s-BLOCK ELEMENT

OBJECTIVES

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, caesium 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. Francium is highly radioactive; its longest-lived isotope 223Fr 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 .

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.

10.1 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.

10.1.1 Electronic Configuration

All the alkali metals have one valence electron, ns^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	$1s^2\,2s^22p^63s^1$
Potassium	K	$1s^22s^22p^63s^23p^64s^1$
Rubidium	Rb	$1s^22s^22p^63s^23p^63d^{10}4s^24p^65s^1$
Caesium	Cs	$1s^22s^22p^63s^23p^63d^{10}4s^24p^6\,4d^{10}5s^65p^66s^1$ or $[Xe]\,6s^1$
Francium	Fr	$[Rn]7s^1$

10.1.2 Atomic and Ionic Radii

Li < Na < K < Rb < Cs

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

10.1.3 Ionization Enthalpy

Li > Na > K > 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.

10.1.4 Hydration Enthalpy

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

$Li^+ > Na^+ > K^+ > Rb^+ > Cs^+$

Li^+ has maximum degree of hydration and for this reason lithium salts are mostly hydrated, e.g., $LiCl\cdot 2H_2O$

10.1.5 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.

Li < **K** < Na < Rb < 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.

(iv) 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 red	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.

(vi) 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 Li	Sodium Na	Potassium K	Rubidium Rb	Caesium Cs	Francium Fr
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 / g cm^{-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.

10.1.6 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 O_2^- ion is stable only in the presence of large cations such as K, Rb, Cs.

$4Li + O_2 \rightarrow 2Li_2O$ (oxide)

$2Na + O_2 \rightarrow Na_2O_2$ (peroxide)

$M + O_2 \rightarrow MO_2$ (superoxide)

(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 reactivity 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.

$2M + 2H_2O \rightarrow 2M^+ + 2OH^- + H_2$

(M = an alkali metal)

It may be noted that although lithium has most negative $E^\ominus$ value , 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 673K (lithium at 1073K) to form hydrides. All the alkali metal hydrides are ionic solids with high melting points.

$2M + H_2 \rightarrow 2M^+H^-$

(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 anion by the cation is called polarisation). The Li+ ion is very small in size and has high 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. The standard electrode potential ($E^\ominus$) which measures the reducing power represents the overall change :

$M(s) \rightarrow M(g)$ sublimationenthalpy

$M(g) \rightarrow M^+(g) + e^-$ ionizationenthalpy

$M^+ (g) + H_2O \rightarrow M^+ (aq)$ hydrationenthalpy

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 :

I^-, Ag, Cl^-, Li, Na

Solution

The order is Li > Na > I– > Ag > Cl–

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

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

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.

$M^+_{(am)} + e^- + NH_3(1) \rightarrow MNH_{2(am)} + \frac{1}{2}H_2(g)$ (where 'am' denotes solution in ammonia.) In concentrated solution, the blue colour changes to bronze colour and becomes diamagnetic.

(vii) ***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.

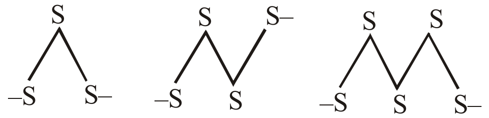
(viii) ***Reaction with N_2***

Only Lithium reacts with N_2 to form ionic lithium nitride Li_3N.

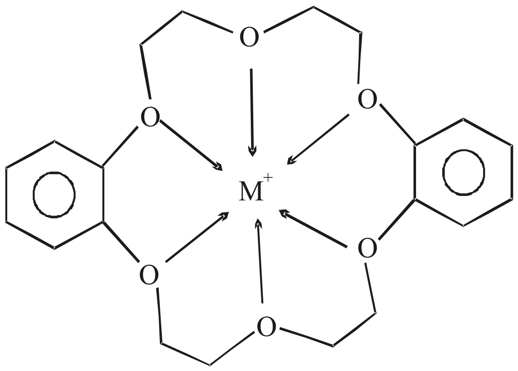
$$3Li + \frac{3}{2}N_2 \rightarrow Li_3N$$

(ix) ***Sulphides***

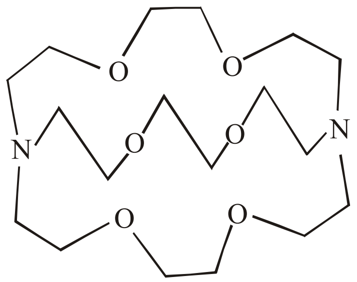
All metals react with S forming sulphides such as Na_2S and Na_2S_n (n = 2, 3, 4, 5 or 6). The polysulphide ions are made from zig-zag chains of sulphur atoms.



(x) ***Crown Ethers and Cryptands :***



Dibenzo-18-Crown-6



Cryptand - 222

[Na (Cryptand 222)]$^+$ Na$^-$ [Contains Na$^-$ (sodide ion)]

[Cs$^+$(Cryptand - 222)] [(Cyrptand-222)e$^-$] [electride]

10.1.7 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 electrochemical cells. Sodium is used to make a Na/Pb alloy needed to make $PbEt_4$ and $PbMe_4$. 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.

10.2 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.

10.2.1 Oxides and Hydroxides

On combustion in excess of air, lithium forms mainly the oxide, Li_2O (plus some peroxide Li_2O_2), sodium forms the peroxide, Na_2O_2 (and some oxide Na_2O) 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 hydrolysed by water to form the hydroxides according to the following reactions :

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

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

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

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

Problem 10.3

Why is KO_2 paramagnetic ?

Solution

The superoxide O_2^- is paramagnetic because of one upaired 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.

$$2Na + \frac{1}{2}O_2 \xrightarrow{180^\circ} Na_2O$$

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

$$Na_2O_2 + 2Na \xrightarrow{\Delta} 2Na_2O$$

$$2NaNO_3 + 10Na \xrightarrow{\Delta} 6Na_2O + N_2$$

$$2NaNO_2 + 6Na \xrightarrow{\Delta} 4Na_2O + N_2$$

Properties :

(i) It is white amorphous mass.

(ii) It decomposes at 400°C into sodium peroxide and sodium

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

(iii) It dissolve violently in water, yielding caustic soda.

$$Na_2O + H_2O \longrightarrow 2NaOH$$

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.

$$2Na + O_2 \longrightarrow Na_2O_2$$

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.

$$Na_2O_2 + 2H_2O \xrightarrow{\sim 0°C} 2NaOH + H_2O_2$$

$$2Na_2O_2 + 2H_2O \xrightarrow{25°C} 4NaOH + O_2$$

$$Na_2O_2 + H_2SO_4 \xrightarrow{\sim 0°C} Na_2SO_4 + H_2O_2$$

(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,

$$2Na_2O_2 + 2CO_2 \longrightarrow 2Na_2CO_3 + O_2$$

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

$3Na_2O_2 + 2C \longrightarrow 2Na_2CO_3 + 2Na$ [deposition of metallic Na]

$$CO + Na_2O_2 \longrightarrow Na_2CO_3$$

$$SO_2 + Na_2O_2 \longrightarrow Na_2SO_4$$

$$2NH_3 + 3Na_2O_2 \longrightarrow 6NaOH + N_2$$

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

Uses:

(i) For preparing H_2O_2, O_2

(ii) Oxygenating the air in submarines

(iii) Oxidising agent in the laboratory.

