Bio Inorganic

Dr. Sarita chauhan,

Associate Professor

B.Sc. vth semester

Department of chemistry

Sri .JNMPG COLLEGE LUCKNOW

Bio molecules

In the developing area of chemistry it is the branch of Science, that relates inorganic chemistry with the biological system. Chemically living beings are having two types of the constituents':

Organic constituent-

This is the main constituent it is derived from inorganic element (C,H,O,N) e.g. Protein, carbohydrate, fats etc.

Inorganic Constituent:-

Although it constitutes a small amount of total body, yet it is important for maintaining the vital activities of a living being.

29 elements were analyzed in the ash of animal tissue they are divided into two category.

Essential Element-

These are recognized as essential and indispensible to life. They are needed for growth and normal function of the animals and plants. Depending upon their absolute amount in the body, they are further divided into two groups.

Macro elements:-

These are required to be present more than 1 mg in the diet. They form nearly 60-80% of the entire inorganic mineral in the body. Macro elements include twelve elements C, H, O, N, Na, K, Mg, Ca, P, Fe, S & Cl. Among these C, H, O, N, are present in substantial amount in every body tissue & get divided from dietary carbohydrates lipids & proteins. The body gets oxygen directly

from atmosphere 85% of total O & 70% total Hydrogen occurs together in the form of water which makes 3/5thof the total body weight. The remaining amount of O_2 &H_2, all N, most of the C and some of the S is derived

from carbohydrates lipids & Proteins which fulfill the basic requirement of tissue structure.

Micro Elements-These are needed in very small amount by the body, almost in micro grams & Nano grams. These are formed as nano elements or oligo elements e.g. Cu, Zn, Co, Mn, Mo, I & F.

Non-Essential Elements-

The non-essential elements are Si, As, Ni, Al, Sn, and V & Ti. These are not actually non-elements but their function in the body is not yet known.

It is important to note that even some essential elements are toxic if consumed in larger quantities. The important biochemical roles of the most essential metal are summarized below.

Sodium(Na) & Potassium(K):-

Na & K occur in plants as well as in animals as the salts (Chlorides, phosphates & carbonates) of inorganic acids & salts of proteins & organic acids sodium has been the main extra cellular cation , where as potassium the main intra calculator action. In view of the close similarity of chemical properties between Na&K, it is surprising that their biological functions are very different. Na+ is actually expelled from cells, where a K is not. This ion transport is called sodium pump, and it encloses the expulsion of Na+ and active take up of K+. Analysis of fluid inside and outside animal cells shows, that concentration of K+ is 0.15 M & the concentration of Na+ is about 0.01M In body fluid (lymph & blood) concentration K+ & Na+ is 0.003 M & 0.15M respectively. The ions require energy, which is obtained by the hydrolysis of ATP. Hydrolysis of one ATP molecule to ADP provides enough energy to move three Na+ ion but out of cell two K+ & one Na+ ion back into the cell.

The different ratio of Na+ & K+ insides & outside cells produces an electrical potential across the cell membrane which is essential for the functioning of nerve & muscle cell. The movements of glucose into cell in associated with Na+ ions.

Calcium(Ca) & Magnesium(Mg):-

Both Ca^{+} and Mg2+ ion are present in body fluid. The concentration of Mg2+ ion is more inside the cell & that of Ca 2+ is more outside the cell .Ca2+ ions are present as phosphates in the bones of both human being & animals in the form of calcium Hydroxide phosphates $[Ca_2(OH)(Po_4)]_3$ and the enamal of teeth as fluoroapatite $[Ca_3(Po_4)_2]:CaF_2$ These ions also play an important role in

The muscle contraction ,the malnutrition in children is mainly due to the deficiency of the Ca^{2}+ ion.Ca^{2+}ion is also important for blood clotting. Both Ca2+ and Mg2+ ions catalyze the formation or pyrophosphate linkages, which control the various biological systems. Deficiency of Ca2+ions causes titany,while excess of it causes calcification. Mg2+ ions are present in chlorophyll which is green colorings matter in plants used in photosynthesis.

