ALKALI AND ALKALINE EARTH METALS

UNIT : 1

1 General introduction , Electric Configuration, Occurrence
2 Anomalous properties of the first element in each group
3 Diagonal relationship
4 Trends in properties like ionization enthalpy, atomic and ionic radii, reactivity with O_2, H_2 and X_2 and water, uses
5 Preperation and properties of some important compounds : Sodium hydroxide, salts of oxo acids ; sodium carbonate and Sodium hydrogen carbonate ; sodium chloride
6 Biological importance of Sodium and Potassium

VERY SHORT ANSWERS:

1. How do alkali metals occur in nature?

A. Alkali metals are highly reactive hence they do not occur freestate. They occur in combined state.

Minerals of Na and K are

Eg: Common salt (NaCl)

2) Sylvine (KCl)

3) Carnallite (KCl, $MgCl_2 6H_2O$)

2. Write the electronic configuration of K and Rb

$K_{19} = 1s^2\ 2s^2\ 3s^2\ 3p^6\ 4s^1$

$Rb_{27} = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 5s^1$

3. Why does the first element in the group show anomalous behaviour. Give a reason.

A. Because of its very small size and non availability of 'd' orbitals.

4. Which elements show diagonal relationship ? Give an example.

A. In the periodic table an element of a group in the 2^{nd} period shows diagonal relationship with the second element of the next group in the third group.

Eg: lithium and magnesium

5. How are IE's changing in the first group elements and why ?

A. IE's decreases because of increase in atomic size from Li to Fr.

6. Size of the alkali's are the biggest in the period. Why?

A. Alkali metals are the biggest in a given period because of lowest nuclear charge and starts with a.new shell.

7. An active metal M gives only oxide MO_2. Guess the metal.

A. Metals like K, Rb, and Cs can form their superoxides MO_2 only.due to large size.

8. Give equations for the formation of caustic soda from NaCl.

A. From the solution of aq NaCl , caustic soda is prepared by electrolysis.

Ionisation : $2NaCl \rightarrow 2Na^+ + 2Cl^-$

At cathode : $2H_2O + 2e^- \rightarrow 2OH^- + H_2 \uparrow$

$2Na^+ + 2OH^- \rightarrow 2NaOH$

At anode : $2Cl^- \rightarrow Cl_2 \uparrow + 2e^-$

9. An equimolecular mixture of Na_2CO_3 and $NaHCO_3$ is heated in rotary vacuum kiln. Explain what happens.

A. Na_2CO_3 is unaffected but $NaHCO_3$ decompose to give Na_2CO_3 and liberates CO_2. Na_2CO_3 does not react.

10. Write an equation for the reaction of Na_2CO_3 with S in a current of SO_2gas.

A. $Na_2CO_3 + SO_2 \rightarrow Na_2SO_3 + CO_2$

$Na_2SO_3 + S \rightarrow Na_2S_2O_3$

11. Write the use of Na_2CO_3 in laundries?

A. In laundries $Na_2CO_3.10H_2O$ is used as washing soda.

SHORT ANSWER QUESTIONS :

1. How do the alkali metals occur in nature ? Discuss.

A. **Occurrence :** Alkali metals are highly reactive. So they do not occur in free state. They are widely distributed in nature in earth's crust. The abundance increases as the atomic number increases. Na and K are the most abundant of the alkali metals. They occur mostly as their halides.

Ex: Common salt (NaCl)

Sylvine (KCl)

Carnalite ($KClMgCl_2.6H_2O$)

2. Mention group IA elements. Write the electronic configurations of any four of the alkali metals.

A. **1) Electronic configuration :** All the alkali metals have one valence electron, ns^1

Element	Symbol	At.No.	Electronic configuration
Lithium	Li	3	$1s^2\,2s^1$
Sodium	Na	11	$1s^2\,2s^2\,2p^6\,3s^1$
Potassium	K	19	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^1$
Rubidium	Rb	37	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^{10}\,4s^2\,4p^6\,5s^1$
Caesium	Cs	55	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^{10}\,4s^2\,4p^6\,4d^{10}\,5s^2\,5p^6\,6s^1$
Francium	Fr	87	$[Rn]7S^1$

Because of their similarity in electronic configuration, $\left[ns^1\right]$, they are placed in the same group and they resemble in their physical and chemical properties.

3. Mention any four uses of anomalous behaviour of Li.

A. **Anomalous properties of Lithium :**

a) Lithium is hard metal while other alkali metals are soft and can be cut with the knife. Its melting point and boiling point are high.

b) Lithium directly unites with N_2 while no other alkali metal combines directly.

$6Li + N_2 \rightarrow 2Li_3N$

c) Lithium element forms a carbide on direct combination. Group IA elements do not form directly. But all these elements are known to give carbides.

d) The solubilities of Lithium hydroxide (LiOH), Lithium carbonate (Li_2CO_3) and Lithium fluoride (LiF) are very less compared to the high solubilities of the other alkali metal compounds.