Oxides of Potassium :

	K_2O,	K_2O_2,	K_2O_3,	KO_2	and	KO_3
Colours :	White	White	Red	Bright Yellow		Orange Solid

Preparation :

(i) $2KNO_3 + 10K \xrightarrow{\text{heating}} 6K_2O + N_2$

** $\underset{\text{(White)}}{K_2O} \xrightarrow{\text{heating}} \underset{\text{(Yellow)}}{K_2O}$

** $K_2O + H_2O \longrightarrow 2KOH$

(ii) $2K + O_2 \xrightarrow[\text{air at 300°C}]{\text{Controlled}} K_2O_2$ [Props: Similar with Na_2O_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

$$\text{K in liq. } NH_3 \xrightarrow{O_2} \underset{\text{white}}{K_2O_2} \longrightarrow \underset{\text{red}}{K_2O_3} \longrightarrow \underset{\text{yellow}}{KO_2}$$

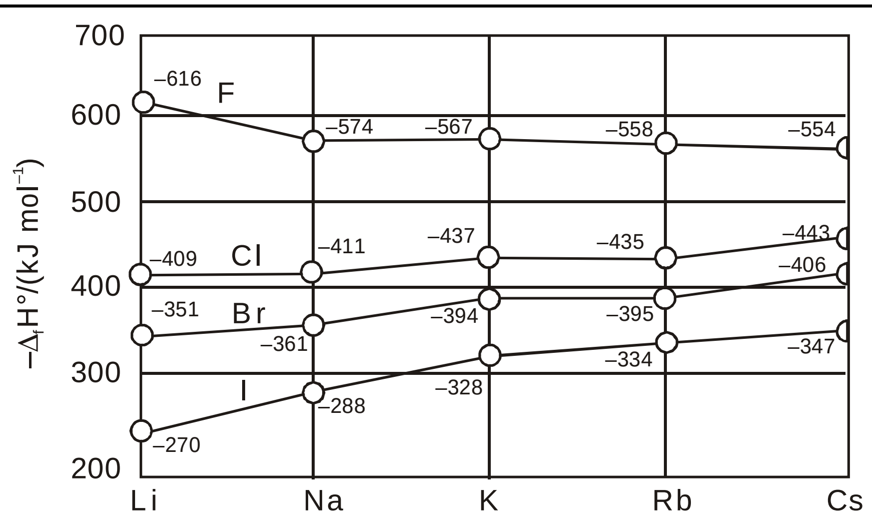
** KO_2 reacts with H_2O and produces H_2O_2 and O_2 both

$$2KO_2 + 2H_2O \xrightarrow{\sim 0°C} 2KOH + H_2O_2 + O_2$$

KO_3 : $\underset{\text{(Dry powdered)}}{KOH} + O_3 \text{ (ozonised oxygen)} \xrightarrow{-10°\text{to}-15°C} \underset{\text{(orange solid)}}{KO_3}$

10.2.2 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.



The standard enthalpies of formation of the halides of Group 1 elements at 298 K

10.2.3 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 hydorgencarbonates 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.

10.3 ANOMALOUS PROPERTIES OF LITHIUM

The anomalous behaviour of lithium is due to the : (i) exceptionally small size of its atom and ion, and (ii) high 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.

10.3.1 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, $LiCl.2H_2O$ 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.

$$4LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$$
$$2NaNO_3 \rightarrow 2NaNO_2 + O_2$$

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

10.3.2 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, Li = 152 pm, Mg = 160 pm; ionic radii : Li^+ = 76 pm, Mg^{2+}= 72 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 direct combination with nitrogen.

(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, $LiCl{\cdot}2H_2O$ and $MgCl_2{\cdot}8H_2O$.

10.4 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), $Na_2CO_3{\cdot}10H_2O$

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:

$$2NH_3 + H_2O + CO_2 \rightarrow (NH_4)_2\,CO_3$$

$$(NH_4)_2\,CO_3 + H_2O + CO_2 \rightarrow 2NH_4HCO_3$$

$$NH_4HCO_3 + NaCl \rightarrow NH_4Cl + NaHCO_3$$

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

$$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$$

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

$$2NH_4Cl + Ca(OH)_2 \rightarrow 2NH_3 + CaCl_2 + H_2O$$

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, $Na_2CO_3{\cdot}10H_2O$. 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 373K, the monohydrate becomes completely anhydrous and changes to a white powder called soda ash.

$$Na_2CO_2.10H_2O \xrightarrow{375K} Na_2CO_3.H_2O + 9H_2O$$

$$Na_2CO_3.H_2O \xrightarrow{>373K} Na_2CO_3 + H_2O$$

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

$$CO_3^{2-} + H_2O \rightarrow HCO_3^{-} + OH^{-}$$

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 form 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 lakh 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 1081K. 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.

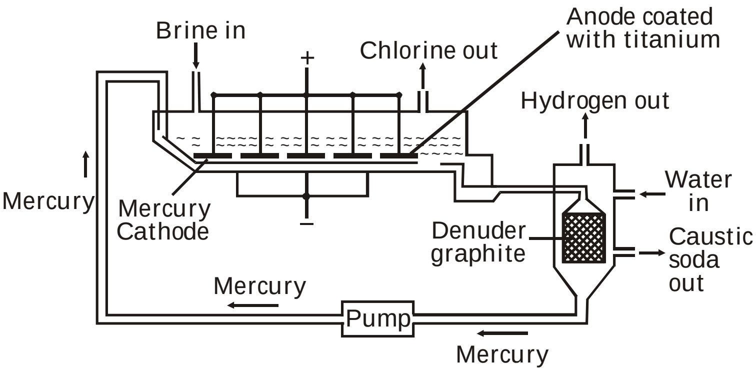
(iii) It is used to prepare freezing mixture in laboratory [Ice-common salt mixture is called freezing mixture and temperature goes down to –23°C.]

(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 anodes are now made of steel coated with titanium. Titanium is very resistance to corrosion)



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

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

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 mercerising 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.

$$Na_2CO_3 + H_2O + CO_2 \rightarrow 2NaHCO_3$$

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

***Potassium carbonate,* K_2CO_3**

It is also called potash or pearl ash. It cannot be made by the use of solvay process as potassium bicarbonate is more soluble than sodium bicarbonate. However, it can be prepared by **Le-Blanc process**. KCl is first converted into K_2SO_4. Potassium sulphate (K_2SO_4) is then heated with $CaCo_3$ and carbon.

$$KCl + H_2SO_4 \longrightarrow KHSO_4 + HCl$$

$$KHSO_4 + KCl \longrightarrow K_2SO_4 + HCl$$

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

It is a white powder , deliquescent in nature. It is highly soluble in water.