Copper and Zinc:-

These metals are essential to all organisms. These are the constituents of organic catalysts in the body called enzymes zinc metalo enzymes catalyses peptide hydrolysis and maintain HCO^{3-}/CO_2 equilibrium. Copper is the constituentes of redox enzymes and hemocyanine. Zinc plays a role in sexual maturation and reproduction. These metals do not exist as free metal ion in living system but as metal chelats of exceptionally high stability A Number of enzymes containing Zn ion are known. Carbonic hydrolysis is one of them which is present in red blood cells RBC and is envolved in respiration. In the presence of carbonic anhydrase the absorption of CO_2 by RBC in muscles and other tissue is faster ,On the other hand, in the reverse reaction it envolved the release of CO_2 in the lungs. The reaction is PH dependent

$$CO_2\ (aq) + H_2O \underset{\text{anhydrase}}{\overset{\text{Carbonic}}{\rightleftharpoons}} H_2CO_3(aq)$$

The carbonic anhydrase has a four co-ordinated link around Zn^{2}+ ion in which three of the ligands are imidazole nitrogen of three higtidine and the fourth is water molecule with PH =7 or hydroxide ion as under Fig-1

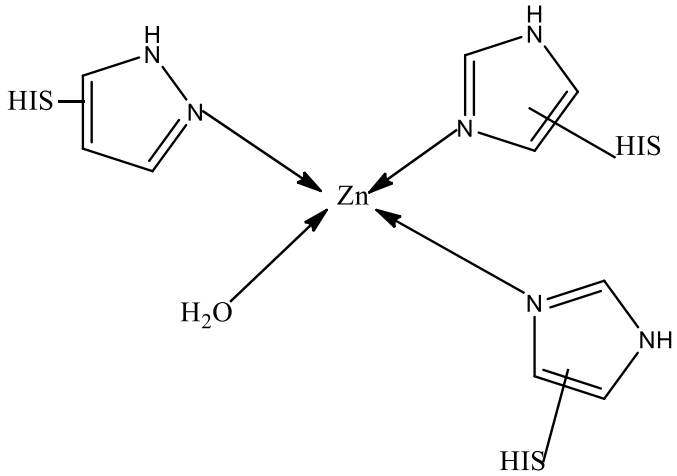


Fig-1

The role of Zn is to reduce the basicity of hydroxy ion to approximately neutral medium. There are some more enzymes know to contain Zn as essential constituent

Some Metallo Enzymes of Zn

Name	Molecular weight	Zn at per atom	Sources
Carbonic anhydrases	30,000	1	Erythrocytes
Carboxyl peptidases	35,000	1	Pancrease
Dihydrogenases	~ 85,000	≥ 2	yeast,Liver
Alkaline Phosphate	~ 89,000	4	E.Coli

Insulin is known to have Zn and in diabetes, the total amount of Zn is in pancreas reduced to half.

In leukemia Zn content of blood leucocytes gets reduced to almost 10% of the normal amount.

Copper is equally important as Zn. A person needs 8 mg of Cu daily. If copper is not in the optimum value, the Fe, which is present in liver cannot be used. As a result the animal suffers from anemia. Copper is present as metals in 80 proteins or as enzymes in the body. Excess of Cu is highly poisonous. The disease caused by the excess of Cu called Wilson's disease .

Cobalt (Co):-

This is also an important trace element the recommended daily allowance is 1 to 2 ug of cyano cobolamine having 0.045 to 0.09ug Co. The

maximum amount of Co is found in liver .65% of the ingested cobalt gets exerted almost completely through kidney Co is present in vitamin B_{12} [Cyano Cabolamine] which is needed for bone marrows function for producing energy Therefore a defiecinecy of cobalt gives rise to limitation of Vit B_{12} supply which may gives rise to nutritional types of anemia, while an excess of Co give rise to over production erythrocytes causing polyanemia certian enzyme like methyl malonyl Cobalamine mutase & rivo nucleotide reductase need VitB_{12} for the activity , Traces of Co are also essential in the diet of animals. Deficiency Co in soiladversely effects the health of grazing animals adding Co salts to soil improves their health.

