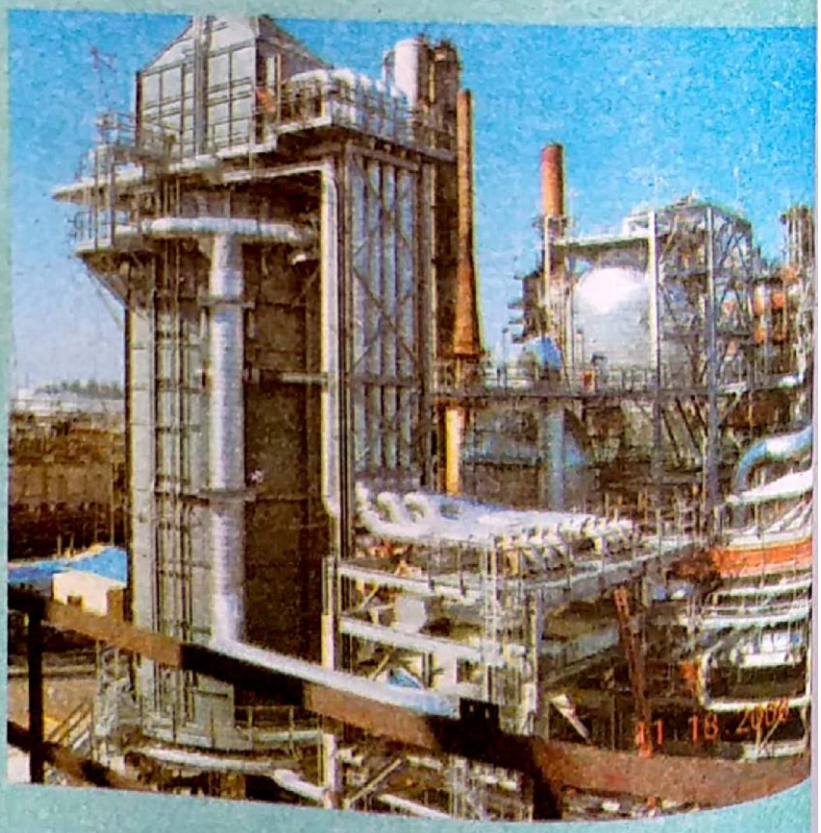
Chapter

16

Chemical Industries

In this chapter you will be able to:

- Describe some metallurgical operations.
- Make a list of raw materials for Solvay's process.
- Outline the basic reactions of Solvay's process.
- Develop a flow sheet diagram of Solvay's process.
- Describe the composition of urea.
- Develop a flow sheet diagram for the manufacture of urea.
- List the uses of urea.
- Define petroleum
- Describe the formation of petroleum and natural gas.
- Describe the composition of petroleum.
- Describe briefly the fractional distillation of petroleum



INTRODUCTION

The rapidly growing population and the desire to raise the standard of living has forced the scientists to devise methods for preparing cheaper substitutes of substances obtained from natural sources. All these substitutes involve chemical process carried out on large scales in chemical industries like soaps, fertilizers, detergents etc.

16.1 Metallurgy and Basic metallurgical operation with reference to copper.

Most of the metals such as iron, copper, sodium etc are found in combined state in nature which are called minerals. An aggregate of mineral and other impurities is known as Ore.

"The art and science of making metals and alloys from their ores with properties suitable for practical uses is called metallurgy.

The ores are mined and subjected to various mechanical and chemical processes. There is no single method for extracting metal from their ores. But certain basic operations are required that is concentration of the ores, roasting, reduction and refining.

16.1.1 Concentration of ores.

In mining the metal, the desired mineral from which a metal is to be extracted often constitutes only a few percent of the metal mined. Therefore it is necessary to separate the desired ore from useless material before proceeding with other metallurgical operations. A number of methods are used for the concentration of ores e.g. cyclone separation, vibrating method, floatation method etc.