Uses : It is used in the manufacture of hard glass. The mixture of K_2CO_3 and Na_2CO_3 is used a **fusion mixture** in laboratory.

10.5 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 143 $mmolL^{-1}$, whereas the potassium level is only 5 $mmolL^{-1}$ within the red blood cells. These concentrations change to 10 $mmolL^{-1}$ (Na^+) and 105 $mmolL^{-1}$ (K^+). These ionic gradients demonstrate that a discriminatory mechanism, called the sodium-potassium 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.

10.6 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.

10.6.1 Electronic Configuration

These elements have two electrons in the *s* -orbital of the valence shell. 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 [Xe] $6s^2$
Radium	Ra	[Rn]$7s^2$

10.6.2 Atomic and Ionic Radii

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

Table : Atomic and Physical Properties of the Alkaline Earth Metals

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	226.03
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
Ionization enthyalpy(II) kJ mol^{-1}	1757	1450	1145	1064	965	979
Hydration enthalpy/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 / g cm^{-3}	1.84	1.74	1.55	2.63	3.59	(5.5)
Standard Potentials E^{-} /V for (M^{+2}/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.

10.6.3 Ionization Enthalpies

Ionization Enthalpy

Be > Mg > Ca > Sr > Ba

Down the group IE decreases due to increase in size

Q. IE_1 of AM < IE_1 of AEM
IE_2 of AM > IE_2 of AEM
[where AM = Alkali metal, AEM = Alkaline earth metal]

***Reason* :** IE_1 of AEM is large due to increased nuclear charge in AEM as compared to AM but IE_2 of AM is large because second electron in AM is to be removed from cation which has already acquired noble gas configuration.

10.6.4 Hydration Enthalpies

Like alkali metal ions, the hydration enthalpies of alkaline earth metal ions decrease with increase in ionic size down the group.

$Be^{2+} > Mg^{2+} > Ca^{2+} > Sr^{2+} > Ba^{2+}$

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 $MgCl_2.6H_2O$ and $CaCl_2\cdot 6H_2O$ while NaCl and KCl do not form such hydrates.

10.6.5 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 greyish.

(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.

10.6.6 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

$$M + 2H_2O \xrightarrow{\Delta} M(OH)_2 + H_2$$

* Be is inert towards water.

* Magnesium react as

$$Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$$

or $$Mg + H_2O \rightarrow MgO + H_2O$$

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.

$$M + X_2 \rightarrow MX_2 \text{ (X = F, Cl, Br, l)}$$

Thermal decomposition of $(NH_4)_2BeF_4$ is the best route for the preparation of BeF_2, and $BeCl_2$ is conveniently made from the oxide.

$$BeO + C + Cl_2 \xrightleftharpoons{600-800K} BeCl_2 + CO$$

(iv) ***Reactivity towards hydrogen :*** All the elements except beryllium combine with hydrogen upon heating to form their hydrides, MH_2. BeH_2, however, can be prepared by the reaction of $BeCl_2$ with $LiAlH_4$.

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

(v) ***Reactivity towards acids :*** AEM react with acids & liberate H_2

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

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

$$Be + 2NaOH \rightarrow Be(OH)_2 \xrightarrow{\text{excess NaOH}} [Be(OH)_4]^{2-}$$

(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. 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 Be^{2+} 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.

$$M + (x + y)\, NH_3 \rightarrow [M(NH_3)_x]^{2+} + 2[e(NH_3)_y]^{-} \text{ (except : Be and Mg)}$$

From these solutions, the ammoniates, $[M(NH_3)_6]^{2+}$ can be recovered.

10.6.7 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. Magnesium-aluminium 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.

10.7 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.

$$MO + H_2O \rightarrow M(OH)_2$$

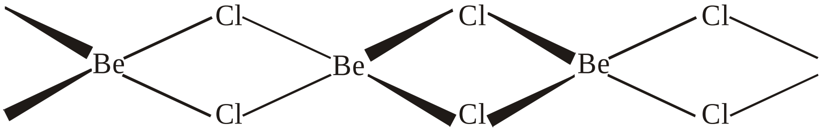
The solubility, thermal stability and the basic character of these hydroxides increase with increasing atomic number from $Mg(OH)_2$ to $Ba(OH)_2$. The alkaline earth metal hydroxides are, however, less basic and less stable than alkali metal hydroxides. Beryllium hydroxide is amphoteric in nature as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

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

$$Be(OH)_2 + 2HCl \rightarrow 2H_2O + BeCl_2$$

(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, $MgCl_2{\cdot}8H_2O$, $CaCl_2{\cdot}6H_2O$, $SrCl_2{\cdot}6H_2O$ and $BaCl_2{\cdot}2H_2O$) down the group. The dehydration of hydrated chlorides, bromides and iodides of Ca, Sr and Ba can be achieved on heating; however, the corresponding hydrated halides of Be and Mg on heating suffer hydrolysis. The fluorides are relatively less soluble than the chlorides owing to their high lattice energies.

(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.

$$2M\,(NO_3)_2 \rightarrow 2MO + 4NO_2 + O_2$$

(M + Be, Mg, Ca, Sr, Ba)

Problem 10.4

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.

10.8 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.

10.8.1 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, $[Be(OH)_4]^{2-}$ just as aluminium hydroxide gives aluminate ion, $[Al(OH)_4]^-$.

(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-}

10.9 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 ($CaCO_3$) in a rotary kiln at 1070-1270 K.

$$CaCO_3 \overset{heat}{\rightleftharpoons} CaO + CO_2$$

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.

$$CaO + H_2O \rightarrow Ca(OH)_2$$
$$CaO + CO_2 \rightarrow CaCO_3$$

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.

$$CaO + SiO_2 \rightarrow CaSiO_3$$
$$6CaO + P_4O_{10} \rightarrow 2Ca_3(PO_4)_2$$

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.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

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

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca\ (HCO_3)_2$$

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

$$2Ca(OH)_2 + 2Cl_2 \rightarrow CaCl_2 + Ca(OCl)_2 + 2H_2O$$

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.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$$

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.

$$CaCO_3 \xrightarrow{1200K} CaO + CO_2$$

It reacts with dilute acid to liberate carbon dioxide.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$$

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), $CaSO_4 \cdot \frac{1}{2} H_2O$

It is a hemihydrate of calcium sulphate. It is obtained when gypsum, $CaSO_4 \cdot 2H_2O$, is heated to 393 K.

$$2(CaSO_4.2H_2O) \rightarrow 2(CaSO_4).H_2O + 3H_2O$$

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 immoblising 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 ($CaSO_4 \cdot 2H_2O$) 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 ($Ca_3Al_2O_6$) 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.

10.10 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 100 mgL^{-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 400 mg per day in man? All this calcium passes through the plasma.

Summary : The ***s*-Block** of the periodic table constitutes **Group1** (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 monopositive **(M^+)** and dipositve **(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 alkalies. Important compounds of sodium includes 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.

FEW IMPORTANT POINTS

(i) Magnesium Peroxide (MgO_2) and Calcium Peroxide (CaO_2) are obtained by passing H_2O_2 in a suspension of $Mg(OH)_2$ and $Ca(OH)_2$.