Selenium(Se):-

This trace element is important for mammals & some higher plants. Mammals and birds required selenium for production of enzyme gluta thione peroxides. Se protects biological system against free radical oxidant & stress. H_2o & organic peroxides which causes oxidant ion damages to cellular component are enzymatically destroyed by selenium protein. Thus selenium protects against oxidation induced cancers live stock grown on selinium deficient postures suffer from white muscle disease however if grazing in a soil with high Se concentration they sufferfrom central nervous system toxinoses .Selenium deficiency in human results in degenerating condition of the heart tissue known as keshan dies.

Molybdenum(Mo):-

Essential to all organism with the possible exception of green algae. Mo is used in enzymes connected with nitrogen fixation and Nirate reduction.

It in moderately toxic and antagonist to copper molybdenum excess in pasturage can cause copper deficiency Mo excess in biological system may cause gout like syndrome.

Chromium(Cr):-

This essential ultra trace element is involved in glucose metabolism and diabetes. Cr (iii) potentials effect of insulin. . Cr (VI) is carcinogenic

Manganese(Mn):-

It is essential to all organisms Mn activates numerous enzymes and is useful for normal bone structure. Manganese ions are also known to activate glucosyl transferase which is concerned with the synthesis of micro polysaccharides of cartilage and also associated with the synthesis of

glycoprotein's Manganese deficiency in soils lead to infertility in mammals bone malformation in growing chicks.

Iodine(I):-Iodine is used by thyroid gland for the formation of thyroxin and iodothyroxin hormones. These hormones take part in the growth, cellular oxidation, reproduction and the activity of the central nervous system.

Fluorine(F):-Traces of fluorine are necessary for the development of teeth and bones. It is very useful in preventing the development of osteoporosis among adults especially in past menopausal women.

METALLOPORPHYRINS;-Metalloporphyrins is an important Bio-inorganic-compound in which a metal ion is surrounded by four nitrogen PORPHYRINS rings (which is a macrocyclic tetradentate ligands) porphyrins are the derivatives of porphyine which consist of four pyrozole units joined across their 2 position via-CH=fragments(Methenes) and it is the parent skeleton porphyrium. In porphyrin the ring Pyrazole ring are numbered I to IV their β-carbons 1-8 '''and the four methine bridge α to δ as indicated in structure A & B.(Fig-2,3)

These porphyrines acts as tetradentate ligand with four nitrogen donor site.

Fig-3

Two of these are tertiary nitrogen donor sites which can from coordinate bonds by donating a pair of electron to each metal ion. The other two or secondary nitrogen donor position each of which looses a proton in forming a co-ordinate bond with a metal ion. Thus a Porphyrins rings act as tetra dente di

negative ligands or (dianion) bi positive cation such as Mg^{2+}, Fe^{2+}, Ni^{2+} form neutral complex with Porphyrins

A bond between nitrogen atom and as atom of the first transition series should be about 200Pm long. The size of the "hole" in the centre of the Porphyrins rings is idial for accommodating metal of the first transition series of B.

The Porphyrins system is fairly rigid and the metal nitrogen bond distances does not very greatly from 193-196 Pm in Nickle Porphyrins and 210Pm in Iron porphyins the rigidity of the rings originates from the delocalization of the π electrons in the Pyrrole rings. The order of stability of complexes of

Porphyrins with +2 metal ion is as follow

$Na^{+}>Cu^{2+}>Co^{2+}>Fe^{2+}>Zn^{2+}$

Porphyrins play a key role in the living organism when there are complexed with iron and bound to proteins as in hemoglobin and myoglobin and the cytochromes. The structure of two important metallo Porphyrins heme and chlorophyll are being considered here.

