COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH
UNIVERSITY GRANTS COMMISSION

CHEMICAL SCIENCES CODE:01

1.10. Bioinorganic chemistry

At a glance: Essential elements in biological systems, metalloproteins and metalloenzymes, metal deficiency and toxicity, nitrogen fixation, hemoglobin and myoglobin, Ionophores, photosynthesis.

Key Statement

Basic key statements: Distribution of the elements in the body (1.10.2), Biological functions of selected metal ions (1.10.3), Classification of elements according to the action in biological process (1.10.4), Application of metal for medicinal use (1.10.5), Deficiency and toxicity (1.10.7), Metalloenzymes (1.10.9), Name of the enzymes (1.10.10), Holoenzyme (1.10.12), Ionophores (1.10.19), Haemoglobin and myoglobin (1.10.21), Cooperative interaction (1.10.23), Porphyrins (1.10.25),

Standard key statements: Some metal dependent human system (1.10.6), Classification of enzymes (1.10.11), Prosthetic group (1.10.13), Carbonic anhydrase (1.10.15), Peroxidases (1.10.16), Carboxypeptidase (1.10.17), Cytochrome P-450 enzymes (1.10.18), Bohr effect (1.10.24), Nitrogen fixation (1.10.28)

Advance key statements: Photosynthesis (1.10.8), Some metal enzymes and their functions (1.10.14), Role of haemoglobin (Hb) and myoglobin(Mb) in biological system (1.10.22), Hemerythrin (1.10.27)

Key Facts

1.10.1. **Introduction:** Bioinorganic chemistry is the gate-way of inorganic chemistry and biochemistry. It describes the mutual relationship between give to subdisciplines, with focus upon the function of inorganic substances in living system, including the transport specification and eventually, mineralization of inorganic materials and including the use of inorganic in medicinal therapy and diagnosis. These substances are metal ions (K+, Ferrous and Ferric), composite ions (molybdate), inorganic molecules (CO, NO, O_3), coordination compounds (*cis*-platin and Carbonyltechnetium).

1.10.2. **Distribution of the elements in the body of an average healthy person (weighing 70 kg):**

Non metals	Distribution (kg)	Metals	Distribution (g)
O	45.5	Ca	1050
C	12.6	K	140
H	7	Na	105
N	2.1	Mg	35
P	0.7	Fe	4.2
		Zn	2.3
		Cu	0.11
		Mn	0.02
		Mo	0.005
		Co	0.003
		Cr	0.0014

1.10.3. Biological functions of selected metal ions:

Metal	Function
Na, K	Regulation of the osmotic pressure, membrane potential, enzyme activity, signalling, charge transfer.
Mg	Chlorophyll, anaerobic energy metabolism.
Zn	In the active centre of Hydrolases, carboanhydrase, alcohol dehydrogenase, syntheses; genetic transcription, stabilization of tertiary and quaternary structure of protein; repair enzymes.
Ca	Signalling, muscle contraction, enzyme regulation, charge carrier, blood clotting, gene regulation.
V,Mo,W,Mn,Fe,Ni,Cu	Active centres in electron transport enzymes, oxygenases, dismutases.
V,Mo	Nitrogen fixation, oxidase
Mn	Photosynthesis, structural, oxidase.
Fe,Cu	Oxygen transport and storage, electron transfer, oxidase.
Ni	Hydrogenase, hydrolase
Co	Synthases and isomerases (cobalamines e.g., Vitamin B-12) ; methylarion of inorganic.

1.10.4. According to the action in biological process and abundance of these elements can be classified in different categories.

- **Essential elements** (O, C, H, N, P, Na, K, Mg, Cl, Ca, S etc.): These are absolutely necessary for ruining the life processes.
- **Trace elements** (I, Fe, Cu, Zn, Mn, Co, Mo, F etc.): Trace elements are essentially required for life processes but exist in low concentration.
- **Non essential element** (Al, Sr, Ba, Sn etc.): Non-essential are not essential. If these are not present, other elements may serve their function.
- **Toxic element** (Cd, Pb, Hg etc.): These elements are those elements which disturb the natural functions of the biological system. They are not required in biological system.
- Medicinally important element (Li, Ba, Gd, Tc, Pt, Au, Sb, Bi etc)

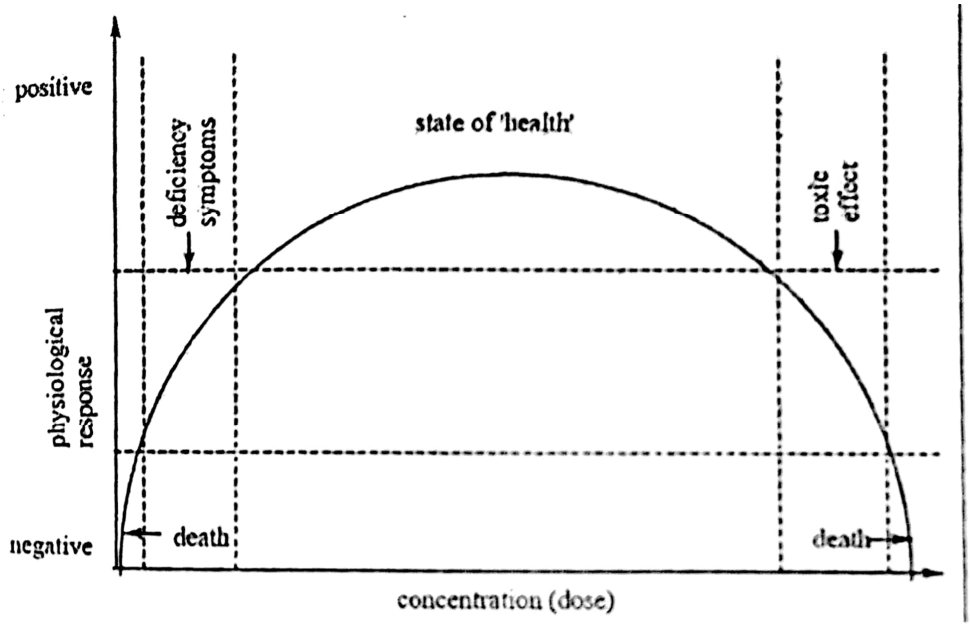
1.10.5. Application of metal for medicinal use:

Metals	Application
Pt	Anti cancer agent
Pt(II)	Chemotherapy of cancer (e.g., *cis*-platin)
Bi(III)	Treatment of gastritis.
Sb(II)	Treatment of inflammatory skin pimples like acne.
Au(I)	Therapy of rheumatic arthritis
$BaSO_4$	Contrast reagent for x-ray tomography, sun protection.
Gd^{3+}	Contrast agent in magnetic resonance tomography of soft tissue.
Li^{+}	Treatment of bipolar disorder and hypertension.
Cd	Carboanhydrase

1.10.6. Some metal dependent human system:

Human system	Metal disbalance	Diseases
Nerve	Na, K, Mg, Ca	Epilepsy, personality change
Muscular	Na, K, Fe	Myotenia
Cardiovascular, heart, blood	Mg, Ca, Na	Hypertension
Blood vessels	Na, K, Fe, Cu	Heart failure
Urinary	K, Mg, Ca	Renal insufficiency
Bone and skeleton	Ca, Mg	Osteoporosis
Digestive	Zn, Fe Cu	Liver cirrosis Wilson's disease

1.10.7. **Deficiency and toxicity:** Concentration of metal ions in body exist in find limit and this is controlled by several biological complexes. When concentration of metal ions falls more than lower limit, deficiency arise and causes health disorder. If concentration exceeds more than upper limit, toxicity happens. a better physiological response occurs when concentration of metal remains in confined limit.



1.10.8. **Photosynthesis:** Photosynthesis is the process by which plants, some protistants use the energy from sunlight to produce carbohydrates. This process takes place in the chloroplast, specially using chlorophyll, the green pigment involved in photosynthesis. CO_2 and H_2O are taken off from the air and soil respectively. Photosynthesis process is carried out by step to step.

i) Light reaction
ii) Light independent/ dark reaction.

Light reaction:

PSII: P680 + hν → b$[P680]^+$ + e^- (via phaeophytin, a chlorophyll depleted of Mg^{2+})

$2[P680]^+ + H_2O \rightarrow 2P680 + ½O^2 + 2H^+$ (catalyzed by water oxidase)

PSI: P700 +hν → $[P700]^+ + e^-$

$[P700]^+ + e^- \rightarrow P700$

$NADP^+ + 2e^- + 2H^+ \rightarrow NADPH + H^+$ (catalyzed by [2Fe, 2S])

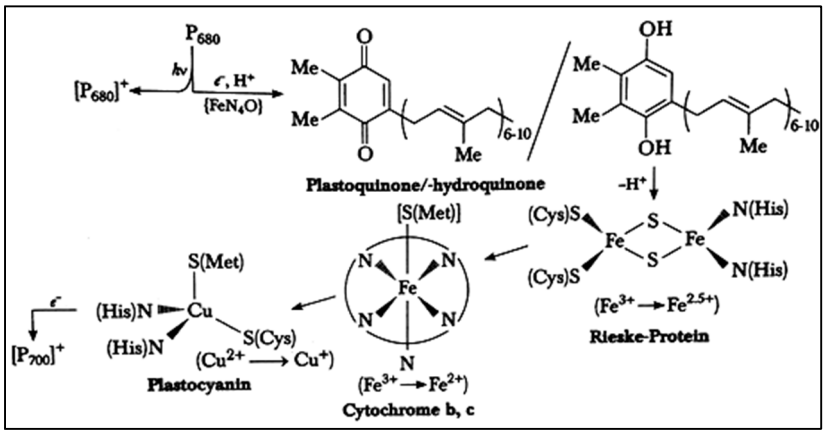
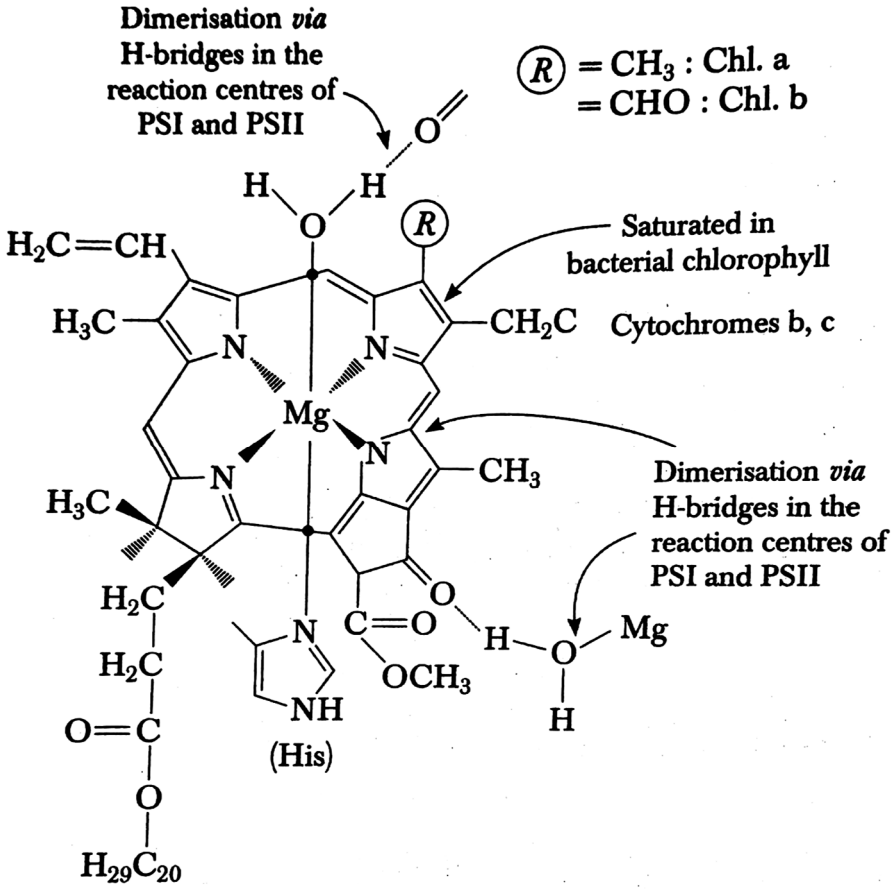