(ii) MgO_2 is used as an antiseptic in tooth paste and as a bleaching agent.

(iii) Preperation of NaOH : Caustication of Na_2CO_3 (Gossage's method):

$$Na_2CO_3 + \underset{\text{(suspension)}}{Ca(OH)_2} \rightarrow 2NaOH + CaCO_3\downarrow$$

Since the K_{sp} ($CaCO_3$) < K_{sp} ($Ca(OH)_2$), 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 $MgCl \cdot 6H O$ undergoes hydrolysis as follows:

EXERCISE # O-1

SELECT THE CORRECT ALTERNATIVE (ONLY ONE CORRECT ANSWER)

Alkali metals

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

SB0001

2. 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, $CaCOH_2$ and Zn

SB0002

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

(A) Li_2CO_3 (B) K_2CO_3 (C) Cs_2CO_3 (D) Na_2CO_3

SB0003

4. 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

SB0004

5. 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

SB0005

6. 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

SB0006

7. The order of solubility of lithium halides in non-polar solvents follows the order

(A) LiI > LiBr > LiCl > LiF (B) LiF > LiI > LiBr > LiCl

(C) LiCl > LiF > LiI > LiBr (D) LiBr > LiCl > LiF > LiI

SB0007

8. The salt which finds uses in qualitative inorganic analysis is

(A) $CuSO_4 \cdot 5H_2O$ or $ZnSO_4 \cdot 5H_2O$ (B) $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$

(C) $Na(NH_4)HPO_4 \cdot 4H_2O$ (D) $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$

SB0008

9. 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

SB0009

10. $CsBr_3$ 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

SB0010

11. $Na + Al_2O_3 \xrightarrow{\text{High temperature}} X \xrightarrow[\text{water}]{CO_2 \text{ in}} Y$; compound Y is

(A) $NaAlO_2$
(B) $NaHCO_3$
(C) Na_2CO_3
(D) Na_2O_2

SB0011

12. aq. $NaOH + P_4$ (white) $\longrightarrow PH_3 + X$; compound X is

(A) NaH_2PO_2
(B) $NaHPO_4$
(C) Na_2CO_3
(D) $NaHCO_3$

SB0012

13. 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-}

SB0013

14. The order of melting point of chlorides of alkali metals is

(A) $LiCl > NaCl > KCl < CsCl$
(B) $LiCl > NaCl > KCl > CsCl$
(C) $NaCl > KCl > CsCl > LiCl$
(D) $LiCl > NaCl > CsCl > KCl$

SB0014

15. NaOH(Solid) + CO $\xrightarrow{200°C}$ X; product X is

(A) $NaHCO_3$
(B) Na_2CO_3
(C) HCOONa
(D) H_2CO_3

SB0015

16. 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

SB0016

17. 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

SB0017

18. Which one of the following fluoride of alkali metals has the highest lattice energy?

(A) LiF
(B) CsF
(C) NaF
(D) KF

SB0018

19. 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

SB0019

20. The correct order of degree of hydration of M^+ ions of alkali metals is

(A) $Li^+ < K^+ < Na^+ < Rb^+ < Cs^+$ (B) $Li^+ < Na^+ < K^+ < Rb^+ < Cs^+$

(C) $Cs^+ < Rb^+ < K^+ < Na^+ < Li^+$ (D) $Cs^+ < Rb^+ < Na^+ < K^+ < Li^+$

SB0020

21. 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 less reactive than potassium at 850 °C with respect to Cl_2

(D) sodium has less affinity to chloride ions in the presence of potassium ion

SB0021

Alkaline earth metals

22. The 'milk of magnesia' used as an antacid is chemically

(A) $Mg(OH)_2$ (B) MgO (C) $MgCl_2$ (D) $MgO + MgCl_2$

SB0022

23. 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

SB0023

24. The hydroxide of IInd A metal, which has the lowest value of solubility product (K_{sp}) at normal temperature (25°C) is

(A) $Ca(OH)_2$ (B) $Mg(OH)_2$ (C) $Sr(OH)_2$ (D) $Be(OH)_2$

SB0024

25. Which of the following metal is inert towards reaction with H_2O.

(A) Be (B) Na (C) Ca (D) K

SB0025

26. $Mg_2C_3 + H_2O \longrightarrow X$ (organic compound). Compound X is

(A) C_2H_2 (B) CH_4 (C) propyne (D) ethene

SB0026

27. The hydration energy of Mg^{2+} is

(A) more than that of Mg^{3+} ion (B) more than that of Na^+ ion

(C) more than that of Al^{3+} ion (D) more than that of Be^{2+} ion

SB0027

28. The correct order of second ionisation potentials (IP) of Ca, Ba and K is

(A) K > Ca > Ba (B) Ba > Ca > K (C) K > Ba > Ca (D) K = Ba = Ca

SB0028

29. 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

SB0029

30. The correct order of solubility is

(A) $CaCO_3 < KHCO_3 < NaHCO_3$ (B) $KHCO_3 < CaCO_3 < NaHCO_3$

(C) $NaHCO_3 < CaCO_3 < KHCO_3$ (D) $CaCO_3 < NaHCO_3 < KHCO_3$

SB0030

31. 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

SB0031

32. 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

SB0032

33. $Y \xleftarrow{\Delta, 205°C} CaSO_4 \cdot 2H_2O \xrightarrow{\Delta, 120°C} X$. 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

SB0033

34. A metal M readily forms water soluble sulphate, and water insoluble hydroxide $M(OH)_2$. 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

SB0034

35. The purpose of addition of gypsum in the cement is -

(A) To slow down the process of setting of the cement

(B) To fasten the process of setting of the cement

(C) Not to affect the process of setting of the cement by any means

(D) None of these

SB0035

36. (Milky Cloud) C $\xleftarrow{CO_2}$ A + $Na_2CO_3 \longrightarrow$ B + C

The chemical formulae of A and B are

(A) NaOH and $Ca(OH)_2$ (B) $Ca(OH)_2$ and NaOH

(C) NaOH and CaO (D) CaO and $Ca(OH)_2$

SB0036

37. The correct order of basic-strength of oxides of alkaline earth metals is

(A) BeO > MgO > CaO > SrO (B) SrO > CaO > MgO > BeO

(C) BeO > CaO > MgO > SrO (D) SrO > MgO > CaO > BeO

SB0037

38. $X \xrightarrow{N_2, \Delta} Y \xrightarrow{H_2O} Z(\text{colourless gas}) \xrightarrow[CuSO_4]{} T(\text{blue colour})$

Then, substances Y and T are

(A) Y = Mg_3N_2 and T = $CuSO_4 \cdot 5H_2O$ (B) Y = Mg_3N_2 and T = $CuSO_4 \cdot 4NH_3$