IRON PORHYRINS : HAEMOGLOBINAL & MYOGLOBIN:-

Oxygen is very important for the survival of organism. It is obtained during photosynthesis involving biologically important redox reaction different proteins have different tendencies to bind and transfer oxygen. These proteins are known as oxygen carries. The two oxygen carrier proteins are hemoglobin.(Hb) and myoglobin (Mb) these are ion Porphyrins complexes which are oxygen transfer and oxygen storage agents in the blood and muscle tissue respectively function these two proteins are as follow.

(i).Hemoglobin picks up the dioxygens from the lungs or gills & transport to the tissue in rest of the body.

(ii)Myoglobin accept oxygen from the hemoglobin in the muscle and stores it until needed for energetic process

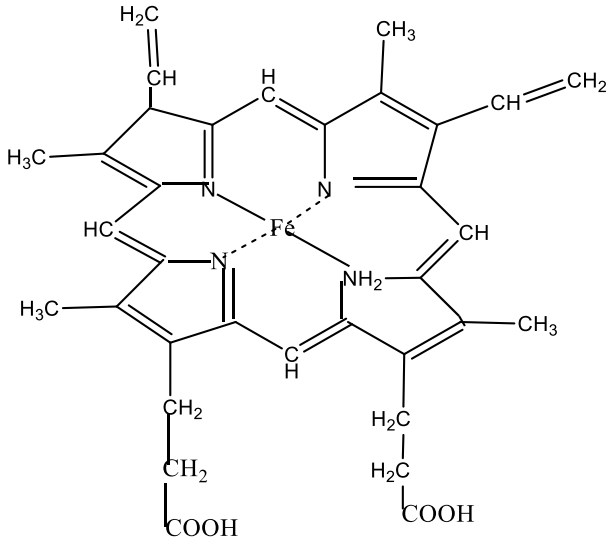
(iii)Deoxygenated hemoglobin uses some of its amino groups to fix up CO_2 and then transport CO_2 back to the lungs

STRUCTURE OF HAEMOGLOBIN

Hemoglobin is considered a tetramer of myoglobin it has a molecular weight of 64,500 and contains four heme groups bond to four protein chain. Two of the chain labeled beta(β) have 146 amino acids and are somewhat similar to the chain in myoglobin the other two labeled alpha, have 141 amino acids and are somewhat less like the myoglobin chain.

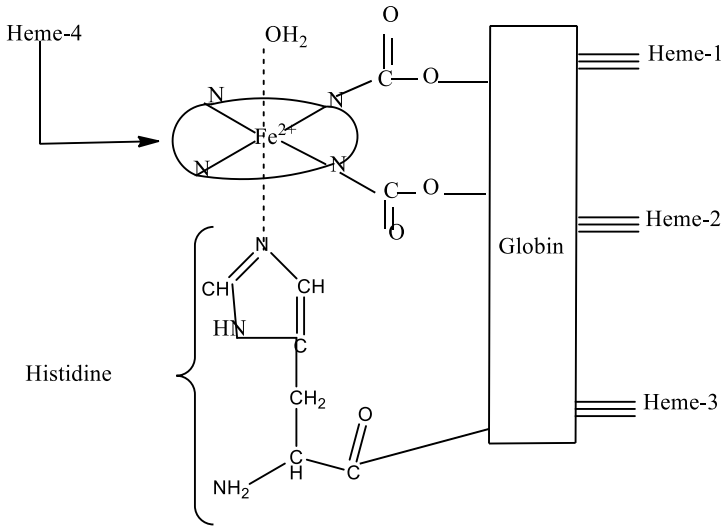
The active site in both the proteins is the planar heme group embedded in a convoluted protein chain (globin) with a coordinate bond between the Iron and the nitrogen atom of the imidozole side chain of a histidine residue (The prominalHb is an octahedral complex of Fe(ll).Fe(ll) occupies the central position and the four corners of the square base are occupied by the four N atom of heme group one axial position is occupied by the H_2o molecule. The four subunits are linked together through salt bridges present between the four polypeptide chains which introduce stain in the molecule of Hb.