Fig: Simplified representation of the electron transport chain between PSII and PSI.

Dark reaction:

$2(NADPH + H^+) + CO_2 \rightarrow \{CH_2O\} + 2NADP^+ + H_2O$ (energy driven by ATP)

Structure of chlorophyll:



Metalloenzymes: Enzymes are biocatalysts synthesized by nature in living cells. There are very specific in their action. The enzymes which have a metal atom in their active site are known as metalloenzymes. These are involved in acid catalyzed hydrolytic reactions, redox reactions involving oxygenases and oxidizes, processes involving rearrangement of C-C linkages.

1.10.9. **Name of the enzymes:** The enzymes are named after the name of the substrate on which they act. For example, the enzyme that catalyzes the peptide hydrolysis is called peptidase, ferredoxin reduction is catalyzed by ferredoxin reductase.

1.10.10. **Classification of enzymes:**

Class	Function	Example
Oxidoreductases	Oxidation reduction	Alcohol dehydrogenase
Transferases	Transfer of functional group from one substrate to another.	Hexokinase
Hydrolases	Hydrolysis of peptide bonds, phosphate esters etc.	Lipase
Lyases	Addition or removal of H_2O, CO_2, NH_3 etc.	Aldolase
Isomerases	Interconversion of isomers.	Triose phosphate isomerase
Ligases	Bond formation coupled with breakdown of ATP.	Glutamine synthetase

1.10.11. **Holoenzyme:** The activity of a number of enzymes depends upon a non protein entity. Such enzymes are referred to as a ***holoenzyme*** which consists of an *apoenzyme* (protein part) and a coenzyme (non protein part). Holoenzyme = apoenzyme + coenzyme

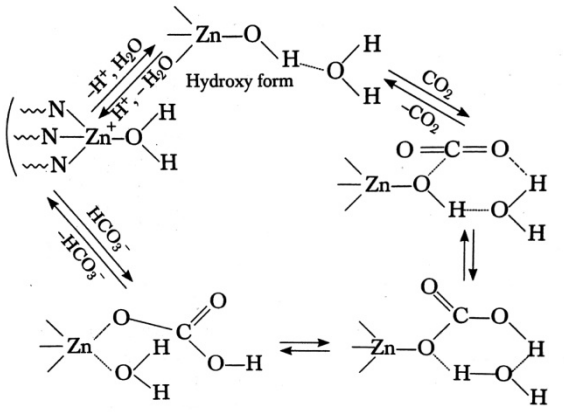
1.10.12. **Prosthetic group**: When the non-protein moiety is tightly bound to the apoenzyme, it is called a prosthetic group. By dialysis, one can strip the enzyme of its coenzyme but not of the prosthetic group. A loosely bound coenzyme is also called a **cofactor**.

1.10.13. **Some metal enzymes and their functions:**

Metal	Enzyme	Biological functions
Fe	Succinate dehydrogenase	Aerobic oxidation of carbohydrates
	Ribonucleotide reductase	DNA synthesis
	Catalase	Protection against H_2O_2
	Cytochrome P-450	Hydroxylation
	Oxygenases	Oxygen incorporation
Cu	Tyrosinase	Skin pigmentation
	Amine oxidase	Oxidation of amine
	Dopamine β hydroxylase	Hydroxylation of dopamine
	Laccase	Oxidation of diphenols to quinines
	Superoxide dismutase	Dismutation of superoxide
Zn	Carboxypeptidase	Protein digestion
	Carbonic anhydrase	Hydration of carbon dioxide and dehydration of carbonic acid
	Alcohol dehydrogenase	Alcohol metabolism
	Alkaline phosphatase	Phosphate hydrolysis
Mn	Arginase	Urea formation
	Pyruvate carboxylase	Pyruvate metabolism
	Oxaloacetate decarboxylase	Decarboxylation

Co	Ribonucleotide reductase	DNA biosynthesis
	Glutamate mutase	Amino acid metabolism
Mg	Hexokinase	Phosphate group transfer
Ca	ATP-ase	Hydrolysis of ATP
Ni	Urease	Urea hydrolysis
Fe and Cu	Cytochrome oxidase	Reduction of O_2 and H_2O
Fe and Mo	Nitrogenase	Nitrogen fixation

1.10.14. **Carbonic anhydrase:** It is a zinc enzyme that catalyzes the hydration of CO_2 and dehydration of carbonic acid (HCO_3^- to be more precise). The Lewis acidity of Zn^{2+} ion polarizes the coordinated H_2O molecule to the point of loss of H^+ ion to form coordinated OH group. It is the hydroxy form of the enzyme which is believed to reversibly hydrate CO_2 to HCO_3^-. the probable mechanism illustrating the role of the enzyme in the process is shown below:



The probable mechanism for reversible hydration of CO_2.