The most important method of concentration used for copper is Froth Floatation. In this method, the ore is crushed to small size and mixed with water containing a small amount of pine oil. The mixture is thoroughly agitated by passing strong current of air. The particles containing ore are wetted by oil and float at top of the mixture in container from which it is collected. The Froth is washed with water and then filtered to obtain concentrated ore of copper. The useless particles settles down in water.

16.1.2 Extraction of metal

The concentrated ore is ready for extraction of metal. Different method are used for extraction of metal like roasting, reduction etc.

Roasting:

The concentrated ore is mixed with silica and calcium carbonate and is heated in blast furnace, matte is formed.

Reduction:

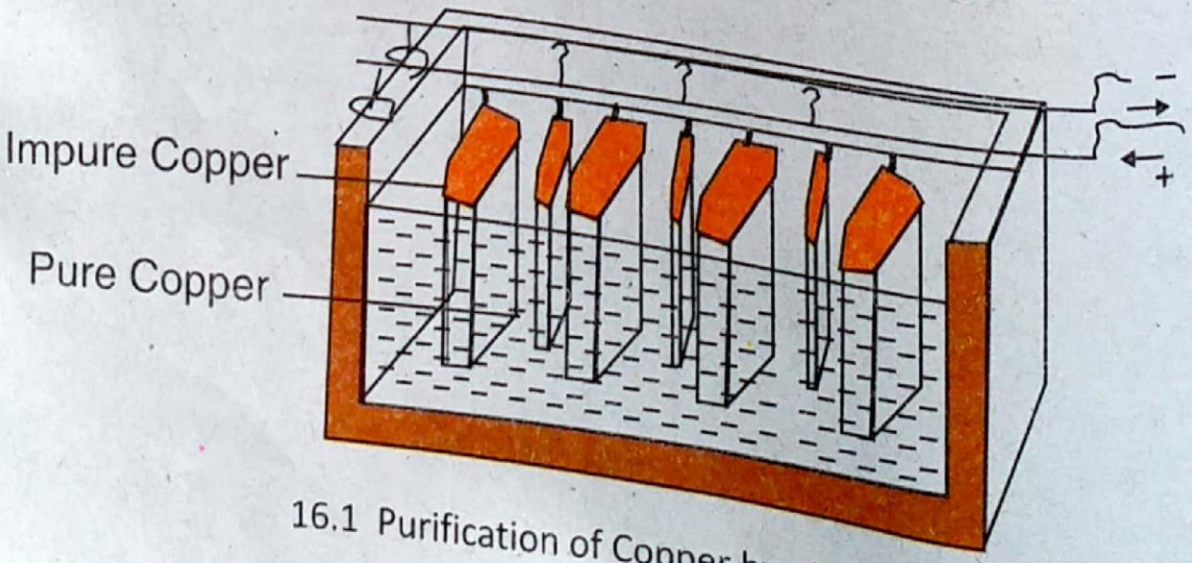
The matte consist of molten copper and iron sulphides. The matte is heated in Bessemer convertor and air is blown through molten copper sulphide which is converted into elemental copper.

$$Cu_2S + O_2 \rightarrow 2\,Cu + SO_2$$

The elemental copper is poured into moulds where it is cooled. It is now called blister copper because it has porous surface which is due to escape of SO_2 gas during solidification.

16.1.3 Electro-refining

The blister copper contains silver, gold etc as impurities. These impurities of copper are removed by electrolytic refining. The blister copper is made anode and a thin sheet of pure copper is made cathode as shown in figure 16.1



16.1 Purification of Copper by electrolysis

The solution of copper sulphate and sulphuric acid is used as electrolyte in electrolytic tank. When current is passed, copper dissolves from impure copper (anode) as copper ions.

$$Cu \rightarrow Cu^{+2} + 2e^{-} \text{ (at anode)}$$

At cathode copper ion is reduced and gets deposited over it.

$$Cu^{+2} + 2e^{-} \rightarrow Cu \text{ (at cathode)}$$

The blister copper (at anode) dissolves slowly and sheet of pure copper (at cathode) builds up to a large slab. The inactive impurities (silver, gold) settle at bottom and are called anode mud.