(C) Y = $Mg(NO_3)_2$ and T = CuO (D) Y = MgO and T = $CuSO_4 \cdot 4NH_3$

SB0038

39. Weakest base among KOH, NaOH, $Ca(OH)_2$ and $Zn(OH)_2$ is

(A) $Ca(OH)_2$ (B) KOH

(C) NaOH (D) $Zn(OH)_2$

SB0039

40. 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 << Y

SB0040

41. In castner-kellner cell if cathode is made up of graphite instead of mercury, then product that will be obtained first at cathode will be -

(A) Na-amalgam (B) Na only (C) H_2 gas (D) NaOH

SB0041

42. Na^+ ion can form complex with which of the following ligand.

(A) Cryptands (B) Crown ether (C) Both (A) and (B) (D) None

SB0042

43. $X + C + Cl_2 \xrightarrow[\text{of about } 1000\,K]{\text{High temperature}} Y + CO$; $Y + 2H_2O \rightarrow Z + 2HCl$

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) $AlCl_3$

SB0043

44. $BeCl_2 + LiAlH_4 \longrightarrow X + LiCl + AlCl_3$

(A) X is LiH (B) X is BeH_2

(C) X is $BeCl_2 \cdot 2H_2O$ (D) None

SB0044

45. The order of thermal stability of carbonates of IIA group is

(A) $BaCO_3 > SrCO_3 > CaCO_3 > MgCO_3$

(B) $MgCO_3 > CaCO_3 > SrCO_3 > BaCO_3$

(C) $CaCO_3 > SrCO_3 > BaCO_3 > MgCO_3$

(D) $MgCO_3 = CaCO_3 > SrCO_3 = BaCO_3$

SB0045

46. A pair of substances which gives all the same products on reaction with water is

(A) Mg and MgO (B) Sr and SrO (C) Ca and CaH_2 (D) Be and BeO

SB0046

47. A metal which is soluble in both water and liquid NH_3 separately -

(A) Cr (B) Mn (C) Ba (D) Al

SB0047

48. $Be_2C + H_2O \longrightarrow BeO + X$

$CaC_2 + H_2O \longrightarrow Ca(OH)_2 + Y$; then X and Y are respectively

(A) CH_4, CH_4 (B) CH_4, C_2H_6 (C) CH_4, C_2H_2 (D) C_2H_2, CH_4

SB0048

49. Which of the following groups of elements have chemical properties that are most similar

(A) Na, K, Ca (B) Mg, Sr, Ba (C) Be, Al, Ca (D) Be, Ra, Cs

SB0049

50. $MgBr_2$ 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

SB0050

EXERCISE # O-2

SELECT THE CORRECT ALTERNATIVES (ONE OR MORE THEN ONE CORRECT ANSWERS)

Alkali metals

1. Nitrogen dioxide can be prepared by heating-

(A) KNO_3 (B) $AgNO_3$ (C) $Pb(NO_3)_2$ (D) $Cu(NO_3)_2$

SB0051

2. Which of the following compounds are not paramagnetic in nature?

(A) KO_2 (B) K_2O_2 (C) Na_2O_2 (D) RbO_2

SB0052

3. 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

SB0053

4. KO_2 finds use in oxygen cylinders used for space and submarines. The fact(s) related to such use of KO_2 is/are

(A) it produces O_2 (B) it produces O_3

(C) it absorbs CO_2 (D) it absorbs both CO and CO_2

SB0054

5. 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

SB0055

6. 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

SB0056

7. Sodium metal is highly reactive and can be stored under

(A) toluene (B) kerosene oil (C) alcohol (D) benzene

SB0057

Alkaline earth metals

8. The compound(s) of IInd A metals, which are amphoteric in nature is/are

(A) BeO (B) MgO (C) $Be(OH)_2$ (D) $Mg(OH)_2$

SB0058

9. The correct statement is/are

(A) $BeCl_2$ is a covalent 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

SB0059

10. 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

SB0060

11. 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

SB0061

12. Which of the following statements are false?

(A) $BeCl_2$ is a linear molecule in the vapour state but it is polymeric form in the solid state

(B) Calcium hydride is called hydrolith.

(C) Carbides of both Be and Ca react with water to form acetylene

(D) Oxides of both Be and Ca are amphoteric.

SB0062

13. Which of the following are ionic carbides?

(A) CaC_2 (B) Al_4C_3 (C) SiC (D) Be_2C

SB0063

14. Which of the following orders are **CORRECT** :

(A) AgCl > AgF : Covalent character order

(B) BaO > BaF_2 : Melting point order

(C) BeF_2 > BaF_2 : Solubility order

(D) $LiNO_3$ < $RbNO_3$: Thermal stability order

SB0064

15. Which of the following statements are **CORRECT** :

(A) Mg is present in chlorophyll

(B) Alkaline earth metals does not form super oxide

(C) $NaHCO_3$ is known as baking soda

(D) Permanent hardness of water is removed by boiling

SB0065

16. Which of the following carbides on hydrolysis does not form methane :

(A) Be_2C (B) CaC_2 (C) SrC_2 (D) Mg_2C_3

SB0066

17. Select the incorrect order for given properties :

(A) Thermal stability : $BaSO_4 > SrSO_4 > CaSO_4$

(B) Solubility : $BaSO_4 > SrSO_4 > CaSO_4$

(C) Thermal stability : $Li_2CO_3 < Na_2CO_3 < K_2CO_3$

(D) Solubility : $Li_2CO_3 > Na_2CO_3 > K_2CO_3$

SB0067

18. The correct statement(s) is/are

(A) Mg cannot form complexes

(B) Be can form complexes due to a very small atomic size

(C) the first ionisation potential of Be is higher than that of Mg

(D) Mg forms an alkaline hydroxide while Be forms amphoteric oxides

SB0068

19. Which of the following is are the characteristic of barium?

(A) It produce water soluble sulphide, sulphite and sulphate

(B) It is a silvery white metal

(C) It forms $Ba(NO_3)_2$ which is used in preparation of green fire

(D) It produce blue-black solution in liquid ammonia

SB0069

EXERCISE # S-1

NUMERIC GRID TYPE QUESTIONS :

1. Find the number of compounds from the following in which the element in the anionic part is in the minimum oxidation state of it

$$LiH,\ Mg_3Bi_2,\ Al_4C_3,\ Ca_3P_2,\ BaO_2$$

SB0070

2. How many nitrate groups are present in 1 molecule of Basic beryllium nitrate?

SB0071

3. Consider the following order :

(1) $CH_4 < CCl_4 < CF_4$: E.N. of central atom C

(2) $Mg^{+2} < K^{+} < S^{-2} < Se^{-2}$: Ionic radius

(3) $Be^{+2}_{(aq)} > Mg^{+2}_{(aq)} > Ca^{+2}_{(aq)}$: Ionic mobility

(4) $Be^{+2} > Li^{+} > Al^{+3}$: Hydrated size

(5) Be > Li > Cs : Reducing power

(6) $F^{\ominus}_{(aq)} > Cl^{\ominus}_{(aq)} > Br^{\ominus}_{(aq)}$: Electrical conductance in infinite dilute solution

Then calculate value of $|x - y|^2$, where x and y are correct and incorrect orders respectively.

