}_2 \rightarrow \text{O}_2^{2-} \rightarrow$ diamagnetic
 $\text{KO}_2 \rightarrow \text{O}_2^- \rightarrow$ paramagnetic
47. $4\text{LiNO}_3 \xrightarrow{\Delta} 2\text{Li}_2\text{O} + 4\text{NO}_2 + \text{O}_2$
48. I. Beryllium oxide is amphoteric in nature.
 II. Beryllium carbonate is kept in the atmosphere of CO_2 because it is thermally less stable.
 III. Beryllium sulphate is readily soluble in water due to high degree of hydration.
 IV. Beryllium shows anomalous behaviour due to small size, high ionization energy and high value of ϕ (polarising power).