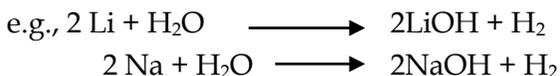


ALKALI AND ALKALINE EARTH METALS

13.1 ALKALI METALS

Periodic discussion and general characteristics

The elements in the Group IA of the periodic table other than hydrogen are called alkali metals, because these dissolve in water giving alkali.



Li (3): $1s^2 2s^1$	[He] $2s^1$
Na (11): $1s^2 2s^2 2p^6 3s^1$	[Ne] $3s^1$
K (19): $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$	[Ar] $4s^1$
Ru (37): $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$	[Kr] $5s^1$
Cs (55):	[Xe] $6s^1$

- Due to one electron in the valance shell, their valency is 1 and oxidation number is +1 in combined state.
- Highly electropositive and extremely reactive elements.
- Low ionization potential and low electronegativity.
- Typical metals possessing metallic lustre, malleability and ductility.
- Silvery white when freshly cut but tarnish in air.
- Good conductors of electricity.
- Relatively soft solids that can be cut with knife. These have relatively low densities.
- Low melting and boiling points. And the m pt and b pt decrease down the group.
- Powerful reducing agents.

Alkali metals impart characteristic colour in Bunsen flame. This is used as a confirmatory test for the presence of the alkali metals. The

characteristic colour is produced when the energy of the flame is absorbed by the electrons resulting jumping of electrons to higher energy level. In a very short interval of time, the electrons jump back to lower (ground) state releasing excess energy in the form of visible light of different colour. Sodium produces yellow flame and Lithium produces Golden yellow flame and K, Rb and Cs give violet flame.

60) Write short notes on characteristics of alkali metals. 5

54) Give the characteristics of alkali metals. 5

76) Why do alkali metals impart characteristic colour when introduced to the flame? 2

72) Give reason: Alkali metals impart characteristic colour to the flame test.

69) Alkali metal impart characteristic colour to the flame. Give reason. 2

76) Sodium metal burns with air giving golden yellow flame. Why? 2

60) What would happen when the nitrate of an alkali metal is heated? (not in syllabus) 2

Solution: When nitrate of alkali metal is heated oxygen and metal nitrate is formed



Which of the following has lowest melting point? (IOM)

a. Li

b. Na

c. K

d. Cs

Sodium

Occurance

Sodium is the sixth most abundant element in the earth's crust. It is the fourth most abundant metal in the earth crust.

Its main minerals are as following:

1. Sodium chloride: The most abundant mineral and ore of Sodium. Found in sea water, various lakes and as rock salt. Sea water normally contains 1.5% of NaCl. Dead sea contains 8% of NaCl.

2. Chile Saltpetre (NaNO_3)
3. Glauber's Salt ($\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$)
4. Borax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) etc.

Extraction from Down's process

Sodium is generally extracted from the most common, abundant and cheap mineral (ore) Sodium chloride.

However it cannot be extracted by chemical (Carbon or aluminum) reduction process because

1. Sodium chloride cannot be easily roasted to get Sodium oxide. Besides Sodium oxide cannot be reduced by Carbon, itself being stronger reducing agent.
2. Carbon reduction has to be carried out at high temperature where sodium forms sodium carbide rather than free sodium metal.

Even electrolytic reduction encountered following difficulties.

- a. NaCl melts at 802°C . Boiling point of Na is 883°C . Therefore if sodium metal is produced at such temperature, Na metal forms metallic fog with NaCl . Such fog can corrode and short circuit the cell and it is difficult to handle and separate.
- b. Both sodium and chlorine produced are highly reactive so can corrode the cell.

To overcome these difficulties, J.C. Down mixed sodium chloride with calcium chloride in the ratio 2:3 which lowers the melting point to about 600°C . At this temperature neither sodium and chlorine corrode the cell nor is metallic fog formed. Even less energy is enough to maintain the temperature.

The Down's cell is a cylindrical iron tank lined inside of refractory material. Graphite anode is kept at the centre and cylindrical iron cathode surrounds it. Anode and cathode are separated by an iron gauze which keeps the products of electrolysis separated.

On passing electricity, these reactions occur,



At anode,



At cathode,



The net cell reaction is: $2\text{NaCl} \longrightarrow 2\text{Na} + \text{Cl}_2$

The sodium metal liberated at cathode rises through the molten sodium chloride because it is lighter. Chlorine gas liberated at anode escapes out. With the progress of reaction, the concentration of NaCl decreases and more fresh NaCl can be added to continue the working of the plant. Calcium is not liberated instead of sodium because it requires higher voltage of electricity.

Advantages:

1. Highly pure Sodium metal is obtained (99.8%).
2. Chlorine is formed as a byproduct which is very useful industrial chemical.
3. Impure salt can be directly used.

53) Why alkali metals cannot be obtained by chemical reduction method?

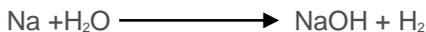
75) Give reason: Carbon reduction process is not applicable for extraction of alkali metals. 1

72) Why is carbon reduction process is not applied for the extraction of alkali metal? Name any suitable method for extraction of these metals. 1+1

70) Can sodium be extracted by the electrolysis of aqueous solution of sodium chloride? If not, why? 2

Solution: Sodium cannot be extracted by the electrolysis of aqueous solution of sodium chloride because discharge potential of hydrogen is lower than that of sodium. Hence hydrogen is liberated first instead of

sodium. Moreover, sodium if formed reacts with water to form sodium hydroxide and hydrogen.