SB0072

4. Consider the following elements :

Li, Cs, Mg, Pb, Al, N

- x = number of elements which can form MO type of oxides.
- y = the highest oxidation state shown by any one of them.
- z = the number of elements which can form amphoteric oxide(s).

Find the sum of x, y and z.

SB0073

Fill your answer as sum of digits till you get the single digit answer.

5. Find the number of s-block elements which can produce ammoniated cation and ammoniated electron with liquid ammonia.

Li, Na, K, Rb, Cs, Ca, Sr, Ba

SB0074

6. How many of the following metal chlorides impart characteristic colour to the oxidising flame.

$LiCl,\ NaCl,\ KCl,\ BeCl_2,\ MgCl_2,\ CaCl_2,\ SrCl_2,\ BaCl_2$

SB0075

EXERCISE # S-2

COMPREHENSION BASED QUESTIONS

Comprehension # 1

$$A \xrightarrow{\Delta} B\text{ (oxide)} + CO_2$$
$$B + H_2O \longrightarrow C$$
$$C + CO_2 \longrightarrow A\text{ (milky)}$$
$$C + NH_4Cl \xrightarrow{\Delta} D\text{ (gas)}$$
$$D + H_2O + CO_2 \longrightarrow E$$
$$E + NaCl \longrightarrow F$$
$$F \xrightarrow{\Delta} Na_2CO_3 + CO_2 + H_2O$$

1. A is :

(A) $Ca(HCO_3)_2$ (B) $CaCO_3$ (C) CaO (D) Na_2CO_3

SB0076

2. B and C are :

(A) CaO, $Ca(OH)_2$ (B) $Ca(OH)_2$, $CaCO_3$

(C) $CaCO_3$, $Ca(OH)_2$ (D) $Ca(OH)_2$, CaO

SB0076

3. D, E and F are :

(A) NH_3, NH_4Cl, NH_4HCO_3 (B) NH_3, NH_4HCO_3, $NaHCO_3$

(C) NH_4HCO_3, Na_2CO_3, $NaHCO_3$ (D) None

SB0076

Comprehension # 2

Alkali metals readily react with oxyacids forming corresponding salts like M_2CO_3, $MHCO_3$, MNO_3, M_2SO_4 etc. with evolution of hydrogen. They also dissolve in liquid NH_3 but without the evolution of hydrogen. The colour of its dilute solution is blue but when it is heated and concentrated then its colour becomes bronze.

4. Among the nitrate of alkali metals which one can be decomposed to its oxide easily?

(A) $NaNO_3$ (B) KNO_3 (C) $LiNO_3$ (D) $RbNO_3$

SB0077

5. Among the carbonates of alkali metals which one has highest stability?

(A) Cs_2CO_3 (B) Rb_2CO_3 (C) K_2CO_3 (D) Na_2CO_3

SB0078

6. Which of the following statement about the sulphate of alkali metal is correct?

(A) Except Li_2SO_4 all sulphate of other alkali metals are soluble in water

(B) All sulphates of alkali metals except lithium sulphate forms alum.

(C) The sulphates of alkali metals cannot be hydrolysed.

(D) All of these

SB0079

7. Which of the following statement about solution of alkali metals in liquid ammonia is correct?

(A) The solution have strong oxidizing properties.

(B) Both the dilute solution as well as concentrated solution are paramagnetic in nature

(C) Charge transfer is the responsible for the colour of the solution

(D) None of these

SB0080

8. Which metal bicarbonates does not exist in solid state?

(i) $LiHCO_3$ (ii) $Ca(HCO_3)_2$ (iii) $Zn\ (HCO_3)_2$
(iv) $NaHCO_3$ (v) $AgHCO_3$

(A) (i), (ii), (iii), (v) (B) (i), (ii), (iii) (C) (i), (ii), (v) (D) (ii), (iii), (iv)

SB0081

MATCH THE COLUMN :

9.

Column-I	**Column-II**
(A) Hydrolith	(P) Contain Ca
(B) Nitrolim	(Q) Used as a fertilizer
(C) Dolomite	(R) Used to prepare H_2
(D) Pearl's ash	(S) Contain potassium

SB0082

10.

Column-I	**Column-II**
(A) Metal sulphate $\xrightarrow{\Delta}$ metal oxide + SO_2 + O_2	(P) Ba
(B) Metal cation + $K_2CrO_4 \longrightarrow$ yellow ppt	(Q) Sr
(C) Metal + $NH_3 \xrightarrow{\text{(liquid)}}$ blue solution	(R) Na
(D) MCl_2 + conc. $H_2SO_4 \longrightarrow$ white ppt.	(S) Mg

SB0083

MATCH THE CODE :

11. List–I	List–II
(P) CaH_2	(1) Paramagnetic anion
(Q) K_2O_2	(2) Homodiatomic, diamagnetic anion
(R) KO_2	(3) Neutral aqueous solution
(S) NaCl	(4) Gives hydrogen on hydrolysis

Codes :

	P	Q	R	S
(A)	3	2	1	4
(B)	4	2	3	1
(C)	4	3	2	1
(D)	4	2	1	3

SB0084

12. Column-I	Column-II
(P) Solvay process used for	(1) NaCl
(Q) Evolve $CO_2\uparrow$ on heating	(2) Na_2O_2
(R) aq. soln. is neutral towards litmus	(3) $NaHCO_3$
(S) Oxone	(4) Na_2CO_3

Codes :

	P	Q	R	S
(A)	3,4	3	1	2
(B)	4,1	1	3	2
(C)	2,3	4	1	3
(D)	2,4	1	3	4

SB0085

ASSERATION & REASONING :

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

13. **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 exciation of the electrons.

SB0086

14. **Assertion** : In fused state, calcium chloride cannot be used to dry alcohol or NH_3.

Reason : Anhy. $CaCl_2$ is not a good desiccant.

SB0087

15. **Assertion** : Diagonal relationship is shown between Be and Al.

Reason : Ionic potential of Be is almost the same as that of Al.

SB0088

16. **Assertion** : Beryllium halides dissolve in organic solvents.

Reason : Beryllium halides are ionic in character.

SB0089

17. **Assertion** : $BeCl_2$ fumes in moist air.

Reason : $BeCl_2$ reacts with moisture to form HCl gas.

SB0090

18. **Assertion** : Calcium carbide on hydrolysis gives methane.

Reason : Calcium carbide contains C_2^{2-} anion.

SB0091

19. **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 $Ca(HCO_3)_2$ when excess of CO_2 is present.

SB0092

20. **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 $Mg(HCO_3)_2$.

SB0093

MATCHING LIST TYPE 1 × 3 Q. (THREE LIST TYPE Q.)