16.2 Manufacture of sodium carbonate by solvay's process

Sodium carbonate is one of the most important chemicals. It is used in the manufacture of glass, paper, textile laundering etc. Sodium carbonate is commercially manufactured by Solvay's process. This process have the following main steps:

16.2.1 Raw material

The raw materials used for manufacture of sodium carbonate are

(i) Sodium chloride ($NaCl$)
(ii) Lime stone ($CaCO_3$)
(iii) Ammonia (NH_3)
(iv) Water (H_2O)

16.2.2 Main process and basic reactions

This process is very simple. Ammonia gas is passed through saturated solution of sodium chloride in saturating tank. The sodium chloride gets saturated with ammonia. Carbon dioxide gas obtained from lime stone is passed into a solution of sodium chloride and ammonia. The series of reaction involved in this process is as under

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

$$NH_3 + H_2O + CO_2 \longrightarrow NH^{+}_4 + HCO^{-}_3$$

$$NH^{+}_4 + HCO^{-}_3 + Na^{+} + Cl^{-} \longrightarrow NaHCO_3 + NH_4Cl$$

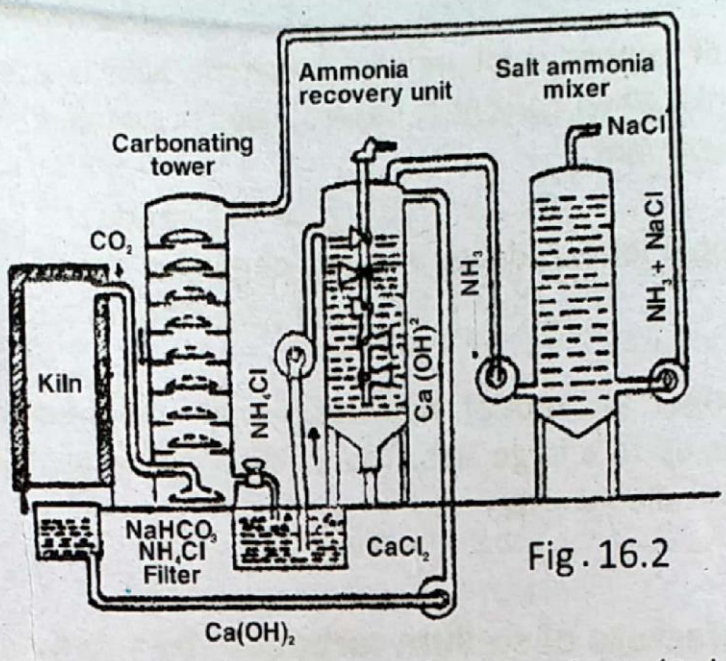


Fig . 16.2

Figure 16.2 Manufacture of sodium carbonate plant. (Solvay's process)

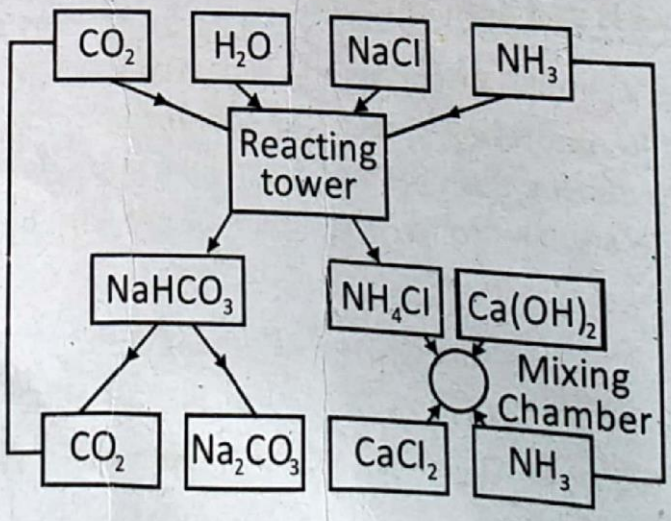
Sodium bicarbonate is precipitated and removed by filtration. The dry sodium bicarbonate is then heated to form sodium carbonate.