- 72) Why is mixture of CaCl_2 and KF added to NaCl during the extraction of sodium? 2
- 62) How is sodium extracted by Down's process? Sketch a diagram of the Down's cell and write reaction involved. What are the difficulties on obtaining sodium by this process and how are they removed? 7
- 75) Sketch a well labeled diagram for the manufacture of sodium by Down's process. What are the advantages of this process? 6
- 59) Describe the extraction of sodium by Down's process. 6
- 69) How is sodium extracted from Down's process? 5
- 74/73/69) Write the principle and process along with self-explanatory diagram for the manufacture of sodium by Down's process. 6
- 70/67) Explain the chemistry of down's process for the extraction of sodium. 5
- 63) Write the principle involved in the extraction of sodium form sodium chloride and also draw a self-explanatory diagram for the Down's process of the extraction of sodium. 5
- 56) How is sodium extracted from sodium chloride using Down's electrolytic cell? 5
- 70) Sketch well labeled diagram for the extraction of sodium by Down's process and explain the principle involved in the process. 6

Properties

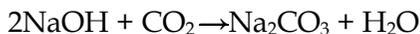
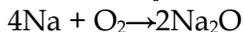
Physical properties

- Soft silvery white metal with metallic lustre could be easily cut with knife.
- Less denser than water.
- M. pt. 97°C B pt. 883°C .

Chemical properties

Action with air

When sodium metal is exposed to air its surface get tarnished due to the formation of layer of sodium carbonate in following steps.



First Sodium metal absorbs oxygen forming sodium oxide which absorbs the moisture changing into sodium hydroxide. The Sodium hydroxide further absorbs Carbondioxide forming sodium carbonate.

Therefore sodium metal is generally stored dipped in kerosene.

56/52) *What happens when a piece of sodium metal is exposed to air?* 2

70) *What happens when sodium is exposed to moist air?* 1

62) *How does sodium react with moist air?* 1.5

75/72) *Give reason: Sodium metal gets tarnished in air.* 1

69) *Why is sodium metal kept in kerosene?* 1

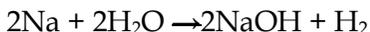
75/74) *Write the reactions for the conversion of sodium into washing soda.*

73) *Convert sodium into washing soda.* 1

70) *Starting from Sodium how would you prepare $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$.*

Action with water

When a piece of sodium is dropped in the water it reacts violently with water forming caustic soda and hydrogen gas. This is a highly exothermic reaction. If large amount of sodium is used explosion occurs.



Even the hydrogen gas formed is highly inflammable gas making the reaction more dangerous.

Therefore sodium fire cannot be extinguished by water.

- 57) What happens when a piece of sodium metal is dropped into water? 2
 59) Write the action of sodium with H₂O. 2
 74/70) Why is sodium fire at laboratory not extinguished by adding water?
 67) Why is sodium fire not extinguished by adding water? 1

Burning in Oxygen

Sodium burns in oxygen forming mainly sodium peroxide and small amount of sodium oxide.



Burning in Carbondioxide

Sodium also burns in the atmosphere of Carbondioxide, therefore even Carbondioxide cannot be used for the fire extinguisher for sodium fire.



Action with acids

It reacts with minerals acids forming salt and displaces hydrogen gas.



Action with Hydrogen

When sodium is heated with hydrogen gas, Sodium hydride is formed which is unstable compound.



Metal hydrides are the compounds where hydrogen has an oxidation number of -1.

Action with other non metals

Sodium reacts with other non metals forming generally binary compounds like





Action with ammonia

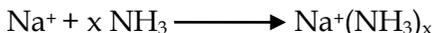
When sodium is heated with ammonia gas at about 300°C, Sodamide is formed.



Sodium metal dissolves in liquid ammonia forming deep blue solution. Here first sodium ionizes as



Then both sodium ion and free electron are ammoniated as:



51) What is the main product obtained when sodium is allowed to react with dry ammonia at 300°C – 400°C? 2

70) What happens when sodium is heated with NH₃? 1

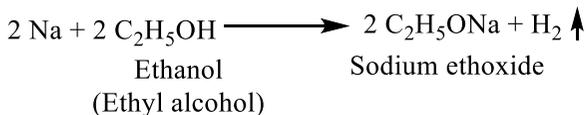
67) What happens when sodium is treated with ammonia? 1

59) Write the action of Sodium with NH₃. 2

62) How does sodium react with NH₃? 1.5

Action with alcohols

Sodium displaces hydrogen gas from alcohols. This reaction shows slight acidic nature of alcohols.



Action with Mercury

Sodium forms homogenous mixture with mercury which is called sodium amalgam.

Uses of Sodium

- In sodium vapour lamp, which illuminates streets with yellow light distinctly visible in the foggy as well.
- To prepare useful compounds like Sodamide, Sodium cyanide, Sodium peroxide etc.
- Sodium amalgam is used as a reducing agent.
- As a lab reagent specially for foreign element detection.

69/59) Mention biological importances of Sodium and Potassium metals. 2

Solution: Sodium and potassium are present in the human body in the form of ions their main functions in the body include

-to maintain the osmotic pressure

-to help in nerve impulse

-to maintain electro-neutrality in body fluids, etc.

Sodium Hydroxide

Manufacture

Sodium hydroxide can be obtained by one of the following processes both of which electrolyze brine solution (nearly saturated NaCl solution) using mercury cathode which has more affinity for sodium ions over hydrogen ions. Therefore sodium is discharged at the cathode rather than hydrogen.

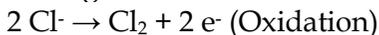
1. Castner-Kellner Cell

Principle:

Sodium chloride dissociates in water to give Na⁺ and Cl⁻ ions as;



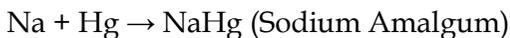
The Cl⁻ ions migrate towards the anode, lose electron and convert into chlorine gas.



In Castner-Kellner process, H⁺ ions are not easily discharged due to high discharge potential of H⁺ ions, on the contrary Na⁺ ions are easily discharge on the mercury surface.



The sodium thus liberated dissolves in mercury forming an amalgam.



