CHAPTER-NO-16: CHEMICAL INDUSTRIES

MINERALS: The naturally occurring metallic compounds are called minerals.

ORES: Those minerals which contains sufficient quantity of metal are called ore. e.g. Hematite (Fe_2O_3) is an ore of iron.

METALLURGY: The process of separating a metal from its ore and preparing it for proper use is known as metallurgy. Four main steps are used in the process of metallurgy.

i) Crushing, grinding or pulverizing of the ore ii) Concentration of the ore

iii) Extraction of metal iv) Refining of metal

i) CRUSHING, GRINDING OR PULVERIZING OF THE ORE:

The first step of the metallurgy is mining. Mining is done through labours or machines. After mining the process of crushing is done. In this process larger stones are converted into smaller stones. After this process grinding is done in which smaller size stones are converted into powder form.

ii) CONCENTRATION: After converting the ore into powder form the mineral is separated from impurities (gangue) by some physical method. This process is called concentration. Three different methods are used for concentration.

1) Magnetic Separation 2) Cyclone Separation 3) Flotation Process

1) MAGNETIC SEPARATION: This process is used for the ore which contain magnetic properties. A moving belt is used for this purpose. In this process the powder form of the ore is dropped over a moving belt. This moving belt moves over two wheels. One wheel is magnetic and the other wheel is non–magnetic. When the magnetic ore passes through the magnetic wheel then this wheel attracts the magnetic ore. The non magnetic impurities fall away from the wheel. In this way the magnetic ore is separated from the impurities.

2) CYCLONE SEPARATION: This process is used where there is a large density difference between the ore and the impurities. In this process a cyclone separator is used in which air under high pressure is blown through the pulverized ore. As a result of this high pressure air the lighter gangue is blown away through the top. But the denser mineral rich particles hit the walls of cyclone separator and fall down to the funnel.

3) **FLOTATION PROCESS**: In this process pulverized ore is fed into a tank containing water and oil–detergent mixture. This mixture is agitated with air. The impurities in this mixture absorbed water and fall down to the bottom. While the mineral particles are mixed with oil and make a form which floats on the top, from where they are separated into another container. After sometime the oil particle mixed with metal particles are evaporated and metal is obtained. Copper ore is concentrated by this process.

EXTRACTION OF METALS

After the removal of gangue from the mineral then the mineral is passed through some special process to extract a pure metal. This process is called extraction of metals.

Extraction of metal involves three special processes to get a pure metal.

a) Roasting b) Smelting c) Refining or purification of metals

a) ROASTING: The process in which minerals are converted into their oxide by heating in the air at a temperature below their melting point is called roasting. For example

the roasting of zincblende (ZnS) is $ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$

Roasting of Cinnabar (HgS) is $HgS + O_2 \longrightarrow Hg + SO_2$

b) SMELTING: The process in which metal ions are reduced to free metal is called smelting. For this purpose some reducing agents such as coke, Carbon monoxide and hydrogen are used.

Some examples of smelting are $Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$

$WO_3 + 3H_2 \longrightarrow W + 3H_2O$

$ZnO + C \longrightarrow Zn + CO$

Smelting of copper is done in two steps.

STEP – I: **HEATING WITH COKE AND SAND**:

In this step copper ore is heated with coke and sand at a temperature of 1100^0C. At this high temperature the material melts and separate into two layers. The bottom layer contains a mixture of Cu_2S and FeS. This mixture is called matte. The upper layer is called silicate slag. It is formed by the reaction of FeO and sand. $2FeS + 3O_2 \longrightarrow 2FeO + 2SO$

$FeO + SiO_2 \longrightarrow FeSiO_3$

STEP – II: **BESSEMERIZATION**:

In this process air is blown through the molten copper matte in a special device known as Bessemer converter. When air is blown through the molten copper matte then any remaining iron sulphide (FeS) is oxidized and removed as slag ($FeSiO_3$). In final smelting step cuprous sulphide (Cu_2S) is oxidized and as a result cuprous oxide is formed. This cuprous oxide reacts with remaining cuprous sulphide to form metallic copper.

$2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$

$Cu_2S + 2Cu_2O \longrightarrow 6Cu + SO_2$

The product formed in the above reaction is called blister copper and it is about 97 to 99% copper.

c) REFINING OR PURIFICATION OF METALS:

The metal obtained as a result of smelting contain some impurities therefore, it must be refined before its proper use. Two main method are used for refining of metal.

i) Electro – refining ii) Distillation

i) **ELECTRO – REFINING**: In this process an electrolytic cell is used in which impure metal act as the anode and a rod of pure metal acts as the cathode.