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

The efficiency of the process is increased by treatment of ammonium chloride (NH_4Cl) solution with calcium hydroxide. Ammonia is recovered and is allowed to enter in the process again and again.

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

The carbon dioxide evolved upon heating the sodium bicarbonate is also returned to process which is shown in flow sheet.



16.3 Flow sheet diagram

16.3 Manufacture of Urea

Agriculture has been one of the oldest industries known to man. Chinese have been using animal manure in their agricultural field. The utility of chemical manure was first pointed out in 1840. Experiments indicate that three elements namely Nitrogen, phosphorus and potassium are very essential for the growth of the plants. Urea is probably the most important nitrogenous fertilizer. It is manufactured as given below.

16.3.1 Raw Materials

Carbondioxide and ammonia are raw materials of urea. Ammonia is prepared by Haber's process from nitrogen and hydrogen and Carbondioxide is obtained from natural gas (CH_4)

16.3.2 Main process and basic reactions

Urea is manufactured by heating ammonia and carbon dioxide at 170–200°C and 100–200 atm pressure.

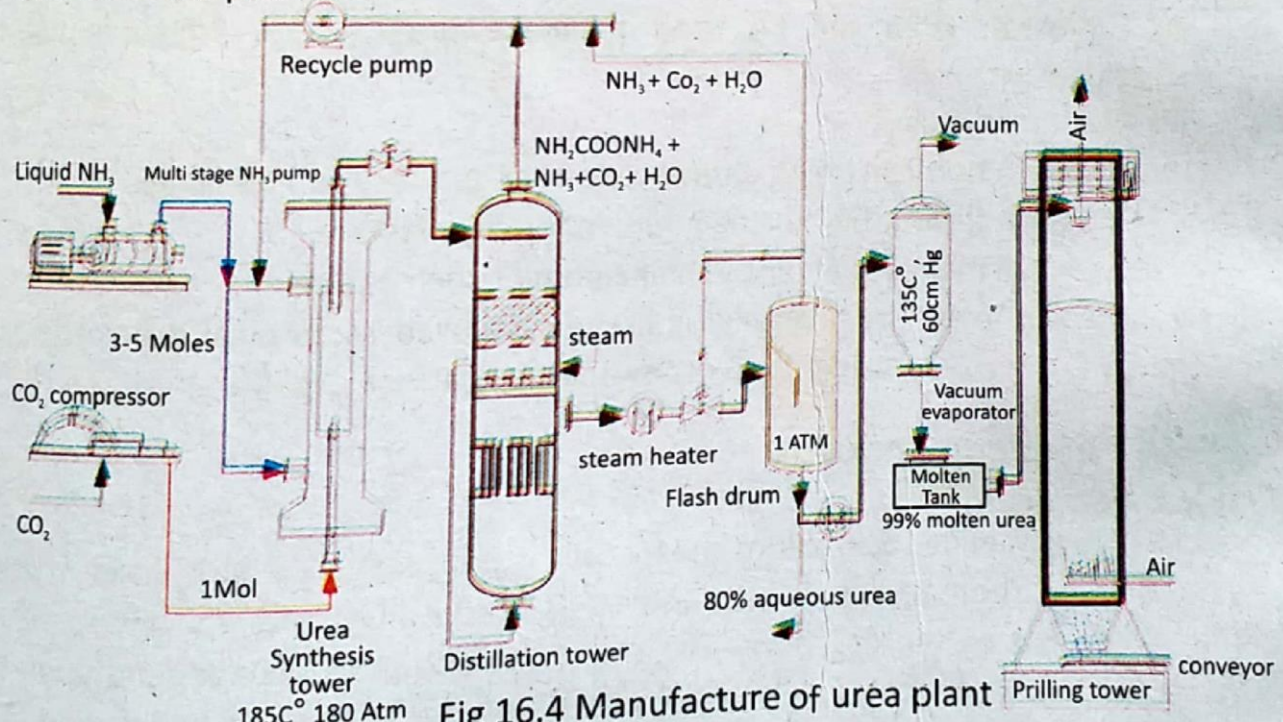


Fig 16.4 Manufacture of urea plant

The formation of urea takes place in two steps

i. Firstly ammonium carbamate is formed by the reaction of ammonia and carbon dioxide. $2NH_3 + CO_2 \longrightarrow NH_2COONH_4$

ii. In second step ammonium carbamate decomposes into urea and water.

$$NH_2COONH_4 \xrightarrow{\text{Heat}} NH_2CONH_2 + H_2O$$
(urea)