Plant

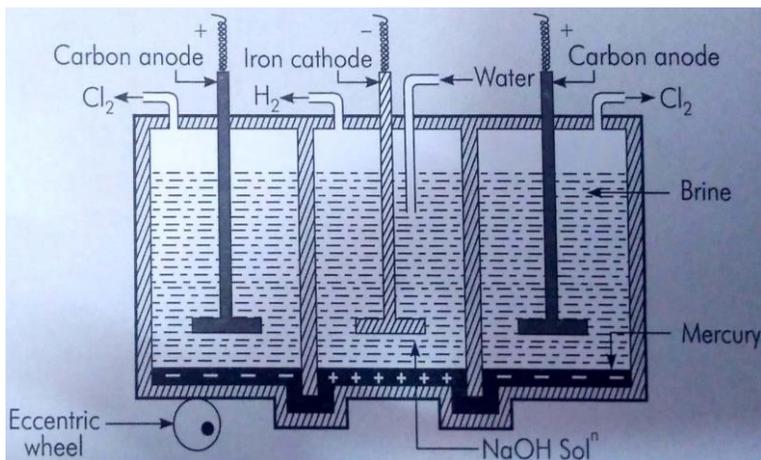


Fig: Castner-Kellner Cell for manufacture of Caustic Soda

Working and Explanation:

A Castner-Kellner cell consists of rectangular tank divided into three compartments by slate partitions that do not touch the bottom. There is a thin layer of Mercury on the bottom which separates the remaining components of the compartments and act as intermediary electrode in the same time.

The outer compartments are fitted with graphite anodes dipped in the brine solution. The middle compartment contains dilute NaOH solution where a series of iron cathode is suspended.

The Mercury pool acts as cathode in the outer compartments and anode in the middle by induction.

The Amalgam formed in outer chamber is made to flow in the middle compartment by rocking motion of the Eccentric wheel fitted below. Where Sodium ionizes again and dissolves in the dilute

NaOH solution and equivalent amount of hydrogen ions are discharged at the iron cathodes (H^+ ion form water). Thus concentration of Na^+ and OH^- ions increases in the middle compartment.

Once the NaOH becomes sufficiently concentrated, it is taken out and further processed to form NaOH pellets or conc. NaOH.

Kellner -Solvay Cell

The mercury containing dissolved sodium is sent to another chamber called Decomposer where sodium reacts with water forming sodium hydroxide and hydrogen. Denuder is packed with graphite blocks as hydrogen is easily liberated over graphite surface.

$$2Na/Hg + 2H_2O \rightarrow 2NaOH + H_2 + 2Hg$$

the mercury is recycled to dissolve more of sodium. The solution, which flows out from denuder, is a NaOH solution, which is evaporated to dryness.

58) Describe the manufacture of sodium hydroxide stressing on principle and diagrammatic sketch. 8

66) How is sodium hydroxide manufactured? 4

74/73) Sketch a well labeled diagram for the manufacture of caustic soda (NaOH) by Castner Kellner's process. Explain the principle and procedure involved in it.

52/51) Describe in brief the manufacture of sodium hydroxide by Castner-Kellner process. 5

57) Write down the principle involved in the manufacture of caustic soda by Solvay Kellner's process. 3

71) Describe the principle behind manufacture of sodium hydroxide by Kellner Solvay cell. 6

72) Describe the manufacture of caustic soda using Kellner Solvay process.

Properties

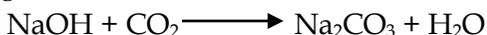
Physical properties

- White deliquescent solid, soapy in touch
- Highly soluble in water, solution highly corrosive to skin and vegetable matter hence called caustic soda
- Strong alkali, turns litmus blue, phenolphthalein pink

Chemical properties

Action of air:

Solid NaOH absorbs moisture from the air turning itself into a solution (deliquescency). Then it further reacts with CO₂ in the air forming sodium carbonate.



67) What happens when CO₂ is passed through sodium hydroxide solution? 1

70) How does NaOH react with CO₂? 1

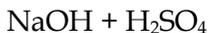
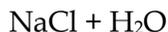
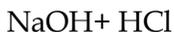
69/66) How is caustic soda converted into washing soda? 1

75/65) How would you convert NaOH into Washing soda? 1.5

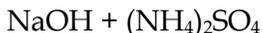
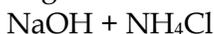
69) How is caustic soda converted into baking soda? 1

Alkaline properties:

NaOH is a typical strong alkali, so reacts with acid giving salt and water.



It reacts with ammonium salt giving sodium salt, water and ammonia gas.



Reaction with salt solutions

NaOH reacts with a number of soluble salts of metals giving insoluble hydroxide.



Reaction with Amphoteric metals:

It reacts with amphoteric metals like Zn, Al, Si etc forming salt and hydrogen gas.



Al +



70) How does NaOH react with Zn? 1

75/ 72) Write the action of Caustic soda with zinc. 1

72) Write the action of NaOH with Zinc. 1

73) What happens when Caustic soda is treated with zinc? 1

74) Convert Caustic soda into sodium silicate. 1

Action with non metals:

Action on halogens (Studied in Halogens chapter-Non metals)

72) Write the action of NaOH with chlorine. 1

72) Write the action of Caustic soda with chlorine. 1

73) What happens when Caustic soda is heated with Sulphur? 1

72) Write the action of NaOH with sulphur. 1

72) Write the action of NaOH with phosphorus. 1

61/52) What happens when sodium hydroxide is heated with yellow phosphorous. 1

58) How does sodium hydroxide react with white and red phosphorus? 2

71) Give properties of NaOH. (not a proper question though)

1

Uses

- Very important industrial alkali, used in production a large number of important compounds
- In manufacture of Soap.
 $\text{Oil} + \text{NaOH} \longrightarrow \text{Soap} + \text{Glycerol}$
- In refining of oil
- In paper and pulp industries
- In manufacture of Rayon
- As a common laboratory reagent

71) Give the uses of Sodium hydroxide.