4. Write a note on the variation of atomic radius in the alkali metals.

A. **Atomic and Ionic radii :**

The atomic and ionic radii of alkali metals and their monopositive ions are tabulated here

Element	Li	Na	K	Rb	Cs
Atomic radius (A^o)	1.23	1.57	2.03	2.16	2.35
Ionic radius(A^o)	0.60	0.95	1.33	1.48	1.69

The atoms of the alkali metals are the largest size in their corresponding periods. These values increase with a rise in atomic number. These metals lose their valence shell electron. Consequent to this cations with smaller sizes are formed. The ions show the same trends as is shown by the atomic radii.

The atomic radius values and the ionic radii values increase gradually due to increase in the number of shells as one moves from Li.

5. Why do the representative elements of the short period show diagonal relation ? Explain.

A. In the periodic table an element of a group in the 2^{nd} period shows similar properties with the second element of the next group in the 3^{rd} period. This relation is known as diagonal relationship.

Ex : Lithium and magnesium show diagonal relationship. The reasons for exhibiting diagonal relationship are : They possess similar polarizing powers, electronegativites and the nature of their compounds are similar

6. Explain how the radii of the alkali metals vary in the group? Are they obeying the periodic law?

A. The atomic and ionic radii of alkali metals and their monopositive ions are tabulated here

Element	Li	Na	K	Rb	Cs
Atomic radius (A^o)	1.23	1.57	2.03	2.16	2.35
Ionic radius(A^o)	0.60	0.95	1.33	1.48	1.69

The atoms of the alkali metals are the largest size in their corresponding periods. These values increase with a rise in atomic number. These metals lose their valence shell electron.

Consequent to this cations with smaller sizes are formed. The ions show the same trends as is shown by the atomic radii.

The atomic radius values and the ionic radii values increase gradually due to increase in the number of shells as one moves from Li.

7. Write a short note on the nature of alkali metals reaction with O_2.

A. **Action with air :** All alkali metals react with oxygen and forms their respective oxides with the liberation of heat. The oxide formed depends on the activity of the metal.

Lithium forms mostly lithium monoxide (Li_2O), sodium forms sodium peroxide (Na_2O_2) and a small amount sodium monoxide (Na_2O). The other alkali metals form superoxides (MO_2). Alkali metal oxides are basic. The stability of superoxides increases down the group due to Increase in the lattice energy

$4Li + O_2 \rightarrow 2LiO_2$ (Monoxide)

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

$2K + O_2 \rightarrow KO_2$ (Superoxide)

$Rb + O_2 \rightarrow RbO_2$ (Superoxide)

$Cs + O_2 \rightarrow CsO_2$ (Superoxide)

8. Give three uses of sodium metal.

A. Uses of sodium metal :

1) As a reagent in organic solutions

2) As a catalyst in the polymerization of isoprene to form rubber

3) Sodium amalgam is a good reducing agent

4) Compounds like Na_2O_2, $NaNH_2$, NaCN and tetraethyl lead are prepared from Na.

9. How do you convert lime stone into caustic soda ? Give equations.

A) $CaCO_3 \rightarrow CaO + CO_2$

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

Causticising process :

$Ca(OH)_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaOH.$

(caustic soda)

10. What is Caustisization ? How is it useful in the preparation of caustic soda?

A) **i) Causticising process :**

This process known as gossage process is not in use now a days. But the principle is worth noting. In this process, milk of lime [$(Ca(OH)_2$] is added to a warm, dilute solution of (10%) of sodium carbonate at 80- 85^oC. The following reaction takes place.

$Ca(OH)_2 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2NaOH$

(milk of lime) (sodium carbonate)

Calcium carbonate is slightly soluble and separates out as a mud at the bottom. This process is called "causticization" or "caustication" process. The caustic soda produced contains Na_2CO_3 and NaCl or Na_2SO_4 as the impurities. Sodium hydroxide formed is about 98% pure substance.

11. What is the role of mercury in the manufacture of caustic soda. Give necessary equations.

A. In the manufacture of caustic soda, mercury acts as 'Intermediate electrode'. It functions as cathode in the outer compartments and as anode in the central compartment.

In the outer compartments as cathode.

$$Hg + 2Na^+ + 2e^- \longrightarrow Na_2Hg$$

In the central compartment at anode :

$$Na_2Hg - 2e^- \longrightarrow 2Na^+ + Hg$$

12. Mention the uses of $NaNO_3$ and $NaNO_2$

A. **Uses of $NaNO_3$:**

i) It is used as nitrogenous fertilizer in agriculture.

ii) it is used in the manufacture of HNO_3, $NaNO_2$ and KNO_3.