The clockwise cycle shows the hydration of CO_2 to HCO_3^-. The anticlockwise cycle shows the release of CO_2 from HCO_3^-.

1.10.15. Peroxidases:

- Peroxidases form a class of enzymes which catalyze the oxidation of substrates by H_2O_2.
- The heme group containing high spin Fe(III) is the prosthetic group present in peroxidases.
- The heme group of a peroxidase is lodged deeply in a larger protein molecule with histidine nitrogen coordinating to 5th position of Fe(III). The 6th coordination site of the peroxidase can be occupied by a water molecule when the enzyme is at rest or by the substrate when it is in function.
- The mechanism illustrating the role of the enzyme in the process is as follows:

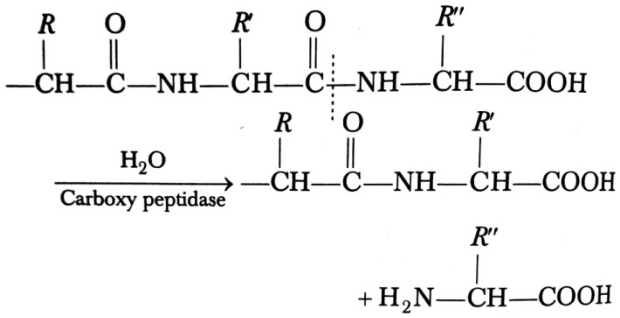
$$H_2O_2 + \underset{\text{Peroxidase enzyme}}{R\text{Fe}^{III}} \longrightarrow R^{\bullet+}\text{Fe}^{IV}{=}O + H_2O$$

$$R^{\bullet+}\text{Fe}^{IV}{=}O + \underset{\substack{\text{(Substrate containing}\\ \text{two removable}\\ \text{hydrogens)}}}{AH_2} \longrightarrow \underset{\text{(Oxidised substrate)}}{R\text{Fe}^{III}} + A + H_2O$$

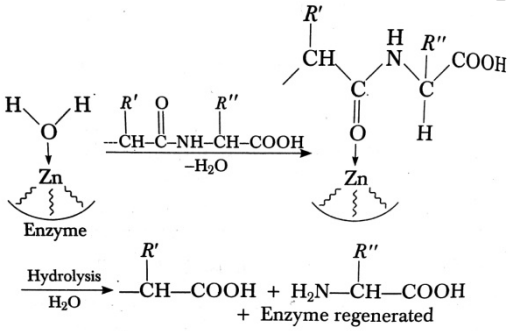
($R^{\bullet+}$ is the cation radical formed by the removal of a π electron from porphyrin part).

1.10.16. Carboxypeptidase:

- It is a Zinc enzyme which hydrolyses the terminal peptide Bond of the peptide chain from the height of its carboxy end as shown below:



- The enzyme is selective. It hydrolyzes those peptides in which the terminal amino acid segment has an aromatic or a branched chain aliphatic substituent R". The active Zn2+ iron is located in a depression formed on the surface of the coiled apoenzyme.

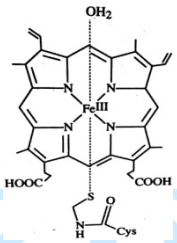


Mechanism for the hydrolysis of the peptide (amide) bond carried out by the enzyme carboxy peptidase.

- It has been established that the Zn^{2+} iron can be replaced by Co^{2+} ions with the retention of enzyme activity as the enzyme would show absorption bands in the visible region due to d-d transition from which valuable information about metal ion environment in the enzyme can be obtained.

1.10.17. Cytochrome P-450 enzymes:

- These are mononuclear heme enzymes which function as mono-oxygenases i.e., catalyzed reactions in which one O-atom of dioxygen is inserted into the substrate while the second O-atom is reduced to water:
  $RH + O_2 + 2H^+ + 2e \rightarrow ROH + H_2O$
- The CO-adducts of the enzyme have absorption band at 450nm and hence the name is Cytochrome P-450. They form a large family of enzymes catalyzing hydroxylation at C, S and N.
- The iron in the heme group of cytochrome P-450 is coordinated to the protein by cysteine sulphur group (Fe-S = 220 pm). The 6th position of the low spin Fe(III) is probably occupied by a molecule of water or hydroxide ion.