Structure of hemoglobin (Hb) contain four heme groups (Fig-4)



Structure of Heme group

Fig-4



Structure of Haemoglobin(Hb) cotaining four heme groups and histidine

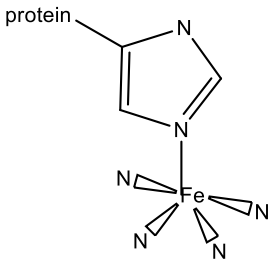
Fig-5

De oxy Hemoglobin⁻

Hemoglobin Hb which has not taken O_2 is called de oxy Hb & the one which has taken O_2 is called oxygenated hemoglobin or oxy hemoglobin (oxy-Hb) Fe(11) present in Hb can be oxidized to Fe(11l) under controlled conditions to form Fe(11) protein , called Met-Hb.Fe(lll) protein is responsible for the brown colour of old meat & dried blood

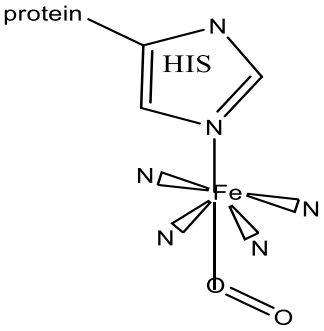
Structure of Myoglobin (Mb)

Heme is also important biologically in myglobin which is used to store oxygen in muscle myglobin is similar to one of the units in hemoglobin it consist of one polypeptide chain(globin) with one heme group(as in fig.)The polypeptide chain consist 150-160 amino acid residues folded about the single heme group.



Square pyramidal sreucture of deoxy-Mb with Fe(ll) lying above the plane of four N atom

Fig-6



Octahedral structure of oxy-Mb with Fe(ll) lying in the plane of four Natoms

Fig-7

Comparison between Hb and Mb:-

Both Mb & Hb are metallic porphyrins which contain heam group in their structure, Heme consists of four N atom of porphyrins coordinate to Fe atom.At high partial pressure of O_2, both Hb & Mb are good binders of O_2 but at low oxygen pressure as in case of muscle Hb is far poor binder.

Role of Hb & Mb in Biological system:-

Hb & Mb play a very importent role in transportation of O_2 form lungs to tissue and Co_2 as (HCO_3^-) from tissue to the lungs Hb is oxygen career.

As we know that O_2 is inhaled in into lungs and binds with Hb present in the lungs (as partial pressure of O_2 in high and form oxyheamoglobin) when Hb

bind with O_2 to form HbO_2 .H_2O molecule present in Hb is reversbly replaced by O_2 to form HbO_2.

$$\text{Hemoglobin} + O_2 \leftrightarrow \text{ox hemoglobin } + H_2O$$

Or Hb coordinating Co-ordinate H_2O mol +O_2

$$Hbo_2 + H_2o$$

Now this oxy Hemoglobin goes to muscular tissue through arteries here the partial pressure of O_2 decrease HbO_2 liberates O_2 the liberated oxygen is taken up by Mb to from oxygenated myoglobin (MnO_2) this is called oxygenate ion of Mb.

$$Hbo_2 \rightarrow Hb + o_2$$

$$Mb + O_2 \rightarrow Mbo_2$$

As the blood runs through arteries to the tissue O_2 bound with MbO_2 is set free. This free oxygen is utilized in the oxidation of glucose from the food to Co_2 and energy in the form of ATP this energy is used by the living organism to perform various metabolism process and for maintain their body temperature.

$$C_6H_{12}O_2 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 38ATP(energy)$$