$NaNO_3 + KCl \rightarrow NaCl + KNO_3$

Uses of $NaNO_2$:

i) Nitrides are important in the manufacture of organo- nitrogen compounds like azodyes.

ii) It is used as a food preservative

iii) In the lab in qualitative and quantitative analysis $NaNO_2$ is used.

13. Which is a better oxidizing agent $NaNO_2$ or $NaNO_3$? Give the reasons to show that

A. $NaNO_2$ is better oxidizing agent

It oxidizes urea to N_2 in acid medium

$CO(NH_2)_2 + 2NaNO_2 + 2H^+ \rightarrow 2N_2 + 3H_2O + CO_2 + 2Na^+$

It oxidizes iodides to iodine in acid medium

$2NaNO_2 + 3H_2SO_4 + 5NaNO_2 \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5NaNO_3$

14. Write about an electrolytic method to prepare Na_2CO_3.

A. Electrolytic method for the preparation of Na_2CO_3 :

1. First NaOH is prepared by electrolytic method (i.e) either by Nelson's process or by Castner – Kellner process.

2. CO_2 and steam are sent at high pressures into NaOH formed in the electrolytic process.

$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

Sodium carbonate

Sodium carbonate is formed and it is then separated by crystallization.

15. What is the role of alkali metals in biology?

A. Sodium and potassium are the most common cations in biological fluids.

i) The ions balance the charges associated with negatively charged organic molecules presenting the cells. The ions help in maintaining osmotic pressure in the cells.

ii) The Na^+ ions are expelled from the cells. The ion transport activity is known as sodium pump.

iii) The presence of Na^+ and K^+ ions inside and outside the cell produces an electrical potential across the membrane.

iv) The presence of Na^+ ions is associated with the movement of glucose into the cells.

v) The K^+ ions are essential for the metabolism of glucose inside the cell, the synthesis of proteins and the activation of certain enzymes.

16. Draw a neat diagram of Nelson cell and label it?

A. Nelson cell

Refer L.A.Q - 6

17. Write the equations for the reaction of C and Si with NaOH.

A. 1) Carbon reduces fused NaOH 6 $NaOH + 2C \rightarrow 2Na + 2Na_2CO_3 + 3H_2$

2) Conc. NaOH react with silicon on heating to give sodium silicate.

$2NaOH + H_2O + Si \rightarrow Na_2Sio_3 + 2H_2\uparrow$

18. To an aluminium sulphate solution an excess of sodium hydroxide solution is slowly added with shaking. Write the reactions.

A. $Al_2[SO_4]_3$ reacts with NaOH and forms hydroxide. The hydroxide formed dissolves in excess of alkali

$Al_2(SO_4)_3 + 6NaOH \rightarrow 2Al(OH)_3 + 3Na_2SO_4$

(excess)

$Al(OH)_3 + NaOH \rightarrow NaAlO_2 \downarrow + 2H_2O$

(sodium meta aluminate)

A. $\underset{\text{Gypsum monoclinic}}{CaSO_4.2H_2O} \xrightarrow{\Delta} \underset{\text{Gypsum orthorhombic}}{CaSO_4.2H_2O} \xrightarrow{120^\circ C} \underset{\text{Plaster of paris}}{CaSO_4.\frac{1}{2}H_2O} \xrightarrow{200^\circ C} CaO + SO_2 + O_2 \xleftarrow{500^\circ C} \underset{\text{dead burnt}}{CaSO_4}$

LONG ANSWER QUESTIONS :

1. Discuss a) Electronic configuration b) Occurrence c) Chemical reactivity with reference to alkali metals and hence justify the inclusion of alkali metals in the same group.

A. 1) Electronic configuration : All the alkali metals have one valence electron, ns^1

Element	Symbol	At.No.	Electronic configuration
Lithium	Li	3	$1s^2\,2s^1$
Sodium	Na	11	$1s^2\,2s^2\,2p^6\,3s^1$
Potassium	K	19	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^1$
Rubidium	Rb	37	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^{10}\,4s^2\,4p^6\,5s^1$
Caesium	Cs	55	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^{10}\,4s^2\,4p^6\,4d^{10}\,5s^2\,5p^6\,6s^1$
Francium	Fr	87	$[Rn]\,7S^1$

Because of their similarity in electronic configuration, $\left[ns^1\right]$, they are placed in the same group and they resemble in their physical and chemical properties.

2) Occurrence : Alkali metals are highly reactive. So they do not occur in free state.

They always occur in the combined state. They are widely distributed in nature in earth's crust. The abundance decreases significantly as the atomic number increases.

'Na' and 'K' are the most abundant of the alkali metals. They occur mostly as their halides.