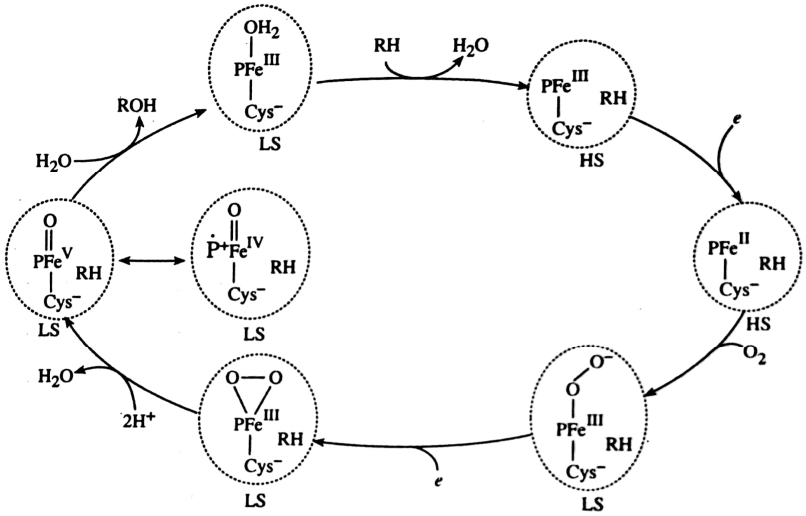
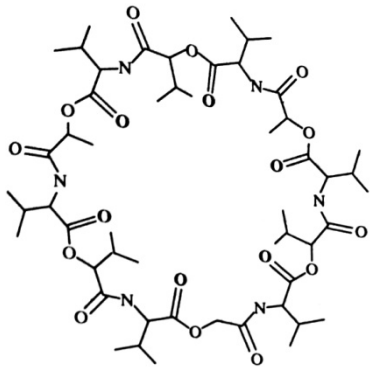


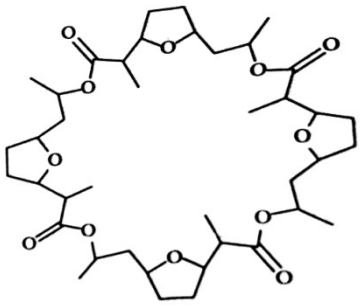
Fig: A likely catalytic cycle for cytochrome P-450. The protein environment is marked by dotted circle and P = Porphyrin.

1.10.18. **Ionophores:** Some naturally occurring molecules have the ability to encapsulate a metal ion from several coordination sites and at the same time provide a layer of organic groups outside the complex. Such ligands are known as Ionophores. Valinomycin and nonactin Irshad cycle proteins.
Valinomycin: It is a cycle protein with 12 peptides, has three repeated sequences L-valine-D-α-hydroxyvaleric acid-D-valine-L-lactic acid. The resulting 36 membered flexible macrocycle can adopt various geometries depending upon the polarity of surrounding medium and the presence or absence of a metal ion within its cavity.



Valinomycin

Nanoactin: It is another naturally occurring Ionophore which also resembles a crown ether- in fact it is a polyester.



Nonactin

1.10.19. **Oxygen carrying metalloproteins:** Nature has designed four O_2-carrying proteins for transport and storage of oxygen in biological systems. These are hemoglobin, myoglobin, hemerythrin and haemocyanin. Hemoglobin and myoglobin are Fe(II)-heme proteins, where as hemerythrin is non heme Fe(II) protein. On the other hand hemocyanin contents copper at its oxygen binding site.

1.10.20. **Haemoglobin and myoglobin:** There are two metalloproteins in vertebrates known as haemoglobin and myoglobin which are responsible for Oxygen uptake and transport. The time of hemoglobin picks up oxygen from lungs transports it and delivers it to myoglobin, which is present in tissues.

1.10.21. Role of haemoglobin (Hb) and myoglobin(Mb) in biological system: Hb and Mb are responsible for the transport and storage of oxygen in higher animals. Hb transport oxygen from its source (lungs, skin, gills) to the site inside the muscle cell, where O_2 is transferred to Mb for use metabolic action. Hb has a additional function, however and that is carry carbon dioxide back to the lungs, this is done by certain amino acids side chain and the heme groups are not directly involved.

Mb is a monomeric protein having molecular weight 17800g with the protein chain containing 153 amino acids residue folded about single heme group. On the other hand Hb is a tetrameric protein. It has a molecular weight 64500g and contents four heme groups bounds to four protein chains. Two of the chains leveled β, having 146 amino acids. These two protein chains are interlinked through the hydrogen bonded (COO^- …….NH_3^+) interaction. Due to this Salt bridge introduction, the peptide chain in deoxyhemoglobin is constrained. Form X-ray study show that there are no Salt bridge bonds on oxy-Hb structure.

The active sites of both Mb and Hb contain the heme group where Fe(II) is equatorially coordinated by the four pyrol-N-atom. The fifth position is coordinated by the history in protein chain (globin part). The 6^{th} position in deoxy-Hb or deoxy-Mb is vacant.

But, hydrophobically shielded by protein chains. As a result only non polar neutral molecules e.g., O_2, CO can bind to the 6th position. In the absence of the protein the 6th position is readily coordinated by polar water molecules and Fe(II) heme is irreversible oxidized by air oxygen to Fe(III)-heme called '**hematin'.** The later due to residual positive charge, is reluctant to bind uncharged ligand e.g., O_2, readily binds charged ligands e.g., OH^-, CN^-, S^{2-} etc. which inhibits oxygenation.