The following column 1, 2, 3 represent elements of s block and their different oxide formation abilities. Answer the questions that follow

Column-1 - Elements of s-Block

Column-2 - Product formed on reaction with excess oxygen

Column-3 - Characteristics of species form on reaction with excess oxygen

Column - 1 Elements	**Column - 2 Product formed on reaction with excess oxygen**	**Column - 3 Characteristics of species form on reaction with excess oxygen**
(I) Na	(A) Superoxide	(P) Paramagnetic
(II) Ba	(B) Peroxide	(Q) Diamagnetic
(III) K	(C) Monooxide	(R) Bond order = 1.5
(IV) Ca	(D) Dioxide	(S) Bond order = 1

21. Which of the following is an **INCORRECT** match.

(A) (I), (B), (QS) (B) (II), (B), (QS) (C) (II), (A), (PR) (D) (IV), (C), (Q)

SB0094

22. Which of the following matches will result in species having magnetic moment equal to that of Mn^{+6}

(A) I, (B), QS (B) IV, B, (QS) (C) IV, (A), (PR) (D) III, (A), (PR)

SB0094

23. On reaction with oxygen, which of the following combination is possible

(A) I, (A, C), (P, Q) (B) I, (B), (Q)

(C) II, (A, B), (P, Q, S) (D) IV, (B, C), Q

SB0094

EXERCISE # JEE-MAIN

1. A metal M readily forms its sulphate MSO_4 which is water soluble. It forms oxide MO which becomes inert on heating. It forms insoluble hydroxide which is soluble in NaOH. The metal M is:- **[AIEEE-2002]**

(1) Mg (2) Ba (3) Ca (4) Be

SB0095

2. KO_2 is used in space and submarines because it **[AIEEE-2002]**

(1) Absorbs CO_2 and increase O_2 concentration

(2) Absorbs moisture

(3) Absorbs CO_2

(4) Produces ozone

SB0096

3. In curing cement plasters, water is sprinkled from time to time. This helps in :- **[AIEEE-2003]**

(1) Hydrating sand and gravel mixed with cement

(2) Converting sand into silicate

(3) Developing interlocking needle like crystals of hydrated silicates

(4) Keeping it cool

SB0097

4. The solubilities of carbonates decreases down the magnesium group due to decrease in-**[AIEEE-2003]**

(1) Inter-ionic attraction

(2) Entropy of solution formation

(3) Lattice energy of solids

(4) Hydration energy of cations

SB0098

5. The substance not likely to contain $CaCO_3$ is :- **[AIEEE-2003]**

(1) Sea shells (2) Dolomite

(3) A marble statue (4) Calcined gypsum

SB0099

6. One mole of magnesium nitride on reaction with excess of water gives :- **[AIEEE-2004]**

(1) Two mole of HNO_3 (2) Two mole of NH_3

(3) 1 mole of NH_3 (4) 1 mole of HNO_3

SB0100

7. Berylium and aluminium exhibit many properties which are similar. But the two elements differ in - **[AIEEE-2004]**

(1) Exhibiting maximum covalency in compounds

(2) Forming polymeric hydrides

(3) Forming covalent halides

(4) Exhibiting amphoteric nature in their oxides.

SB0101

8. The ionic mobility of alkali metal ioins in aqueous solution is maximum for :- **[AIEEE-2006]**

(1) Rb^+ (2) Li^+ (3) Na^+ (4) K^+

SB0102

9. The products obtained on heating $LiNO_3$ will be :- **[AIEEE-2011]**

(1) $LiNO_2 + O_2$ (2) $Li_2O + NO_2 + O_2$

(3) $Li_3N + O_2$ (4) $Li_2O + NO + O_2$

SB0103

10. What is the best description of the change that occurs when $Na_2O(s)$ is dissolved in water ? **[AIEEE-2011]**

(1) Oxidation number of sodium decreases

(2) Oxide ion accepts sharing in a pair of electrons

(3) Oxide ion donates a pair of electrons

(4) Oxidation number of oxygen increases

SB0104

11. Which of the following on thermal-decomposition yields a basic as well as an acidic oxide ? **[AIEEE-2012]**

(1) NH_4NO_3 (2) $NaNO_3$ (3) $KClO_3$ (4) $CaCO_3$

SB0105

12. Fire extinguishers contain H_2SO_4 and which one of the following :-**[JEE MAIN-2012, Online]**

(1) $CaCO_3$ (2) $NaHCO_3$ and Na_2CO_3

(3) Na_2CO_3 (4) $NaHCO_3$

SB0106

13. Based on lattice energy and other considerations, which one of the following alkali metal chloride is expected to have the highest melting point ? **[JEE MAIN-2012, Online]**

(1) RbCl (2) LiCl (3) KCl (4) NaCl

SB0107

14. Which one of the following will react most vigorously with water ? **[JEE MAIN-2012, Online]**

(1) Li (2) K (3) Rb (4) Na

SB0108

15. A metal M on heating in nitrogen gas gives Y. Y on treatment with H_2O gives a colourless gas which when passed through $CuSO_4$ solution gives a blue colour, Y is :- **JEE MAIN-2012, Online]**

(1) NH_3 (2) MgO (3) Mg_3N_2 (4) $Mg(NO_3)_2$

SB0109

16. The correct statement for the molecule, CsI_3, is : **[JEE(Main)-2014]**

(1) it contains Cs^{3+} and I^- ions

(2) it contains Cs^+, I^- and lattice I_2 molecule

(3) it is a covalent molecule

(4) it contains Cs^+ and I_3^- ions

SB0110

17. Which of the following statements about Na_2O_2 is **not** correct ? **[JEE MAIN-2014, Online]**

(1) Na_2O_2 oxidises Cr^{3+} to CrO_4^{2-} in acid medium

(2) It is diamagnetic in nature

(3) It is the super oxide of sodium

(4) It is a derivative of H_2O_2

SB0111

18. Amongst LiCl, RbCl, $BeCl_2$ and $MgCl_2$ the compounds with the greatest and the least ionic character, respectively are : **[JEE MAIN-2014, Online]**

(1) RbCl and $MgCl_2$

(2) LiCl and RbCl

(3) $MgCl_2$ and $BeCl_2$

(4) RbCl and $BeCl_2$

SB0112

19. The correct order of thermal stability of hydroxides is : **JEE(Main)Online-2015]**

(1) $Ba(OH)_2 < Sr(OH)_2 < Ca(OH)_2 < Mg(OH)_2$

(2) $Mg(OH)_2 < Sr(OH)_2 < Ca(OH)_2 < Ba(OH)_2$

(3) $Mg(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Ba(OH)_2$

(4) $Ba(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Mg(OH)_2$

SB0113

20. Which of the alkaline earth metal halides given below is essentially covalent in nature :-

(1) $SrCl_2$ (2) $CaCl_2$ (3) $BeCl_2$ (4) $MgCl_2$

JEE(Main)Online-2015]

SB0114

21. Which one of the following alkaline earth metal sulphates has its hydration enthalpy greater than its lattice enthalpy ? **[JEE(Main)-2015]**