The urea solution is concentrated in vacuum evaporators, which is then rapidly cooled and solidified. The flow sheet diagram of manufacture of urea is given below.

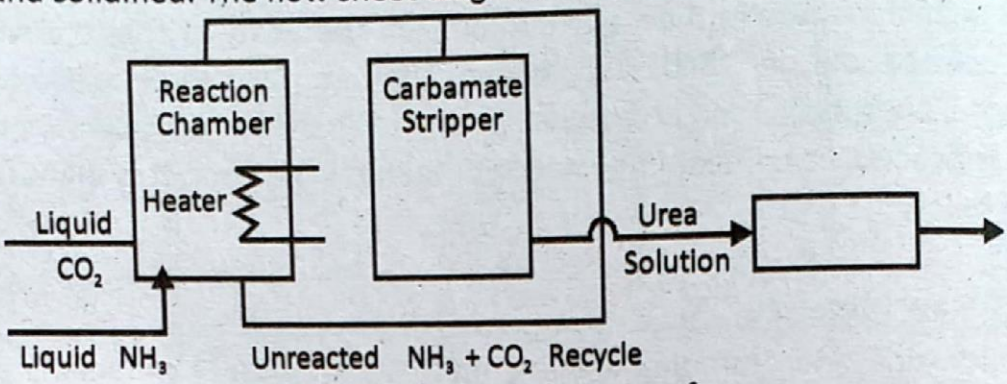


Fig. 16.5 Flow sheet diagram of urea

Urea is used in different fields.

i. Agriculture: Urea is widely used as fertilizer.

ii. Chemical Industries: Urea is used as raw material for manufacture of many important chemical compounds like plastic, resins, various adhesives, etc.

iii. Explosive: Urea can be used to make urea nitrate which is highly explosive.

iv. Commercial uses:
- A non-corroding alternate to rock salt for road de-icing.
- A flavour enhancing additive for cigarettes.
- A main ingredient in hair remover such as veet

v. Medical uses: Urea containing cream are used as tropical dermatological products to promote rehydrations of skin.

16.4 Petroleum industry

16.4.1 Petroleum

Petro means rock, oleum means oil. It is present as dark viscous liquid under the earth. It is also known as crude oil or mineral oil. It mainly consists of hydrocarbons. The wealth of a country may depend upon the presence of crude oil. Therefore it is also known as liquid gold. The important petroleum producing countries are USA, Mexico, Iran, Iraq and other middle-east countries.

16.4.2 Origin of petroleum

The origin of petroleum lies in plants and animals which lived on earth and in the sea, many millions of years ago. These organisms died and their remains became

buried under the earth. Due to the bacterial decomposition and under the action of earth heat and pressure these animal and plant remains were converted to liquid hydrocarbon, the petroleum. The gaseous hydrocarbon that were produced constitute the natural gas.