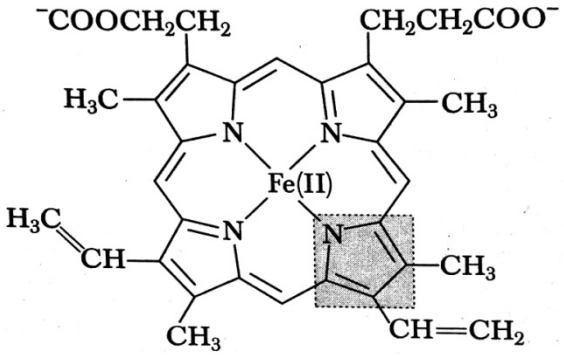
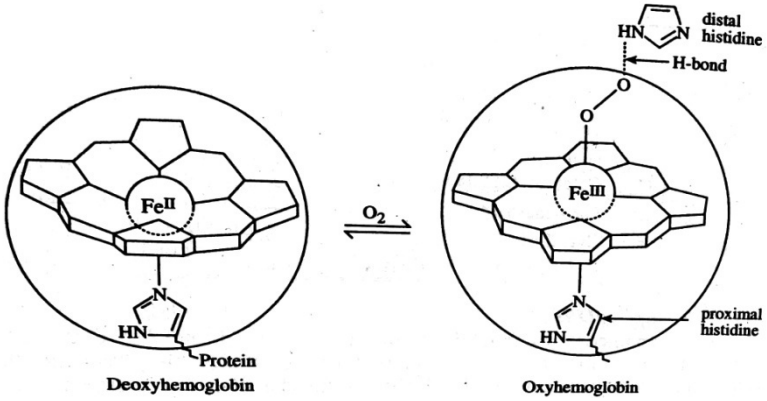


Fig: The heme group in Hb and Mb

(Globin) Fe(II)-heme + O_2 → (Globin) Fe(II)-heme-O_2

Fe(II)-heme + O_2 → Fe(III)-heme (hematin)

Being, 5 coordinated Fe(II) heme in deoxyhemoglobin, the metal ion present in high spin configuration, where the 'Fe(II)-N' Bond length in high spin Fe(II)-N compounds are 2.18 A°, which is much greater than the size of porphyrin cavity (2.05A°). So penta coordinated Fe(II) deoxyhemoglobin has a square pyramidal geometry and it is situated about 0.8A° out of the porphyrin plane. When oxygen binds to the Fe(II) heme at the vacant 6th position and resulting octahedral field is sufficiently strong to transform high Spin (0.92A°) to low spin (0.75A°). As a result Fe(II) sits on the cavity of the porphyrin. This movement of Fe(II) causes the coordinated histidine to move towards the porphyrin plane. This brings about conformational change throughout the peptide chain amounting to rupture of some Salt bridge interaction.



1.10.22. **Cooperative interaction:** Due to the movement of Fe(II) ion in oxygenation, the Salt bridge structure (COO^-.....NH_3^+) lost and the constrain Hb tetramer then relaxes by exposing the 6th position of the remaining heme groups towards oxygenation. This phenomenon is known as 'Cooperative interaction'.

Oxygenation of Hb is autocatalytic due to the cooperative introduction, but such effect is absent in Mb due to its monomeric nature. As one subunit of tetrameric Hb is oxygenated, Co operative interaction enhances another subunits to take up oxygen.

$Hb + O_2 \leftrightharpoons Hb(O_2)$……$k_1$

$Hb(O_2) + O_2 \leftrightharpoons Hb(O_2)_2$……$k_2$

$Hb(O_2)_2 + O_2 \leftrightharpoons Hb(O_2)_3$……...$k_3$

$Hb(O_2)_3 + O_2 \leftrightharpoons Hb(O_2)_4$……...$k_4$

As a result the successive rate constant of hemoglobin increases $k_1 < k_2 < k_3 < k_4$ instead of statistically expected order $k_1 > k_2 > k_3 > k_4$. The constant k_4 corresponds to the oxygenation of the relaxed Hb tetramer and it is quite close to the oxygenation binding constant of myoglobin where cooperative interaction is absent.

The partial pressure of O_2 in the lungs is about 100mm Hg and in the tissue is about 40 mm Hg. The reaction of O_2 with Hb and Mb are as follows

$Hb + 4O_2 \leftrightharpoons Hb(O_2)_4$

$Hb(O_2)_4 + 4Mb \leftrightharpoons 4Mb(O_2) + Hb$

The function of Hb is to bind oxygen in the lungs and to carry it without any loss and release it to myoglobin in the cellular tissues. This implies that myoglobin should have a greater affinity for oxygen at low partial pressure. Experimentally the oxygen saturation curves for Hb and Mb are as shown in the figure:

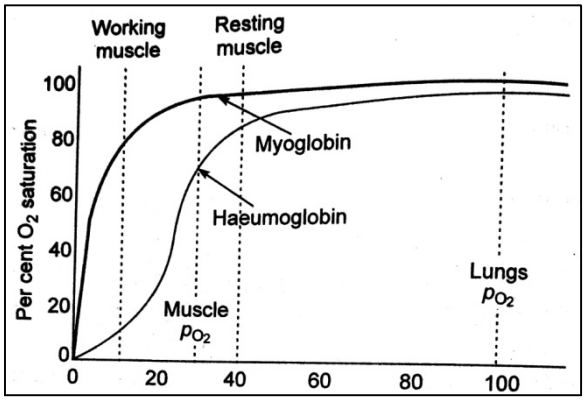


Fig: O_2 binding curve for Hb and Mb at different partial pressure.

The degree of saturation for myoglobin is higher than for hemoglobin at low partial pressure as shown by the comparison of the saturation curves for myoglobin and hemoglobin at various partial pressures.