Water produced in the above reaction retained in the body while Co_2 combines with the amino groups hemoglobin to form carb-amino hemoglobin which decomposes to give Co_2 & Hb Co_2 is exhaled out and Hb goes to the lungs for reuse. The complete process may be shown as under

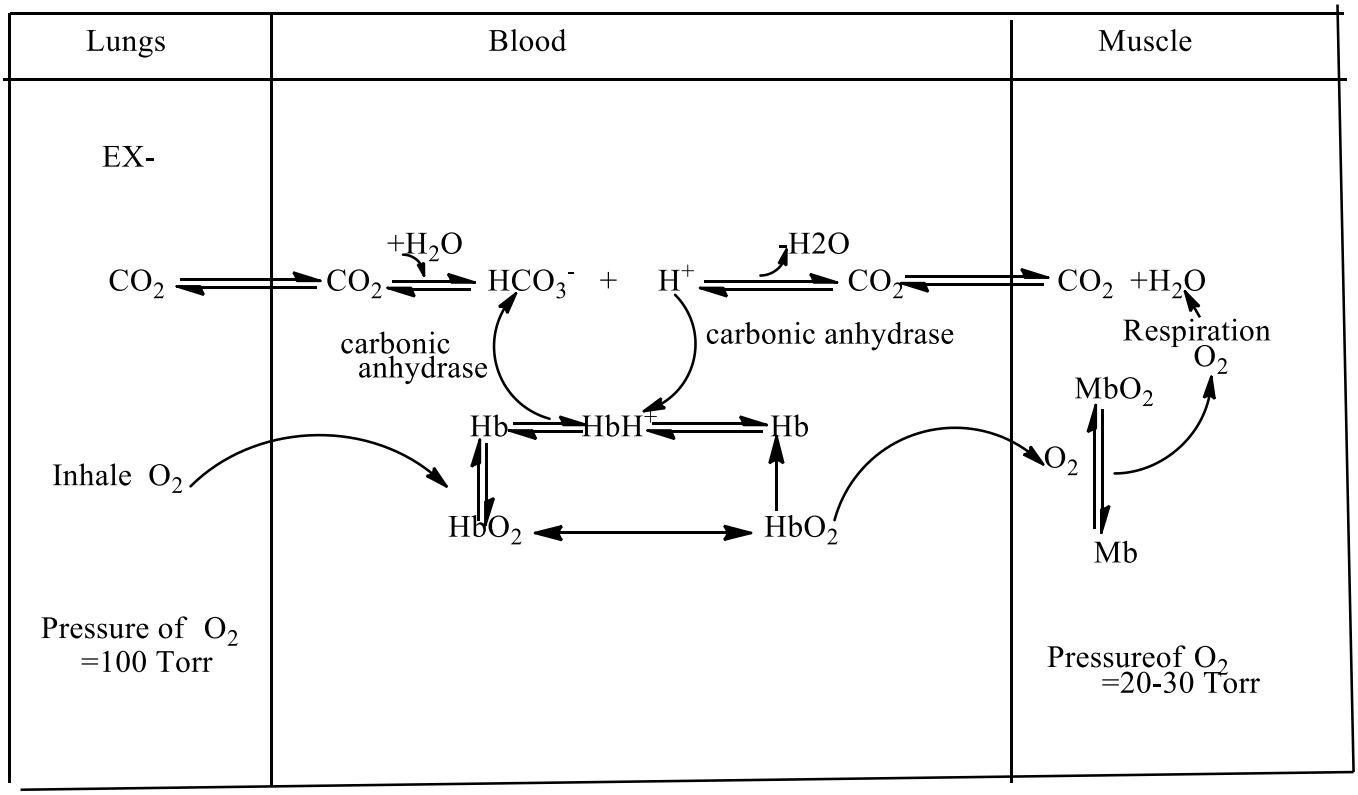


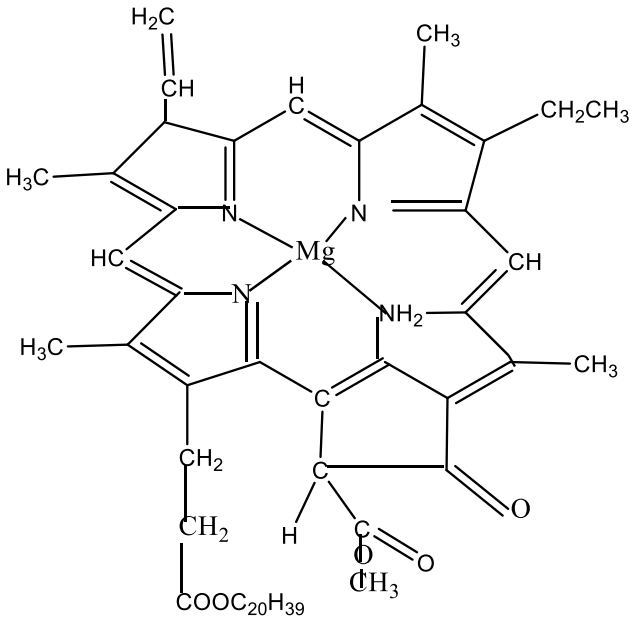
Fig-8

Photosynthesis

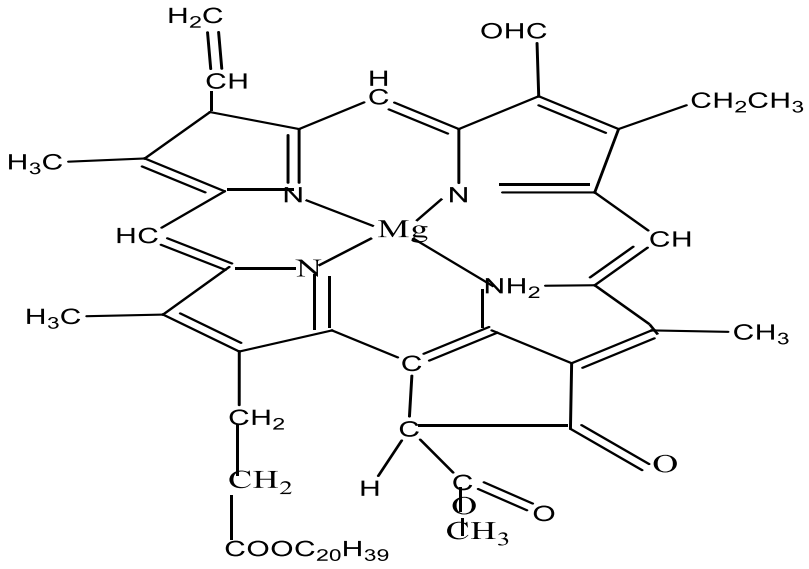
Photosynthsis is a biochemical reaction which takes place in presence of chlorophyll.The green plant synthsis their food i.e. glucose and evolve O_2 in presence of chlorophyll. Its reaction is given below:

$$6CO_2 + 6\,H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sun light}} C_6H_{12}O_6 + 6O_2$$

Structure of Chlorophyll



Structure of Chlorophyll-A



Structure of Chlorophyll -b Fig-10

Questions

1. Draw the structure of Hemoglobin and its role in biological system.

2. How Mayoglobin differ from Hemoglobin and describe its function in human system.

3. Explain the role of Magnesium in Chlorophyll and discuss the structures of chlorophyll a and chlorophyll b.

4. What are Metaloporphyrins.Dicusse Iron-metalloporphyrin in O_2 Career.

5. Shorts notes:

a.Na^+-K^+ Pump

b.Role of Ca inhuman body

c.Role of Iodine in Human body

6. What are essential trace element and discuss their role in biological system.

7. Give illustrated account of MetalloEnzymes.

8. What are MetalloEnzymes.Describe two MetaloEnzymes.

9. Explain mechanism of Oxy hemoglobin and de oxy hemoglobin in biological system.