Ex : Common salt (NaCl)

Sylvine (KCl)

Carnalite $\left(KCl\,MgCl_2\,6\,H_2O\right)$

3) Chemical reactivity :

Increases from Lithium to caesium

a) Action with air : All alkali metals react with oxygen and forms their respective oxides with the liberation of heat. The oxide formed depends on the activity of the metal.

Lithium forms mostly lithium monoxide $\left(Li_2O\right)$, sodium forms sodium peroxide $\left(Na_2O_2\right)$ and a small amount of sodium monoxide $\left(Na_2O\right)$. The other alkali metal form super oxides $\left(MO_2\right)$

Alkali metal oxides are basic. The stability of the super oxides increases down the group due to increase in the lattice energy.

b) Reactivity with H_2 :

Alkali metals react with H_2 directly at $200-600°C$ and form hydrides. The reaction can be written as follows :

$$2M + H_2 \xrightarrow{300-600^\circ C} 2MH$$

where M = Li, Na, K, Rb or Cs. These hydrides are ionic in nature, their ionic nature increases with the metallic nature of alkali metals.

c) Reactivity with halogens :

All the alkali metals react with halogens to give the binary compounds. The chemical reactivity in the alkali metals increases with increase in atomic number

$$2M + X_2 \longrightarrow 2MX$$ (where M is any alkali metal)

All the metal halides are ionic compounds

d) Reactivity with water :

The alkali metals decompose water vigourously and liberate hydrogen gas. The chemical reactivity of these metals increases as the atomic number increases. The metal hydroxides are formed.

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

Where M = any one of the alkali metals

The members of alkali metals show a marked resemblance in their properties and possess the same electronic configuration. There is gradation in the properties with the increase of atomic number. This justifies their inclusion in the same group of the periodic table.

2. How are the following properties of alkali metals varying in the group, a] lonization enthalpy b] atomic and ionic size c] reaction with H_2. Alkali metals belong to the same group of the periodic table. Justify.

A. Except first period, rest of the six periods of the periodic table start with a member of alkali group, next to the elements of zero group, alkali metals form the most homogeneous of all the groups of the periodic table. The members of this group show a marked resemblance in their properties and possess the same electronic configuration. There is gradual gradation in the properties with the increases of atomic number. This justifies their inclusion in the same group of the periodic table. The main properties of alkali metals ar discussed below for this justification.

a) Ionisation Enthalpy : The ionization enthalpy of the alkali metals are considerably low and decreases down the group from Li to Cs. This is because the effect of increasing size outweight the increasing nuclear charge, and the outermost electron is very well screened from the nuclear charge.

b) Atomic and ionic radii : The atomic and ionic radii of alkali metals and their monopositive ions are tabulated here.

Element	Li	Na	K	Rb	Cs
Atomic radius (A^o)	1.23	1.57	2.03	2.16	2.35
Ionic radius(A^o)	0.60	0.95	1.33	1.48	1.69

The atoms of the alkali metals are the largest size in their corresponding periods. These values increase with a rise in atomic number. These metals lose their valence shell electron. Consequent to this the cations with smaller sizes are formed. The ions show the same trends as is shown by the atomic radii. The atomic radius values and the ionic radii values increase gradually due to the increase in the number of shells as one moves down as Li to Cs.

c) Reactivity with H_2 : Alkali metals react with H_2 directly at $300-600°C$ and form hydrides. The reaction can be written as follows.

$$2M + H_2 \xrightarrow{300-600°C} 2M$$

where M= Li, Na, K, Rb or Cs. These hydrides are ionic in nature. Their ionic nature increases with the metallic nature of alkali metals.

3. Enumerate the anomalous behaviour of Li.

A. Because of its small size and electronic configuration in penultimate shell, Li differs from the rest of the elements in the group.

Some abnormal characters of Lithium :-

a) Lithium is hard metal while other alkali metals are soft and can be cut with the knife. Its melting point and boiling point are high.

b) Lithium directly unites with N_2 while no other alkali metal combines directly

$$6Li + N_2 \rightarrow 2Li_3N$$

c) Lithium hydroxide is a weaker alkali than the alkali metal hydroxides.

d) Lithium elements forms a carbide on direct combination. Other elements in this group do not form directly.

4. In what respects does Li show diagonal relationship with Mg ?

A. **Diagonal relationship of Li :**

In the periodic table of an element of a group in the 2^{nd} period shows similar properties with the second element of the next group in the third period. This relation is known as diagonal relationship. For example, lithium and magnesium show diagonal relationship.The elements that show diagonal relationship have similar polarizing powers, electronegativities, nature of compounds. The diagonal similarity may be due to the effects of size and charge. For example, charge per unit area.