2

Sodium carbonate

Manufacture By Ammonia Solvay process

Principle:

Brine solution is saturated with ammonia by bubbling ammonia gas and the ammoniacal brine is then treated with carbon dioxide. First ammonium bicarbonate is formed which further reacts with sodium chloride to give sodium bicarbonate



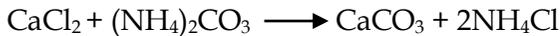
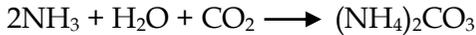
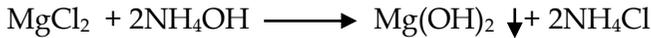
Sodium bicarbonate is sparingly soluble in water in presence of sodium chloride. Hence sodium bicarbonate formed gets precipitated out, which is separated out by filtration. The sodium bicarbonate is then calcined to get sodium carbonate.



Working of the Plant:

1. Saturation of brine

In ammonia absorber, brine solution (about 30% NaCl) is saturated with ammonia gas. Impurities like CaCl_2 , MgCl_2 etc present in brine are precipitated as hydroxide and carbonates are removed.

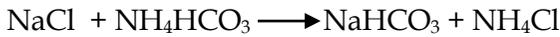
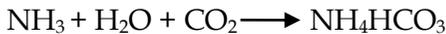


Ammoniated brine is then pumped to the carbonation tower.

2. Carbonation

Carbonation tower works on counter current principle.

Ammoniated brine is allowed to trickle down a tower and carbon dioxide is passed from the bottom at about 2 atm pressure and temperature is maintained to about 30 °C. Sodium bicarbonate and ammonium chloride are formed.



Sodium carbonate is filtered and filtrate (NH_4Cl with little NH_4HCO_3) is pumped to the ammonia generator.

3. Recovery of ammonia

In ammonia generator, ammonium chloride reacts with lime to generate ammonia gas.



4. Generation of CO_2

In lime kiln, limestone is heated to produce CO_2 required for carbonation.



CaO is treated with water to get slaked lime and pumped into ammonia generator.

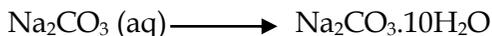


5. Calcination

Sodium bicarbonate obtained by filtration is heated to get anhydrous sodium carbonate.

6. Crystallization

Aqueous sodium carbonate solution may be subjected to crystallization to get washing soda.



68) Write the chemical principle and stepwise procedure involved in the manufacture of sodium carbonate by Solvay process and sketch a well labeled diagram for it. What are the merits of this process? 6+2

61) Describe the manufacture of sodium carbonate by ammonia soda process. Also mention the function of limestone in the manufacturing process. 8+2

76/65) Explain the principle and process and write a well labeled diagram for the manufacture of Washing soda by Solvay ammonia process.

70) How is sodium carbonate manufactured by Solvay ammonia process? Why is it difficult to get potassium carbonate by this method? 6+2

75/73/72) Sketch a neat and well labeled diagram for the manufacture of sodium carbonate by Solvay ammonia process. Explain the chemical principle involved. What are the advantages of this process? 6

54) Describe the steps in the manufacture of Sodium carbonate by Solvay process. 5

MCQ The byproduct of Solvay process is (10M)

a) CaO b) NaHCO_3 c) CaCl_2 d) NaHCO_3 and CO_2

Properties

Physical Properties

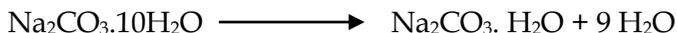
- Sodium carbonate crystal called washing soda, water of crystallization 10.

- Efflorescent substance(loses water of crystallization when exposed to open atmosphere)

Chemical properties

1. Action of Heat

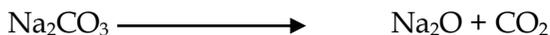
On exposure to open atmosphere, washing soda ($\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$) loses 9 of its water of crystallization.



On further heating (below 100°C) it loses the remaining water molecule giving anhydrous salt, also called soda ash.



Heating to temperature near 750°C results decomposition into sodium oxide and Carbondioxide.



73) *What happens when washing soda is exposed to air?* 1

67) *What happens when washing soda is heated?* 1

76/73) *What happens when washing soda is heated upto 750°C ?* 1

76) *How would you convert washing soda into Soda ash?* 1

2. Action with Sand

Sodium silicate is formed when it is fused with sand.



76/73) *What happens when washing soda is fused with excess sand (SiO_2)?*

76) *How would you convert washing soda into Sodium silicate?* 1

3. Action with SO_2

Sodium carbonate reacts with sulphur dioxide in presence of sulphur to give sodium thiosulphate.



4. Formation of insoluble carbonates

When sodium carbonate is treated with some soluble salts like CaCl_2 , BaCl_2 , AgNO_3 , MgCl_2 etc the carbonates of respective metals are precipitated out.



5. Action with calcium hydroxide

It forms caustic soda with calcium hydroxide (milk of lime).



6. Action with acids

It is readily decomposed by acids with effervescence due to evolution of CO_2 . This reaction can be used for the detection of carbonate.



7. Action of water (Hydrolysis)

It is soluble in water due to hydrolysis into sodium hydroxide (strong base) and carbonic acid (weak acid). The solution is slightly basic (alkaline).



Uses of Sodium carbonate (Washing soda)

1. The largest use for manufacture of glass.
2. As water softening agent.
3. For making wood pulp, paper etc.
4. As a reagent.

76/68) Give any two uses of sodium carbonate. 1

75/73) Give two major uses of Washing soda. 1

75/72/65) Write the molecular formula of Baking soda and Soda ash. 1.5

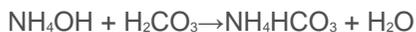
75/72/55) What are the chemical formula of caustic soda, washing soda and baking soda? What are their main uses? 2

58) Write the chemical formulae of washing soda and baking soda. What are their uses? 2

50) What happens when sodium chloride is heated with yellow phosphorus? (not in syllabus) 1

What happens when carbon dioxide is passed into ammoniacal brine solution?