(1) $BaSO_4$ (2) $SrSO_4$ (3) $CaSO_4$ (4) $BeSO_4$

SB0115

22. The commercial name for calcium oxide is : **[JEE(Main)-2016]**

(1) Quick lime (2) Milk of lime (3) Limestone (4) Slaked lime

SB0116

23. The correct order of the solubility of alkaline-earth metal sulphates in water is : **[JEE(Main)-2016]**

(1) Mg < Sr < Ca < Ba

(2) Mg < Ca < Sr < Ba

(3) Mg > Ca > Sr > Ba

(4) Mg > Sr > Ca > Ba

SB0117

24. The main oxides formed on combustion of Li, Na and K in excess of air are respectively :

(1) Li_2O, Na_2O_2 and KO_2 (2) Li_2O, Na_2O and KO_2 **[JEE(Main)-2016]**

(3) LiO_2, Na_2O_2 and K_2O (4) Li_2O_2, Na_2O_2 and KO_2

SB0118

25. Both lithium and magnesium display several similar properties due to the diagonal relationship ; however, the one which is incorrect is : **[JEE(Main)-2017]**

(1) Both form basic carbonates

(2) Both form soluble bicarbonates

(3) Both form nitrides

(4) Nitrates of both Li and Mg yield NO2 and O2 on heating

SB0119

26. Which of the following ions does **not** liberate hydrogen gas on reaction with dilute acids?

(1) Ti^{2+} (2) Cr^{2+} **[JEE(Main)-2017 on line]**

(3) Mn^{2+} (4) V^{2+}

SB0120

27. In KO_2, the nature of oxygen species and the oxidation state of oxygen atom are, respectively

[JEE(Main)ONLINE-2018]

(1) Superoxide and –1/2

(2) Oxide and -–2

(3) Peroxide and –1/2

(4) Superoxide and –1

SB0121

EXERCISE # JEE-ADVANCED

1. The species that do not contain peroxide linkage are - **[JEE 1992]**

(A) PbO_2 7(B) H_2O_2 (C) SrO_2 (D) BaO_2

SB0122

2. Read the following statement and explanation and answer as per the options given below :

Statement-1 : The alkali metals can form ionic hydrides which contain the hydride ion H^-.

Statement-2 : The alkali metals have low electronegativity ; their hydrides conduct electricity when fused and liberate hydrogen at the anode. **[JEE 1994]**

(A) Both 1 and 2 are true and 2 is the correct explanation of 1.

(B) Both 1 and 2 are true but 2 is not the correct explanation of 1.

(C) 1 is true but 2 is false.

(D) 1 is false but 2 is true.

SB0123

3. The following compounds have been arranged in order of their increasing thermal stabilities. Identify the correct order. **[JEE 1996]**

K_2CO_3(I) $MgCO_3$(II) $CaCO_3$(III) $BeCO_3$(IV)

(A) I < II < III < IV (B) IV < II < III < I

(C) IV < II < I < III (D) II < IV < III < I

SB0124

4. Property of all the alkaline earth metals that increase with their atomic number is - **[JEE 1997]**

(A) ionisation energy (B) solubility of their hydroxides

(C) solubility of their sulphate (D) electronegativity

SB0125

5. Highly pure dilute solution of sodium in liquid ammonia - **[JEE 1998]**

(A) shows blue colour (B) exhibits electrical conductivity

(C) produces sodium amide (D) produces hydrogen gas

SB0126

6. The set representing the correct order of first ionization potential is - **[JEE 2001S]**

(A) K > Na > Li (B) Be > Mg > Ca (C) B > C > N (D) Ge > Si > C

SB0127

Asseration and Reason

7. This questions contains statement-1 (asseration) and statement-2 (reason) and has 4 choices (a), (b), (c) and (d) out of which only one is correct.

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

Statement-1 : Alkali metals is liquid ammonia give solvated species of the type $[M(NH_3)_n]^+$ (M = alkali metals). **[JEE 2007]**

(A) Both 1 and 2 are true and 2 is the correct explanation of 1.

(B) Both 1 and 2 are true but 2 is not the correct explanation of 1.

(C) 1 is true but 2 is false.

(D) 1 is false but 2 is true.

SB0128

8. 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

SB0129

ANSWER KEY

EXERCISE # O-1

1. (A) **2.** (A) **3.** (A) **4.** (D)

5. (A) **6.** (D) **7.** (A) **8.** (C)

9. (B) **10.** (C) **11.** (C) **12.** (A)

13. (C) **14.** (C) **15.** (C) **16.** (D)

17. (A) **18.** (A) **19.** (A) **20.** (C)

21. (B) **22.** (A) **23.** (C) **24.** (D)

25. (A) **26.** (C) **27.** (B) **28.** (A)

29. (C) **30.** (D) **31.** (A) **32.** (A)

33. (A) **34.** (B) **35.** (A) **36.** (B)

37. (B) **38.** (B) **39.** (D) **40.** (A)

41. (C) **42.** (C) **43.** (B) **44.** (B)

45. (A) **46.** (C) **47.** (C) **48.** (C)

49. (B) **50.** (D)

EXERCISE # O-2

1. (B),(C), (D) **2.** (B),(C) **3.** (A),(B) **4.** (A),(C)

5. (A),(B),(C) **6.** (A), (B) **7.** (A), (B),(D) **8.** (A),(C)

9. (A),(B),(C) **10.** (A),(C) **11.** (A), (C) **12.** (C),(D)

13. (A),(B),(D) **14.** (A),(B),(C),(D) **15.** (A),(B),(C) **16.** (B),(C),(D)

17. (B), (D) **18.** (B),(C),(D) **19.** (B),(C),(D)

EXERCISE # S-1

1. (4) **2. (6)** **3. (4)** **4. (10), OMR - (1)**

5. (8)

6. (6)

Except Be & Mg other s-block metals impart characteristic colour to oxidising flame.

EXERCISE # S-2

- **Comprehension Based Questions**

Comprehension # 1

1. (B) **2.** (A) **3.** (B)

Comprehension # 2

4. (C) **5.** (A) **6.** (D) **7.** (D) **8.** (A)

- **Match the column**

9. (A) $\rightarrow$ P,R ; (B) $\rightarrow$ P,Q ; (C) $\rightarrow$ P ; (D) $\rightarrow$ S

10. (A) $\rightarrow$ P,Q,S ; (B) $\rightarrow$ P,Q; (C) $\rightarrow$ P,Q,R ; (D) $\rightarrow$ P,Q

- **Match the code**

11. (D) **12.** (A)

- **Asseration & Reasoning**

13. A **14. C** **15. A** **16. C**
17. A **18. D** **19. A** **20. A**
21. C **22. D** **23. B**

EXERCISE # JEE-MAIN

1. (4) **2.** (1) **3.** (3) **4.** (4)
5. (4) **6.** (2) **7.** (1) **8.** (1)
9. (2) **10.** (3) **11.** (4) **12.** (4)
13. (4) **14.** (3) **15.** (3) **16.** (4)
17. (3) **18.** (4) **19.** (3) **20.** (3)
21. (4) **22.** (1) **23.** (3) **24.** (1)
25. (1) **26.** (3) **27.** (1)

EXERCISE # JEE-ADVANCED

1. A **2. A** **3. B** **4. B**
5. A,B **6. B** **7. B** **8. A,B**