Lithium shows similarity to Magnesium in the following respects.

a) Lithium is slow to react with water. Magnesium decomposes water only in hot condition.

$$2Li + 2H_2O \rightarrow LiOH + H_2 ;$$

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

b) Lithium combines directly with N_2 forming nitride.

$$6Li + N_2 \rightarrow 2Li_3N$$

c) Both Lithium and Magnesium give only monoxides Li_2O ; MgO

d) Lithium chloride is deliquescent like $MgCl_2$. LiCl undergoes hydrolysis to a smaller extent in hot water in a similar way to $MgCl_2$

e) Due to their covalent nature, the halides lithium and magnesium are soluble in organic solvents.

f) Both Li^+ and Mg^{+2} are highly hydrated

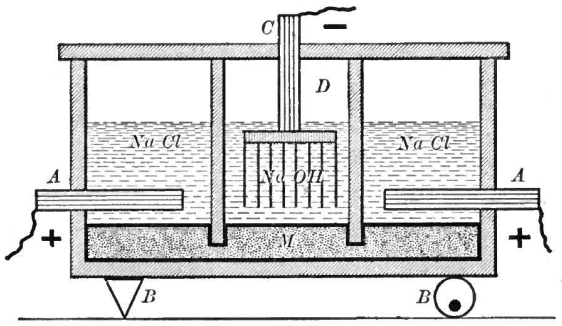
g) The carbonates, phosphates, and fluorides of both Li and Mg are sparingly soluble in water.

h) Lithium alkyls(Li^+R) are chemically similar to Grignard reagents in organic synthesis.

5. Drawing a neat diagram of the electrolytic cell, write an essay on the manufacture of NaOH by castner – kellner.

A. **Castner Kellner process :-**

This process is also called mercury cathode process.



Castner - Kellner process

It consists of rectangular tank divided into three compartments by slate partitions which do not touch the bottom. The bottom of the tank is covered with mercury which can circulate in to the three compartments by an eccentric wheel arranged at the outside bottom of the tank.

The outer compartment consists of brine solution and carbon anode while the central compartment consists of very dilute NaOH and suspended iron anodes. Mercury due to induction acts as cathode in outer compartments and anode in middle compartment.

On passage of current in outer compartments chlorine is liberated at anode while sodium forms amalgam with mercury and is brought into the central compartment by using eccentric wheel. OH^- combine with sodium ions formed by the oxidation of Na amalgam and form NaOH. The concentration of NaOH in the middle compartment increases and is thus drawn off from time to time evaporated and cast into sticks.

In outer compartments:-

Ionisation : $2NaCl \rightarrow 2Na^+ + 2Cl^-$

At anode: $2Cl^- \rightarrow Cl_2 \uparrow + 2e$ (Oxidation)

At cathode: $2Na^+ + Hg + 2e \rightarrow Na_2Hg$ (Reduction)

In middle compartment:-

At anode: $Na_2Hg \rightarrow 2Na^+ + 2e^- + Hg$

At cathode: $2H_2O + 2e \rightarrow 2OH^- + H_2 \uparrow$

$2Na^+ + 2OH^- \rightarrow 2NaOH$

6. Which process according to Nelson's or castner – kellner process , is better for producing NaOH; explain the process

A. **Nelson's Process:- (Perforated diaphragm Process)**

Principle: In this method NaOH is manufactured by the electrolysis of brine solution using perforated steel U-tube as cathode and a graphite rod as anode.

$$NaCl \rightleftharpoons Na^+ + Cl^- \left(Ionization\right)$$

$$H_2O \rightleftharpoons H^+ + OH^- \left(Ionization\right)$$

$$2H^+ + 2e^- \rightarrow H_2 \left(at\ cathode\right)$$

$$\left.\begin{aligned} 2H^+ + 2e^- &\longrightarrow H_2 \left(at\ cathode\right) \\ 2Cl^- &\longrightarrow Cl_2 + 2e^- \left(at\ anode\right) \end{aligned}\right\} \text{(Electrolysis)}$$

$$Na^+ + \longrightarrow NaOH$$

Process :

Nelson's cel consists of a perforated steel U – tube lined inside with asbestos, which acts as cathode. Brine solution is taken into it. The whole apparatus is suspended in an iron tank, provided with outlets (one for H_2 and the other for Cl_2) The tank is provided with steam arrangement. A graphite rod suspended in the brine solution acts as anode.

The cathode and anode are connected by means of wires to the terminals of a battery and at the same time steam is passed. Electrolysis takes place. NaOH collects into the the trough provided at the bottom.