Answer – When carbon dioxide is passed into ammoniacal brine solution then sodium bicarbonate is formed.



Discuss the manufacture of washing soda from Solvay ammonia process.

Answer – Sodium Carbonate is an important compound. It is manufactured by Ammonia-Solvay Process.

Principal

In the preparation of sodium carbonate by solvay ammonia process carbon dioxide is passed into concentrated solution of brine saturated with ammonia and ammonium bicarbonate is obtained.

Raw

Materials

The raw materials for the manufacture of sodium carbonate are

1. Brine
2. Ammonia, which is made by Haber's Process
3. CO₂, CaOH, which are obtained from limestone.

Ammonia-Solvay

Process

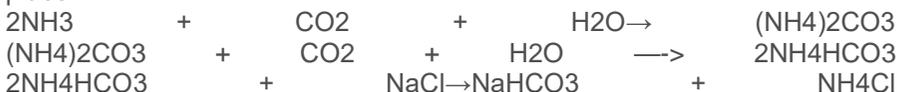
The Ammonia-Solvay Process consists of the following steps.

Step I – Ammonation of Brine

In first step, ammonia gas is mixed with brine. This process is carried in Ammonation Tower. The ammoniation tower consists of mushroom shaped buffels at short intervals. Brine is introduced from the top and ammonia is introduced from bottom. They both flow towards each other. Buffels control the flow of brine and ensure that they are mixed to the point of saturation with ammonia.

Step II – Carbonation of Ammoniated Brine

In this step, ammoniated brine is mixed with carbon dioxide brine is mixed with carbon dioxide in a tower called carbonating tower. Ammoniated Brine is fed from the top where as carbon dioxide ascends from the bottom. When these two substances meet, the following chemical reactions takes place



Sodium bicarbonate is relatively insoluble, which is precipitated out from the solution by cooling the lower part of the tower. Sodium bicarbonate is separated from soluble ammonium chloride by vacuum filtration.

Step III – Production of Soda Ash

Sodium bicarbonate is heated in a long iron tube to obtain anhydrous sodium carbonate or Soda Ash.

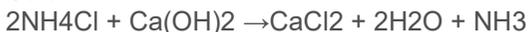
This carbon dioxide is recycled to the solvay tower. This hydrated sodium carbonate is also called washing soda.

Recovery

of

Ammonia

Ammonia gas is recovered from the remaining solution by treating it with Calcium Hydroxide.



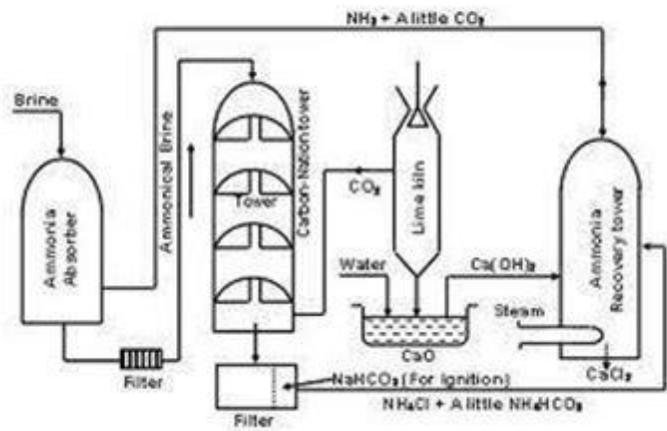


Fig:-Ammonia-Solvay Process

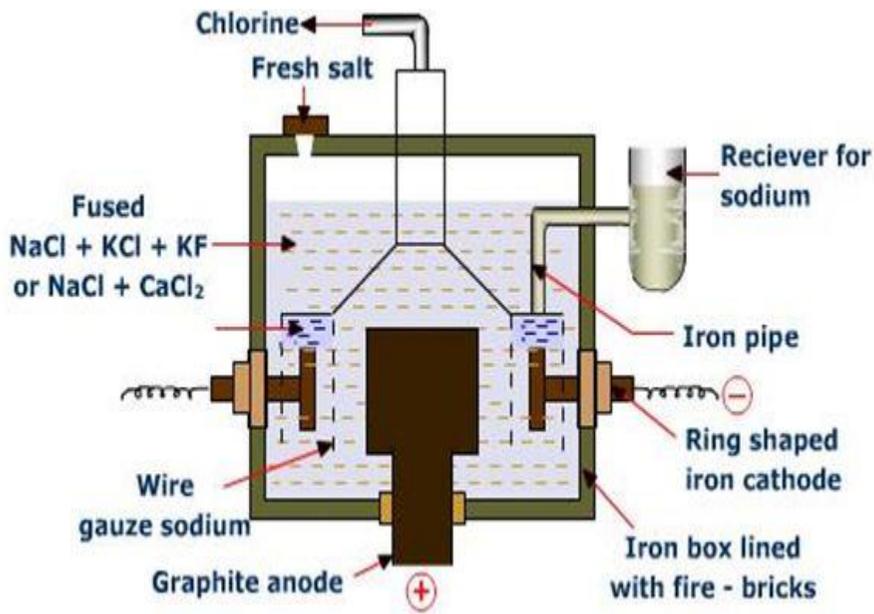


Fig:- Down's process

B. chlorine gas is reacted with dilute and cold NaOH?

Answer – when chlorine gas is reacted with dilute and cold NaOH then Hypohlite.



c. washing soda is heated?

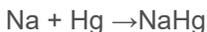
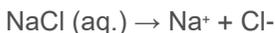
Answer – on heating washing soda it loses water and forms soda ash



How can you manufacture sodium hydroxide using Kellner –Solvay cell?