16.4.3 Drilling of petroleum

Petroleum usually occur at depth of 500 feet or more. The crude oil is found in porous rocks. It is often associated with natural gas which exerts pressure on the oil surface and drives it out through natural opening of earth.

In the case of artificial mining, mines are bored. When the oil pocket is pierced the gas pressure, forces the oil out. If there is no natural gas present in pocket, air pressure is applied to raise the oil from the well. The oil obtained from the mine is conveyed by system of pipe lines to refinery for refining.

16.4.4 Important Fractions of Petroleum

Petroleum or crude oil has often been described as a useless mixture of very useful substances. The conversion of crude oil into useful products is called refining which is carried out in a fractionating column.

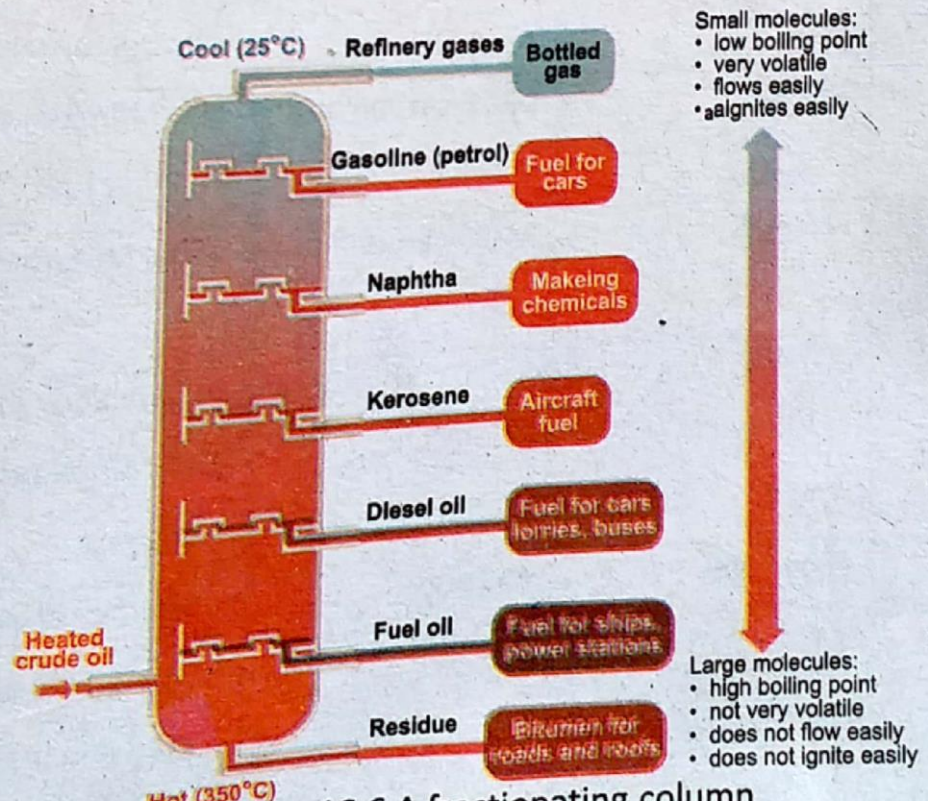


Fig. 16.6 A fractionating column

Different fractions of petroleum are separated by fractional distillation. The fractions are separated according to difference in their boiling points.

The petroleum is heated above 400°C in furnace as shown in fig 16.6. The vapour of petroleum, under high pressure are carried to fractionating column. The column is divided into several compartments, each of which has specific range of temperature. As the petroleum vapours rise up in the column, they condense and separate out into several fractions.

The following are important fractions and uses obtained from the refining of crude oil are given in table below.