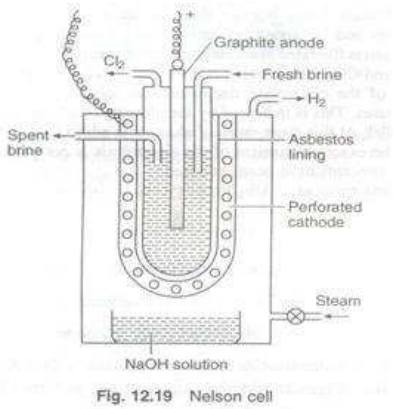


Fig. 12.19 Nelson cell

7. Write an essay on the properties of sodium hydroxide.

A. **Properties of NaOH :-**

1) Basic Nature: NaOH is a strong alkali. It readily reacts with acids to form salt

$NaOH + HCl \rightarrow NaCl + H_2O$

2) Caustic Property: When NaOH falls on the skin, it break downs the proteins of the skin and flesh into a pasty mass. This is known as caustic property and hence NaOH is known as caustic soda.

3) Action of air: It absorbs CO_2 and forms sodium carbonate and with excess of CO_2 forms sodium bicarbonate.

$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

$Na_2CO_3 + H_2O + CO_2 \rightarrow 2NaHCO_3$

4) Reaction with ammonium salts :

When any ammonium salt is treated with NaOH solution, ammonia is evolved .

$NH_4Cl + NaOH \rightarrow NaCl + H_2O + NH_3 \uparrow$

5) Reaction with non metals :

a) Reaction with halogens :

i) Fluorine reacts with cold dilute NaOH to give oxygen difluoride OF_2.

$2F_2 + 2NaOH \rightarrow 2NaF + OF_2 + H_2O$

ii) Fluorine reacts with cold dilute NaOH to give oxygen

$2F_2 + 4NaOH \rightarrow 4NaF + 2H_2O + O_2 \uparrow$

iii) Cl_2, Br_2, or I_2 reacts with cold dil. NaOH to give hypohalite

Eg: $Cl_2 + 2NaOH \rightarrow NaCl + NaClO + H_2O$

sodium hypo chlorite

iv) Cl_2, Br_2, or I_2 react with hot conc. NaOH to give halite

Eg: $3Cl_2 + 6NaOH \rightarrow 5NaCl + NaClO_3 + 3H_2O$

Sodium chlorate

b) Action with Sulphur : With sulphur, NaOH gives sodium thiosulphate, sodium sulphide (or) sodium polysulphide

$6NaOH + 4S \rightarrow 2Na_2S + Na_2S_2O_3 + 3H_2O$

(or)

$6NaOH + 12S \rightarrow 2Na_2S_5 + Na_2S_2O_3 + 3H_2O$

c) Action with Phosphorus : White phosphorus gives phosphine with NaOH.

$3NaOH + 4P + 3H_2O \rightarrow 3NaH_2PO_2 + PH_3$

d) With carbon and silicon : Carbon reduces fused NaOH

$6NaOH + 2C \rightarrow 2Na + 2Na_2CO_3 + 3H_2 \uparrow$

Concentrated NaOH reacts with silicon on heating to give sodium silicate.

$2NaOH + H_2O + Si \rightarrow Na_2SiO_3 + 2H_2$

6) Reaction with metals: Zn, Al, Sn etc, liberate H_2 on reaction with NaOH. Besides these metals Be, Ge and other atmospheric metals(metalloids) also produce H_2.

$Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2\uparrow$

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

(dil) sodium meta aluminate

$2Al + 2NaOH + 2H_2O \rightarrow 2Na_3AlO_3 + 3H_2\uparrow$

(conc) sodium aluminate

$Sn + 2NaOH + H_2O \rightarrow 2Na_2SnO_3 + 3H_2\uparrow$

Sodium stannate

7) Precipitation reactions : With Fe^{2+} Salts NaOH gives green precipitate of ferrous hydroxide and is insoluble even in excess of NaOH.

$FeSO_4 + 2NaOH \rightarrow Fe(OH)_2\downarrow + Na_2SO_4$

With Fe^{3+} salts NaOH gives red precipitate of ferric hydroxide and it is insoluble even in excess of NaOH.

$FeCl_3 + 3NaOH \rightarrow Fe(OH)_3\downarrow + 3NaCl$

Zn, Al, and Sn salts give white coloured hydroxide precipitates which are soluble in the excess of NaOH.

$ZnSO_4 + 2NaOH \rightarrow Zn(OH)_2\downarrow + Na_2SO_4$

(white ppt)

$Zn(OH)_2 + 2NaOH \rightarrow Na_2ZnO_2\downarrow + 2H_2O$

sodium zincate

$AlCl_3 + 3NaOH \rightarrow Al(OH)_3\downarrow + 3NaCl$

Gelatinous white ppt

$Al(OH)_3 + NaOH \rightarrow NaAlO_2\downarrow + 2H_2O$

Sodium meta aluminate

8. Describe Solvay process with suitable equations.

A. **Sodium carbonate is prepared by Ammonia soda (or) Solvay process.**

Raw materials : The raw materials required are 1) Brine solution (saturated) 2) Ammonia and 3) Lime stone.