Answer – Manufacture of sodium hydroxide by Kellner Solvay Process

The cell is provided with flowing mercury cathode and graphite anode. When brine solution is electrolyzed, sodium ions are discharged at mercury cathode and form sodium amalgam which flows out of voltameter and decomposed with water to give sodium hydroxide. On the other hand chloride ions are discharged at graphite anode to give chlorine gas which escapes out of the voltameter.



This cell has no compartments. Mercury enters into the cell and forms a thick layer on the bottom of the cell. It serves as the cathode and is made to flow slowly across the bottom during electrolysis. The anode consists of platinum or carbon rods. The electrolyte is sodium chloride solution when electrolysis is carried, sodium ion are discharged at mercury cathode and form sodium amalgam which flows out the other end. Chlorine is evolved at the anode and escapes out. Sodium ions discharge on the mercury cathode in preference to H⁺ ions which have a large over-voltage on mercury and the sodium atom so formed dissolve to form sodium amalgam. This amalgam flows out at the other end in a vessel containing water in the

presence of iron (on which hydrogen has a very small over-voltage). It decomposes to give caustic soda and hydrogen.

7.

Briefly describe the steps involved in the manufacture of sodium carbonate by Solvay process.

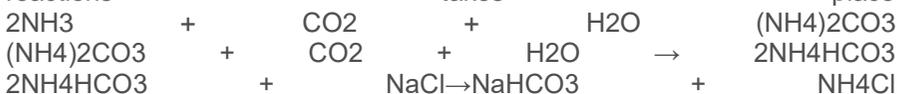
Answer – Sodium Carbonate is an important compound. It is manufactured by Ammonia-Solvay Process. the steps involved in the manufacture of sodium carbonate by Solvay process are as follows

Step I – Ammonation of Brine

In first step, ammonia gas is mixed with brine. This process is carried in Ammonation Tower. The ammoniation tower consists of mushroom shaped buffels at short intervals. Brine is introduced from the top and ammonia is introduced from bottom. They both flow towards each other. Buffels control the flow of brine and ensure that they are mixed to the point of saturation with ammonia.

Step II – Carbonation of Ammoniated Brine

In this step, ammoniated brine is mixed with carbon dioxide. Brine is mixed with carbon dioxide in a tower called carbonating tower or Solvay tower. Ammoniated Brine is fed from the top where as carbon dioxide ascends from the bottom. When these two substances meet, the following chemical reactions take place



Sodium bicarbonate is relatively insoluble, which is precipitated out from the solution by cooling the lower part of the tower. Sodium bicarbonate is separated from soluble ammonium chloride by vacuum filtration.

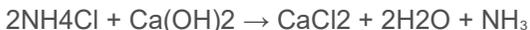
Step III – Production of Soda Ash

Sodium bicarbonate is heated in a long iron tube to obtain anhydrous sodium carbonate or Soda Ash.

This carbon dioxide is recycled to the solvay tower. This hydrated sodium carbonate is also called washing soda.

Step IV - Recovery of Ammonia

Ammonia gas is recovered from the remaining solution by treating it with Calcium Hydroxide.

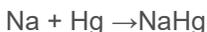
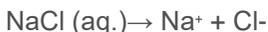


8.

Give the preparation, properties and uses of sodium hydroxide.

Answer – Manufacture of sodium hydroxide by Kellner Solvay Process

The cell is provided with flowing mercury cathode and graphite anode. When brine solution is electrolyzed, sodium ions are discharged at mercury cathode and form sodium amalgam which flows out of voltameter and decomposed with water to give sodium hydroxide. On the other hand chloride ions are discharged at graphite anode to give chlorine gas which escapes out of the voltameter.



This cell has no compartments. Mercury enters into the cell and forms a thick layer on the bottom of the cell. It serves as the cathode and is made to flow slowly across the bottom during electrolysis. The anode consists of platinum or carbon rods. The electrolyte is sodium chloride solution when electrolysis is carried, sodium ions are discharged at mercury cathode and form sodium amalgam which flows out the other end. Chlorine is evolved at the anode and escapes out. Sodium ions discharge on the mercury cathode in preference to H^+ ions which have a large over-voltage on mercury and the sodium atom so formed dissolves to form sodium amalgam. This amalgam flows out at the other end in a vessel containing water in the presence of iron (on which hydrogen has a very small over-voltage). It decomposes to give caustic soda and hydrogen.

The properties of sodium hydroxide are

-It is white opaque crystalline solid

-It is highly hygroscopic

-It is highly soluble in alcohol

1.

Explain the principal, process and draw a well labeled diagram for the manufacture of washing soda by Solvay's ammonia process. Write molecular formula of backing soda and soda ash. How do you convert NaOH into washing soda?

Answer – Sodium Carbonate is an important compound. It is manufactured by Ammonia-Solvay Process.

Principal

In the preparation of sodium carbonate by solvay ammonia process carbon dioxide is passed into concentrated solution of brine saturated with ammonia and ammonium bicarbonate is obtained.

Raw

The raw materials for the manufacture of sodium carbonate are

1. Brine
2. Ammonia, which is made by Haber's Process
3. CO₂, CaOH, which are obtained from limestone.

Materials

Ammonia-Solvay

The Ammonia-Solvay Process consists of the following steps.

Step I – Ammoniation of Brine

In first step, ammonia gas is mixed with brine. This process is carried in Ammoniation Tower. The ammoniation tower consists of mushroom shaped buffels at short intervals. Brine is introduced from the top and ammonia is introduced from bottom. They both flow towards each other. Buffels control the flow of brine and ensure that they are mixed to the point of saturation with ammonia.

Step II – Carbonation of Ammoniated Brine

In this step, ammoniated brine is mixed with carbon dioxide brine is mixed with carbon dioxide in a tower called carbonating tower or Sonvai tower.