EXAMPLE: For electrolytic refining of copper a special electrolytic tank is used in which impure slabs (sheets) of copper acts as anode and pure copper sheets acts as cathode. Acidified copper sulphate solution is used as an electrolyte. When an electric current is passed through the solution then impure copper dissolves in the solution and form $\mathbf{Cu^{+2}}$ ions. These $\mathbf{Cu^{+2}}$ ions gain two electrons at cathode and produce **Cu** atoms. These **Cu** atoms are deposited on the cathode. In this way the pure copper is collected at cathode. The impurities like '**Au**' and '**Ag**' fall off the anode as anode mud.

Reaction at Anode: $Cu \longrightarrow Cu^{+2} + 2e$

Reaction at Cathode: $Cu^{+2} + 2e \longrightarrow Cu$

ii) DISTILLATION: Those metals which has relatively low melting point such as '**As**' and '**Hg**' are refined by distillation.

SOLVAY PROCESS

Sodium carbonate (Na_2CO_3) or soda ash is an important industrial chemical. It is used in the manufacturing of glass, soaps, detergents, paper and many other important chemicals. It is prepared by a special process known as Solvay process.

RAW MATERIALS: In this process three basic raw materials are used.

a) Ammonia (NH_3) b) Brine (concentrated sodium chloride solution)

c) Lime stone ($CaCO_3$) [source of carbon-dioxide and slaked lime $\mathbf{Ca(OH)_2}$]

BASIC REACTION: Solvay process consists of six basic steps.

STEP – I: **PREPARATION OF AMMONICAL BRINE**:

Ammonical brine is prepared by dissolving ammonia gas in brine. This ammonical brine is fed into the carbonating tower.

STEP – II: **CARBONATION**:

Carbonation is the process in which carbon dioxide is passed through ammonical brine in a carbonating tower. Following reactions takes place in carbonating tower.

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

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

In the lower part of the carbonating tower the temperature of the mixture decreases up to $\mathbf{15^0C}$. At this low temperature $\mathbf{NaHCO_3}$ precipitates out.

STEP –III: **FILTRATION**: Filtration is the process in which precipitates of $\mathbf{NaHCO_3}$ are separated from the milky solution. The resulting material is used as baking soda.

STEP –IV: CALCINATIONS: In this process sodium hydrogen carbonate (**$NaHCO_3$**) is heated to get sodium carbonate. In this reaction carbon dioxide gas is released.

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

STEP – V: **PREPARATION OF CARBONDIOXIDE AND SLAKED LIME**:

In this step lime stone heated in a kiln. As a result carbon dioxide(**CO_2**) and lime (**CaO**)is produce.

$$CaCO_3 \longrightarrow CaO + CO_2$$

Carbon dioxide produced in this reaction is fed into the carbonating tower whereas equal amount of lime (**CaO**) and water (**H_2O**)are mixed together to produced slaked lime **$Ca(OH_2)$**.

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

STEP – VI: **RECOVERY OF AMMONIA**: Ammonium chloride (**NH_4Cl**) produced in the carbonating tower is heated with slaked lime. As a result ammonia is produced. Almost all the ammonia use in this process is recovered in last step. $2NH_4Cl + Ca(OH)_2 \xrightarrow{\text{Heat}} 2NH_3 + CaCl_2 + 2H_2O$

ADVANTAGES OF SOLVAY PROCESS:

1) In this process the raw materials are cheap and easily available.

2) In this process no harmful products are produced therefore, it is a pollution free process.

3) In this process there is no solution to be evaporated. Therefore it consumes less fuel.

4) In this process carbon dioxide and ammonia are recovered and re-used.

5) In this process pure sodium carbonate (**Na_2CO_3**) and sodium hydrogen carbonate **$NaHCO_3$** are produced.

FERTILIZER

Fertilizers are the compound which are put in the soil to provide elements essential for plant's life. They are added to the soil to make up deficiency caused by the previous crops.

There are two major classes of fertilizers.

1) Natural Fertilizers 2) Synthetic Fertilizers

UREA: Urea is a synthetic fertilizer it has following qualities.

i) In urea percentage of nitrogen is highest among all the synthetic nitrogen fertilizers.

ii) It does not affect the texture of the soil.

iii) In the soil urea hydrolysis very quickly and produce ammonium carbamate. This ammonium carbamate changes into ammonia (**NH_3**), and this ammonia decomposes into nitrogen (**N_2**) and hydrogen (**H_2**). Nitrogen is very important component of plant life. It gives green colour to the leaves and increases quality and yield of the crop.