Principle : Brine solution is saturated with Ammonia and CO_2 gas is passed through it. Then sodium bicarbonate is formed.

$NH_3 + H_2O + CO_2 \longrightarrow NH_4HCO_3$

$NH_4HCO_3 + NaCl \longrightarrow NaHCO_3 + NH_4Cl$

The sodium bicarbonate thus formed on heating decomposes to give sodium carbonate.

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

Process :

1) **Saturation of Brine with Ammonia :** Ammonia absorber is filled with brine solution and saturated with ammonia gas containing a little amount of CO_2. Then the calcium and magnesium impurities present in the brine, precipitate as their carbonate and hydroxides.

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

$$MgCl_2 + (NH_4)_2 CO_3 \longrightarrow MgCO_3 + 2NH_4Cl$$

The precipitates are filtered in "Filter press" and the filtrate is cooled and sent to Carbonation Tower.

2. **Carbonate of ammonical Brine** : This process is carried out is Carbonation tower. It is a tall cylindrical tower containing perforated plates arranged one above the other. Ammoniacal brine solution is dropped from upper half and CO_2 gas is passed from the lower part. Then both of them react together forming sodium bicarbonate.

   i. $NH_3 + H_2O + CO_2 \longrightarrow NH_4HCO_3$

   ii. $NaCl + NH_4HCO_3 \longrightarrow NaHCO_3 + NH_4Cl$

3. **Filtration :** The dense liquid from the carbonate tower is sent into rotary vacuum filter and filtered.

4. **Fusion of sodium bicarbonate** : The $NaHCO_3$ obtained in the Rotary filter is heated to high temperatures. Then $NaHCO_3$ decomposes to give Na_2CO_3.

$$2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + H_2O + CO_2$$

5. **Recovery of Ammonia :** The filtrate from the Vaccum filter is pumped into ammonia recovery tower, mixed with Ca $(OH)_2$ and heated with steam. Then NH_3 gas is liberated which is sent back to saturation tower.

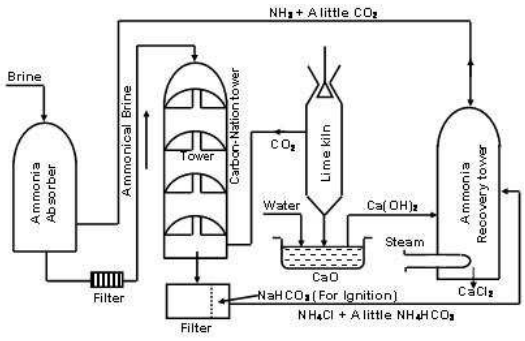
$$NH_4HCO_3 \xrightarrow{\Delta} NH_3 + H_2O + CO_2$$

$$2NH_4Cl + Ca(OH)_2 \xrightarrow{\Delta} CaCl_2 + 2NH_3 + 2H_2O$$

Note : The milk of lime required for the regeneration of NH_3 is obtained from the Lime Kiln by heating lime stone.

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

$$CaO + H_2O \longrightarrow Ca(OH)_2$$



Preparation of sodium carbonate
Solvay process

9. Write any four chemical properties of Na_2CO_3 . Why does a solution of Na_2CO_3 give yellow colour with methyl orange.

A. **Chemical properties of Na_2CO_3 :**

i) Reaction with acid : Acids liberate CO_2 from sodium carbonate. Salts are the products.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

ii) Reaction with non – metals and their compounds : Sodium carbonate reacts with S and SO_2 to give sodium thiosulphate.

$$Na_2CO_3 + SO_3 \rightarrow Na_2SO_3 + CO_2$$

$$Na_2SO_3 + S \rightarrow Na_2S_2O_3$$

Over all reaction :

$$Na_2CO_3 + SO_2 + S \rightarrow Na_2S_2O_3 + CO_2$$

iii) An aqueous solution of sodium carbonate when saturated with CO_2 , gives sodium bicarbonate

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

iv) " Water glass" is formed when Na_2CO_2 is fused with silica (SiO_2)

$$Na_2CO_3 + SiO_2 \rightarrow Na_2SiO_3 + CO_2$$

v) Reaction with compounds : Insoluble metal carbonates are precipitated from solutions on addition of sodium carbonate solutions.

$$MgCl_2 + Na_2CO_3 \rightarrow MgCO_3\downarrow + 2NaCl$$

$$ZnSO_4 + Na_2CO_3 \rightarrow ZnCO_3\downarrow + Na_2SO_4$$

Methyl orange gives yellow colour to strong alkaline solutions. Na_2CO_3 solution undergo anionic hydrolysis to form alkaline solutions. Therefore Na_2CO_3 gives yellow colour with methyl orange.