The equilibrium constant for the myoglobin complexation is given by the simple equation expression

$$K = \frac{[Mb(O_2)]}{[Mb][O_2]}$$

If 'f' be the fraction of myoglobin complex with oxygen and 'p' be the partial pressure of O_2, then

$$K = \frac{f}{(1-f)p}$$

$$f = \frac{kp}{1+kp}$$

A plot of 'f' vs 'p' will give the curve for Mb as shown in the above figure. Mb is largely converted to oxy-myoglobin even at low oxygen concentration, such occurs in the cells. In general town the equation can be written as

$$\boxed{f = \frac{kp^n}{1 + kp^n}}$$

This is known as **Hill's equation**.

Equilibrium constant for the formation of oxy-hemoglobin is somewhat more complicated. The Hill's equation should be

$$K = \frac{[Hb(O_2)_4]}{[Hb][O_2]^{2.8}} \; and; \; f = \frac{kp^{2.8}}{1 + kp^{2.8}}$$

Here for Hb, the n is only 2.8(< 4.0) indicates that the f is not proportional to the partial pressure of oxygen. The value of the exponent less than 4 is an indication of cooperativity among the four subunits of hemoglobin. Hb is less oxygenated at low oxygen concentration and at high oxygen concentration hemoglobin is oxygenated to the same extent as myoglobin. The cooperative effect favours the oxygen transport since it helps the hemoglobin to be saturated in the lungs and deoxygenated in the muscles.

1.10.23. **Bohr effect:** Oxygenation of Hb is pH dependent. This phenomenon is known as Bohr effect. Due to the absence of cooperative interaction myoglobin oxygenation does not show Bohr effect. Oxygenation is favoured by Basic condition due to the elimination of (COO^-….NH_3^+) Salt bridge bonds. Deoxygenation is favoured in acidic condition:

$$\text{Deoxy - Hb} + O_2 \underset{\text{Acid}}{\overset{\text{Base}}{\rightleftharpoons}} \text{Oxy-Hb}$$

Hence, oxygen is released more rapidly in cells where metabolism is active and consequently high concentration of carbon dioxide resulting in low pH.

1.10.24. **Porphyrins:** Porphyrins are tetrapyrrole macrocycles with conjugated double bonds and various groups attached to the perimeter. The porphyrins can accept two hydrogen ions to form +2 diacids or donate two protons to form -2 dianions.

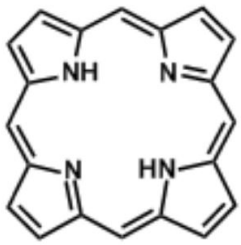


Fig: Porphyrin

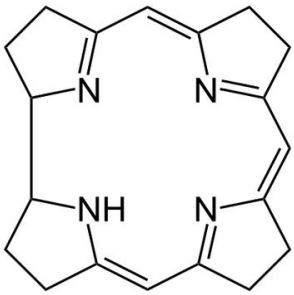
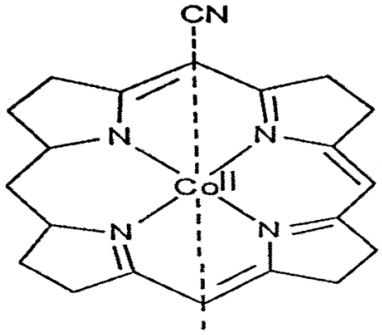


Fig: Corrin

- The porphyrin and corrin ring systems are of great biological importance. Four pyrrole units are linked by -CH= Bridges but in corrin ring one -CH= group is less .
- The corrin ring has 19 carbons, whereas Porphyrins have 20 carbons.
- The pyrrol like rings in corrin are fully saturated 'edge-carbon' centre whereas Porphyrins are highly conjugated.
- Because of the high number of carbon centre, corrin are more flexible than porphyrins and are not as flat.
- Porphyrins are aromatic in nature.
- These rings are intensity coloured.

Most importance of these rings in the bio system can be illustrated as:

- Iron complex of the substituted porphin is heme.
- When magnesium lies at the centre of substituted porphin ring, the resulting complex is called **chlorophyll**.
- If Cobalt is the central metal atom of substituted corrin ring system, it is called vitamin B_{12} (**cobalamine**).It is the well known naturally occurring organometallic compound. Cobalt is present in +3 oxidation state in vitamin B_{12}. It is only vitamin known that contain metal. Vitamin B_{12} is the only known essential biomolecule with stable metal carbon Bond.



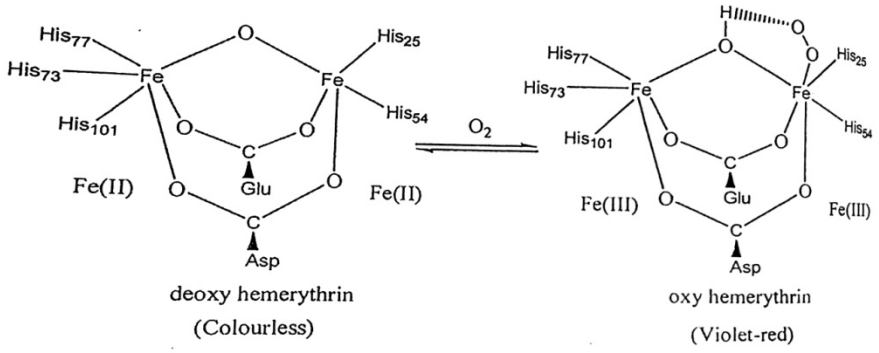
1.10.25. **Porphyrins are found in many metalloenzyme:**

	Enzyme	Function
Fe-porphyrin	Cytochrome	Electron transfer
Fe-porphyrin	Hemoglobin, Myoglobin	Dioxygen carrier
Mg-porphyrin	Chlorophyll	Photosynthesis

1.10.26. **Hemerythrin:**

- An oxygen uptake metalloprotein.
- Non heme Iron protein.
- Fe(II) oxidation State.
- It consists of 8 identical units each containing two iron atom.
- Its molecular weight is 108000.
- Deoxyhemerythrin is paramagnetic and high spin in nature.
- The environment of iron atom is pseudo octahedral.
- Antiferromagnetic coupling of to iron gives rise to diamagnetism of oxyhemerythrins at low temperature.