Ammoniated Brine is fed from the top where as carbon dioxide ascends from the bottom. When these two substances meet, the following chemical reactions

takes place



Sodium bicarbonate is relatively insoluble, which is precipitated out from the solution by cooling the lower part of the tower. Sodium bicarbonate is

separated from soluble ammonium chloride by vacuum filtration. Step III – Production of Soda Ash Sodium bicarbonate is heated in a long iron tube to obtain anhydrous sodium carbonate or Soda Ash. This carbon dioxide is recycled to the solvay tower. This hydrated sodium carbonate is also called washing soda.

Recovery of Ammonia

Ammonia gas is recovered from the remaining solution by treating it with Calcium Hydroxide.

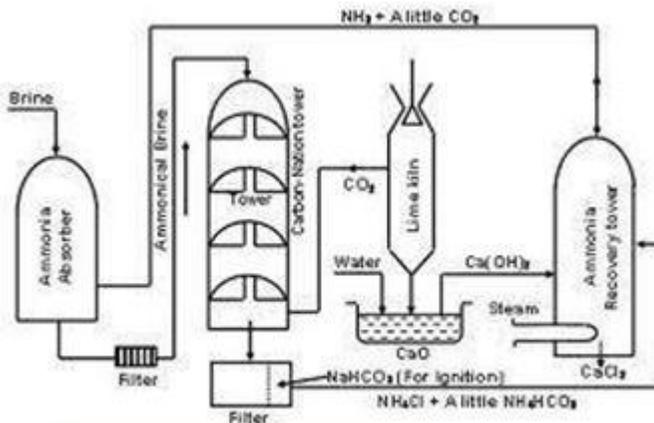
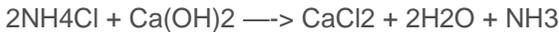
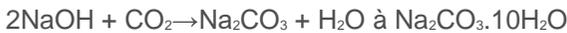


Fig:- Ammonia-Solvay Process

The molecular formula of baking soda and soda ash are NaHCO_3 and Na_2CO_3 respectively.

To convert NaOH into washing soda it is treated with moist carbon dioxide



2.

Sketch a well labeled diagram for the extraction of sodium by down's process and explain the principle involved in the process.

a. why is sodium kept in kerosene ?

b. alkali metals impart characteristic color to the flame. Give reason.

Answer –

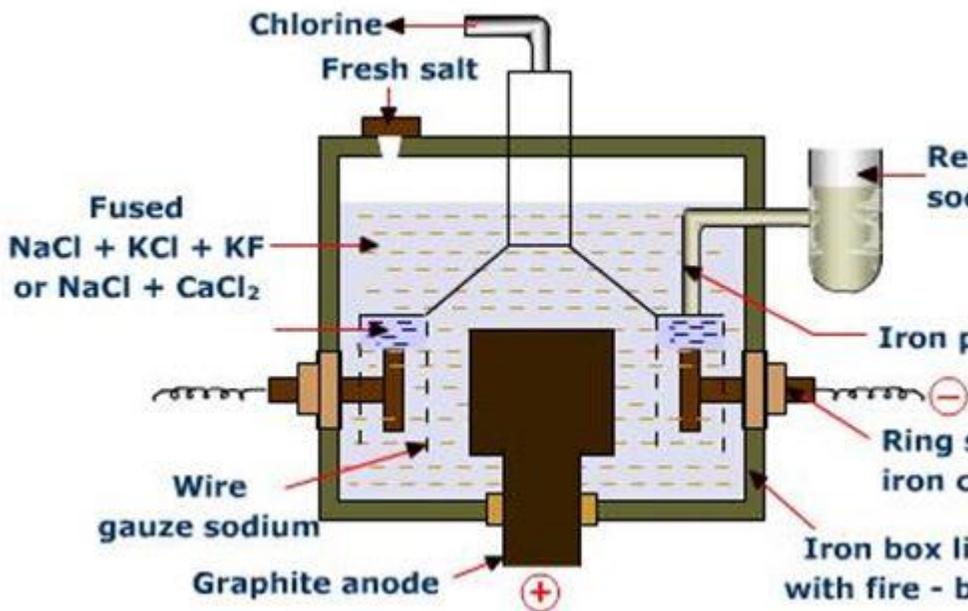


Fig:-downs process cell for the extraction of sodium

Sodium is the strongest reducing agent and is highly reactive. It cannot be extracted by chemical reduction method or carbon reduction method. It is because Sodium metal has less affinity with carbon but more affinity with halogen or oxygen, High temperature is needed for the reduction of halide or oxide of sodium metal by carbon and at high temperature carbon reacts with sodium metal to form sodium carbide, Aqueous solution cannot be used for the electrolytic reduction of sodium chloride because active sodium metal reacts with water to form NaOH and hydrogen.

In order to overcome above difficulties Sodium metal is extracted by electrolysis of the fused sodium chloride by down's process. In this process sodium is obtained by the electrolysis of a mixture of sodium chloride (40%) and calcium chloride (60%) in fused state. The function of calcium chloride is to lower the operating temperature from 820° C (m.pt of NaCl) to about 600°C.



The main reasons for lowering temperature are:

-Melting point of sodium chloride is very high. It is very difficult to maintain it in the molten state during electrolysis.

-Sodium is volatile at the temperature needed for the electrolysis and therefore a part of the metal produced vaporizes.

-Molten sodium get dispersed in molten sodium chloride to form a metallic fog at high temperature.

-Both sodium and chlorine, products of electrolysis have corrosive action on the material of the vessel employed for the electrolysis at such a high temperature.

Down's cell consists of a steel tank lined with heat resistant bricks. A circular graphite rod is placed in the centre of the cell which is surrounded by a cylindrical iron cathode. Anode and cathode are separated by a steel gauze cylinder through which molten sodium chloride can pass but molten sodium cannot. The purpose of using steel gauge is to keep sodium separate from chlorine which would otherwise react each other. Anode is covered by a dome shaped steel hood which provides the outlet for the escape of chlorine gas. The molten metal liberated at the cathode moves up and flows into the receiver containing kerosene oil. Sodium metal obtained by this method is about 99.5% pure. Chlorine is the by product in this process.