MANUFACTURE OF UREA

RAW MATERIAL: Two main raw material are used to manufacture urea.

i) Ammonia ($\mathbf{NH_3}$) **ii**) Carbon dioxide ($\mathbf{CO_2}$)

MAIN STEPS: Three main steps are uses to manufacture urea.

STEP – I: **PRODUCTION OF AMMONIUM CARBAMATE**:

In first step ammonia ($\mathbf{NH_3}$) and carbon dioxide ($\mathbf{CO_2}$) are combined together to form ammonium carbonate. $2NH_3 + CO_2 \longrightarrow NH_2COONH_4$

STEP – II: **DISTILLATION OF AMMONIUM CARBAMATE**:

In this step distillation of ammonium carbamate is carried out in the presence of steam.

$$NH_2COONH_4 \longrightarrow NH_2CONH_2 + H_2O$$

$$NH_2COONH_4 \longrightarrow NH_2 - C - NH_2 + H_2O$$

STEP – III: **EVAPORATION OF LIQUID UREA**:

In this step liquid urea is evaporated in a vacuum evaporator. After the process of evaporation the remaining mixture is cooled and sent to the Prilling tower. In this way urea prills are produced these urea prills are packed and then marketed.

Page – No – 160 – Q – No – 2(i):

Q: How are urea prills produced?

Ans: When liquid urea is sprayed from the top of a prilling tower under high pressure and hot current of air is introduced from the base. Then as a result liquid urea evaporates to form prills or granules. These urea prills are packed, stored and then marketed.

Q–No–2(ii): What is slaked lime? How it is produced?

Ans: Slaked lime is hydrated form of quick lime (**CaO**). Its chemical name is calcium hydroxide and its formula is $\mathbf{Ca(OH)_2}$. It is produced in two steps.

Step –I: $\mathbf{CO_2}$ is produced by heating $\mathbf{CaCO_3}$

$$CaCO_3 \xrightarrow{\text{Heat}} CaO + CO_2$$

Step – II: Equal amounts of lime (**CaO**) and water ($\mathbf{H_2O}$) are mixed to produced slaked lime $\mathbf{Ca(OH)_2}$.

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

Q–No–2(iii): Write chemical reactions that take place during carbonation in Solvay process.

Ans: In the carbonating tower $\mathbf{CO_2}$ is passed through ammonical brine. Following reaction takes place.

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

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

Q – No – 2(iv): Explain the process 'Roasting' with two examples.

Ans: The process in which minerals are converted into oxide by heating in the air at a temperature below their melting point is called roasting.

Example – I: Roasting of Zinc blend (**ZnS**) is

$$2\,ZnS + 3O_2 \longrightarrow 2\,ZnO + 2SO_2$$

Example – II: Roasting of cinnabar (**HgS**) is

$$HgS + O_2 \longrightarrow Hg + SO_2$$

Q – No – 2(v): Write chemical reactions that take place during urea formation.

Ans: Two basic chemical reactions take place during urea formation.

FIRST REACTION: **NH_3** and **CO_2** react together to form ammonium carbamate (**NH_2CONH_4**)

$$2NH_3 + CO_2 \longrightarrow NH_2COONH_4$$

SECOND REACTION: Ammonium carbamate is evaporated with the help of steam. As a result of dehydration of ammonium carbamate urea is formed.

$$NH_2COONH_4 \longrightarrow NH_2CONH_2 + H_2O$$

$$NH_2COONH_4 \longrightarrow NH_2 - C - NH_2 + H_2O$$

Q–No–5: How was crude oil formed?

Ans: It is believed that petroleum was formed from organisms that lived millions of years ago. When plants and animals in the sea died then after the passage of time layers of sand, rock and mud deposited over those dead organisms. In the absence of air and under bacterial effect the remains of those dead organisms changed into dark brownish viscous liquid called petroleum. It is also called crude oil.

Q–No–6: State five specific products made from crude oil?

Ans: Five specific products made from crude oil are:

i) Gasoline (petroleum) ii) Diesel Oil iii) Kerosene oil

iv) LPG (Liquefied petroleum gases included methan, ethane and propane) v) Jet Fuel

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Q–No–9: Describe composition of urea.

Ans: Urea is an organic compound with the chemical formula NH_2CONH_2 or $(NH_2)_2CO$ $NH_2 - C - NH_2 + H_2O$. In the molecule of Urea two – **NH_2** groups joined with carbonyl group – C – or (C = 0).

Q–No–11: Describe composition of petroleum.

Ans: Petroleum is mixture of hydrocarbon in different solids, liquids and gas. It particularly contains alkanes, cycloalkanes and aromatic hydrocarbons. It can also contain different compounds of oxygen, nitrogen and sulphur.