Alkali and Alkaline Earth Metals

UNIT: 2

1 Electronic configuration of Alkaline earth metals
2 Industrial use of lime and lime stone
3 Biological importance of Mg and Ca
.

VERY SHORT ANSWERS

1. Write the electronic configurations of a) Ca b) Sr

Calcium $_{20}Ca = [Ar]4s^2$

Strontium $_{38}Sr = [Kr]5s^2$

2. Write the names and formulae of any two minerals of beryllium.

A. Beryl $3BeO.Al_2O_3.6SiO_2$

Chrysoberyl $BeO.Al_2O_3$

Phenacite $2BeO.\ SiO_2$ (or) Be_2SiO_4

SHORT ANSWER QUESTIONS:

1. In what respect the halides of Be differ from those of other elements of the group.

A. 1. Beryllium halides are covalent in nature. This is due to its high polarizing power. Beryllium halides are hygroscopic in nature and fume in air due to hydrolysis.

These halides do not conduct electricity in their molten state

2. The halides of other metals (Mg, Ca, Sr and Ba) are ionic solids. Their solubility in water is decreases with increasing atomic number of the metal. These are good conductors in molten state.

2. Write a note on the importance Mg^{+2} in biology.

A). **Role of Mg^{+2} in biology:**

1) Mg^{+2} ions are concentrated in animal cells.

2) Enzymes like "Phosphohydrolases" and " Phosphotransferases" contain Mg^{+2} ions. These enzymes participate in ATP reactions and release energy in the process. Mg^{+2} forms a complex with ATP.

3) Mg^{+2} is a constituent of chlorophyll, the green component of plants.

3. What is the importance of Ca^{+2} in the functioning of cell?

A. **Role of Ca^{+2} in the functioning of cell:**

i) Ca^{+2} is present in bones and teeth

ii) The ions balance the charges associated with negatively charged organic molecules present in the cell. The ions help in maintaining osmotic pressure of the cell.

iii) Ca^{+2} ions play important role in blood clotting, maintaining regular heart beat and muscle contraction.

4. Imagine what would happen if gypsum is gradually heated to 500°C. Give equations.

A. $\underset{\text{Gypsum monoclinic}}{CaSO_4.2H_2O} \xrightarrow{\Delta} \underset{\text{Gypsum orthorhombic}}{CaSO_4.2H_2O} \xrightarrow{120^\circ C} \underset{\text{Plaster of paris}}{CaSO_4.\frac{1}{2}H_2O} \xrightarrow{200^\circ C} CaO + SO_2 + O_2 \xleftarrow{500^\circ C} \underset{\text{dead burnt}}{CaSO_4}$

LONG ANSWER QUESTIONS:

1. What are the anomalous characters of Be? Give them.

A. **Anomalous properties of Beryllium:**

I] Be compounds are predominantly covalent due to its high polarizing power and its salts are readily hydrolyzed.

2] Be is not easily affected by dry air and does not decompose water at ordinary temperature

3] Be is an amphoteric metal. It dissolves in alkali solutions forming beryllates.

2 How are ionization potentials of alkaline earth metals varying from Be to Ba? Account for the change. Why do the 2nd group elements have higher IE values than 1st group elements?

A. **Trends in ionization enthalpy:-**

The ionization enthalpies of he alkaline earth metals are given below.

Element	Be	Mg	Ca	Sr
1^{st}IE(kJ mol^{-1})	899.25	737.35	589.47	548.32
2^{nd}IE (kJ$mol^{-)}$	1757.10	1450.70	1145.40	1064.30

The 1^{st} ionization energy values gradually decrease from Be to Ba. This can be explained on the increasing sizes of the atoms from Be to Ba. Due to the increase in size the valency shell electrons go farther away from the nucleus and so their coulombic forces of attractions decrease. Hence, removal of the electron from the valency shell becomes easier. That means IE is lower.

The second IE values are approximately double than those of the first IE values. The high values are expected due to an increase in the effective attracting nuclear charge when a unipositive ion is formed.

The ionization enthalpy of alkaline earth metals is greater than those of the alkali metals. This is due to greater nuclear charge as compared to alkali metals.

3. What is mortar? Write on what you know about it.

A. **Mortar:-**

i) An intimate mixture of 1 part of slaked lime and 3 parts of sand and water is known as lime mortar.

ii) Sand present in mortar makes it porous and harder.

iii) While hardening, the sand prevents the cracks on contraction.

iv) Slaked lime when mixed with sand hardens slowly due to the formation of calcium silicate.

$$Ca[OH]_2 + SiO_2 \rightarrow CaSiO_3 + H_2O$$

v) Mortar mixed with cement is called cement mortar. This is stronger than mortar.

vi) Lime stone and clay when heated together give hydraulic mortar. This also sets to hard mass on addition of water.

vii) Hydraulic mortar is used for bleaching purpose and as an antiseptic.