Sodium is kept in kerosene because it reacts with moist air to form sodium carbonate





Alkali metals impart characteristic color to the flame because when alkali metals or its compound are introduced into a flame, the electron absorbs energy from the flame and gets excited to higher level which on coming to ground state emits energy in the form of visible spectrum

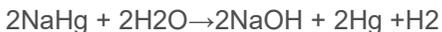
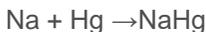
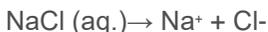
3.

Describe with neat diagram the technical preparation of sodium hydroxide by Solvay-Kellner process. Write down the action of NaOH as A. aluminium

B. aluminium chloride

Answer – Manufacture of sodium hydro-oxide by Kellner Solvay Process

The cell is provided with flowing mercury cathode and graphite anode. When brine solution is electrolyzed, sodium ions are discharged at mercury cathode and form sodium amalgam which flows out of voltmeter and decomposed with water to give sodium hydroxide. On the other hand chloride ions are discharged at graphite anode to give chlorine gas which escapes out of the voltmeter.

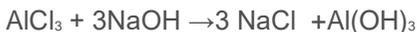


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Sodium hydroxide reacts with aluminium to form sodium Meta aluminate



Sodium hydroxide reacts with aluminium chloride to form sodium chloride and aluminium hydroxide



5.

Describe manufacture of sodium carbonate by ammonia soda process. Also mention the function of lime stone in the manufacturing process.

Answer – Sodium Carbonate is an important compound. It is manufactured by Ammonia-Solvay Process.

Principal

In the preparation of sodium carbonate by solvay ammonia process carbon dioxide is passed into concentrated solution of brine saturated with ammonia and ammonium bicarbonate is obtained.

Raw

Materials

The raw materials for the manufacture of sodium carbonate are

1. Brine
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Ammonia-Solvay

Process

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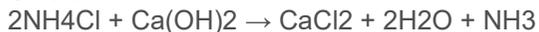
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Sodium bicarbonate is heated in a long iron tube to obtain anhydrous sodium carbonate or Soda Ash.

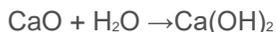
This carbon dioxide is recycled to the solvay tower. This hydrated sodium carbonate is also called washing soda.

Recovery of Ammonia

Ammonia gas is recovered from the remaining solution by treating it with Calcium Hydroxide.



The function of lime stone in the manufacturing process is to produce carbon dioxide for carbonation of brine



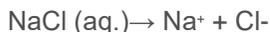
6.

Describe the neat and well labeled diagram of the technical preparation of NaOH by

i. Solvay-Kellner process

Manufacture of sodium hydro-oxide by Kellner Solvay Process

The cell is provided with flowing mercury cathode and graphite anode. When brine solution is electrolyzed, sodium ions are discharged at mercury cathode and form sodium amalgam which flows out of voltmeter and decomposed with water to give sodium hydroxide. On the other hand chloride ions are discharged at graphite anode to give chlorine gas which escapes out of the voltmeter.



At Anode: $\text{Cl}^- - e \rightarrow \text{Cl}$

$\text{Cl} + \text{Cl} \rightarrow \text{Cl}_2$

At Cathode: $\text{Na}^+ + e \rightarrow \text{Na}$

$\text{Na} + \text{Hg} \rightarrow \text{NaHg}$

$2\text{NaHg} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + 2\text{Hg} + \text{H}_2$

This cell has no compartments. Mercury enters into the cell and forms a thick layer on the bottom of the cell. It serves as the cathode and is made to flow slowly across the bottom during electrolysis. The anode consists of platinum or carbon rods. The electrolyte is sodium chloride solution when electrolysis is carried, sodium ions are discharged at mercury cathode and form sodium amalgam which flows out the other end. Chlorine is evolved at the anode and escapes out. Sodium ions discharge on the mercury cathode in preference to H^+ ions which have a large over-voltage on mercury and the sodium atoms so formed dissolve to form sodium amalgam. This amalgam flows out at the other end in a vessel containing water in the presence of iron (on which hydrogen has a very small over-voltage). It decomposes to give caustic soda and hydrogen.

Answer -

ii. Castner-Kellner process

Answer – Caustic Soda or Sodium Hydroxide is one of the most important chemicals of industrial use and its preparation by Castner-Kellner's Process is given below

Castner-Kellner's

Process

Caustic Soda is manufactured by an electrolytic process. This process is carried out in an electrolytic cell known as Castner-Kellner's cell and the process is called Castner-Kellner's Process.

Construction

of Castner-Kellner's

Cell

Sodium hydroxide is obtained by the electrolytic solution is a 25% of NaCl solution (brine) in a specially designed cell called Castner-Kellner cell. The anode consists of carbon rods whereas cathode iron rods.

Working

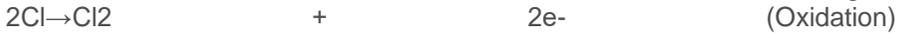
of

Castner-Kellner's

Cell

Sodium chloride dissociates in water to give Na^+ and Cl^- ions are

$2\text{NaCl} \rightarrow 2\text{Na}^+ + 2\text{Cl}^-$
 The Cl^- ions migrate towards carbon rods, it gains electron and convert into chlorine gas.



In castner-kellner's process, H^+ ions are not easily discharged due to high voltage of H^+ ions, on the contrary Na^+ ions are easily discharge over mercury surface. The sodium thus liberated dissolves in mercury forming an amalgam.



The mercury containing dissolved sodium is sent to another chamber called Denuder where sodium reacts with water forming sodium hydroxide and hydrogen. Denuder is packed with graphite blocks as hydrogen is easily liberated over graphite surface.



the mercury is recycled to dissolve more of sodium. The solution, which flows out from denuder, is a NaOH solution, which is evaporated to dryness.