Table 16.1

Fraction	Boiling point (°C)	Size of molecule	Uses
Petroleum gases	Below 40	Up to 4 carbon atoms	Methane for cooking and butane for camping gas
Petrol and Naphtha	40-130	4-12 carbon atoms	Naphtha for lighter fuel Petrol for cars
Paraffin Oil (Kerosene)	150-200	10-16 carbon atoms	Paraffin for heating and jet fuel
Diesel Oil (DERV)	225-300	14-25 carbon atoms	Fuel for lorries and ships
Lubricating oil	300-400	20-70 carbon atoms	Lubrication of machines and engines
Bitumen	Above 400	Residue	Bitumen is heated with gravel and sand and made into road coal tar

Organic vs synthetic fertilizers

1. Most organic fertilizer are derived from plants and animals like manure, bone, blood, meat etc. which is broken down by bacteria before they can be used by plants and soils.
   Synthetic fertilizers are commercially produced from petroleum or natural gas and are easy to apply in granular or liquid form.
2. The beauty of organics is that they are slowly released naturally. Therefore they are for entire season. Whereas synthetic fertilizer leach from soil with watering and can be used by plant instantly.
3. Organic fertilizers are present on surface and lot of work is required to mix them with the soil. Synthetic fertilizer are easy in use as they seep into the soil deep as soon as water is applied.

KEY POINTS

- Metal may exist in nature in free or combined state. In combined state it is called mineral.
- The art and science of making metal and alloy from their ore is called metallurgy.
- Metals can be extracted from their ores by means of a process consisting of concentration, roasting and refining.
- The blister copper is refined by electrolysis.
- Sodium carbonate is manufactured commercially by solvay process.
- Raw materials used for the commercial production of sodium carbonate are NaCl, $CaCO_3$, NH_3 and H_2O.
- Chinese were the first to use animal manure in their agriculture fields.
- Urea is probably the most important artificial fertilizer.
- Raw material used for production of urea are CO_2 and NH_3.
- Petroleum is a dark viscous liquid found under the earth crust.
- Different fractions of petroleum are separated by fractional distillation.

Q.1 Choose the appropriate answer for the following.

I. The metal present in combined state is called_____

(a) mineral (b) metal (d) solid (d) none of these

II. The blister copper is refined by_____

(a) concentration (b) reduction

(c) electrolysis (d) boiling

III. Sodium carbonate is commercially manufactured by_____process

(a) Solvay's (b) Ostwald's

(c) Haber's (d) Frasch

IV. Chemical formula of urea is _____

(a) NH_2COONH_4 (b) NH_2CONH_2

(c) NH_4Cl (d) Na_2CO_3

V. Urea is probably most important_____fertilizer.

(a) sulphur (b) nitrogenous

(c) phosphate (d) organic

VI. Raw material used for manufacturing urea are_____

(a) CO_2 and NH_3 (b) H_2 and NH_3

(c) HCl and NH_3 (d) non of these

VII. Petroleum is mixture of many_____

(a) hydrocarbons (b) hydroxide (c) acids (d) salt

VIII. Different fractions of petroleum are separated by_____

(a) fractional distillation (b) steam distillation

(c) cooling (d) none of these

IX. Which one is a step of metallurgical process_____

(a) roasting (b) rusting

(c) crystallization (d) none of these

X. The blister form of copper is _____copper.

(a) pure (b) impure (c) refined (d) raw

Q.2 Give short answers

i. What is metallurgy?
ii. How blister copper is purified?
iii. How sodium carbonate is commercially prepared?
iv. Describe the concentration of copper ore.
v. What is drilling of petroleum?
vi. Draw flow sheet diagram of solvay's process.
vii. What is origin of petroleum.

Q.3 Comprehensive questions.

i. Describe the composition of petroleum in detail.
ii. How is urea manufactured commercially?
iii. Describe the extraction of copper from its ore.
iv. Describe in detail the solvay's process.
v. Define fractional distillation? How fractional distillation is carried out in petroleum.