- The oxyhemerythrins has lower magnetic moment at room temperature. It becomes diamagnetic at 1400 K to 4200K.



1.10.27. **Nitrogen fixation:** It is biogenic and non-biogenic transformations of elemental N_2 into nitrogen compounds, affording to overcome the bonding energy between the two trebly bonded nitrogen atoms. The biogenic fixation carried out by free living nitrogen fixing bacteria and cyanobacteria, some archaea and by symbiotic bacteria associated with leguminous plants, leads to ammonium ions. Biogenic fixation accounts for about 60% of the overall nitrogen supply. Non-biogenic non-anthropogenic fixation, which can occur by electric discharge in the troposphere and by cosmic radiation in the stratosphere, accounts for 10%. The remaining 30% of worldwide N_2 fixation go back to the Haber-Bosch process and composition of fossil fuels and products produced from crude oil.

It essentially occurs in anaerobic conditions.

99% in the nitrogen fixing bacteria composed of proteins of two kinds i.e., reductase (Fe-S protien) and nitrogenase (Fe-Mo-S protien). Reductase supplies electrons which are used by the nitrogenase to reduce the nitrogen to NH_4^+. Destroy geometry of the reaction catalyzed by the nitrogenase complex is $N_2 + 6e + 12ATP \rightarrow 2NH_4^+ + 12ADP + 4H^+$

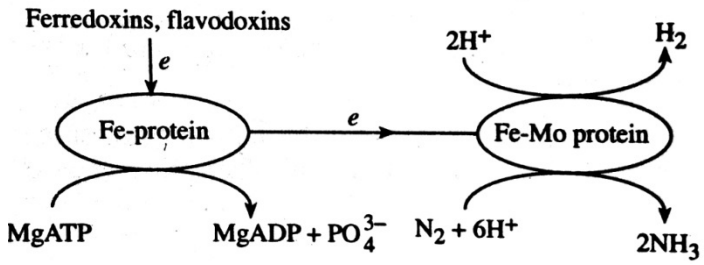
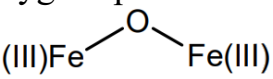
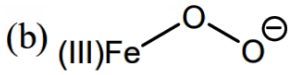


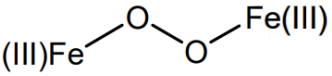
Fig: Nitrogen fixation (schematic).

NET JUNE 2016

Q. In the absence of bound globin chain, heme group on exposure to O2 gives the iron-oxygen species

(a) 

(b) 

(c) 

(d) Fe(IV) = O

Ans. Absence of globin chain following reaction is occur

$$PFe^{II} + O_2 \rightarrow PFe^{II} - O_2 + Fe^{II}P \rightarrow PFe^{III} - O - O - Fe^{III}P$$

$$\leftrightarrow 2PFe^{IV} = O \xrightarrow{PFe^{II}} PFe^{III} - O - Fe^{III}P$$

Correct option is (a).

Q. Correct combination of number and size of rings present in a metal ion-porphine complex (inlcuding metal ion bearing chelate rings) is

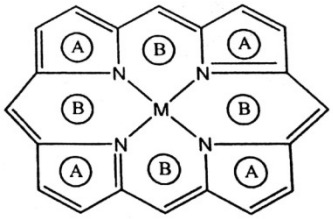
(a) four 5-membered and four 6-membered

(b) two 5-membered and six 6-membered

(c) six 5-membered and two 6-membered

(d) five 5-membered and three 6-membered

Ans. Structure of m-porphyrine complex can be shown as



Here (A) represents 5 membered ring

(B) represents 6 membered ring

Correct option is (a).

Q. In human body cis-platin hydrolyzes to diaqua complex and modifies the DNA structure by binding to

(a) N-atom of guanine base

(b) O-atom of cytosine base

(c) N-atom of adenine base

(d) O-atom of thymine base

Ans. Cis-platin modifies the DNA structure by binding to N-7 nitrogen atom of guanine base.

$cis\text{-}[Pt(NH_3)_2Cl_2] + H_2O \leftrightharpoons cis\text{-}[Pt(NH_3)_2Cl(H_2O)] + Cl^-$

$\rightarrow cis\text{-}[Pt(NH_3)_2Cl]\text{-}N(DNA) \leftrightharpoons cis\text{-}[Pt(NH_3)_2(H_2O)\text{-}N(DNA)]$

$\rightarrow cis\text{-}[Pt(NH_3)_2]{=}N(DNA)$

Correct option is (a).

NET DEC 2016

Q. In the catalytic hydration of CO_2 by carbonic anhydrase, CO_2 first interacts with

(a) OH group of the active site of the enzyme and then with zinc

(b) H_2O of the active site of the enzyme and then with zinc

(c) zinc of the active site of the enzyme and then with OH group

(d) zinc of the active site of the enzyme and then with H_2O

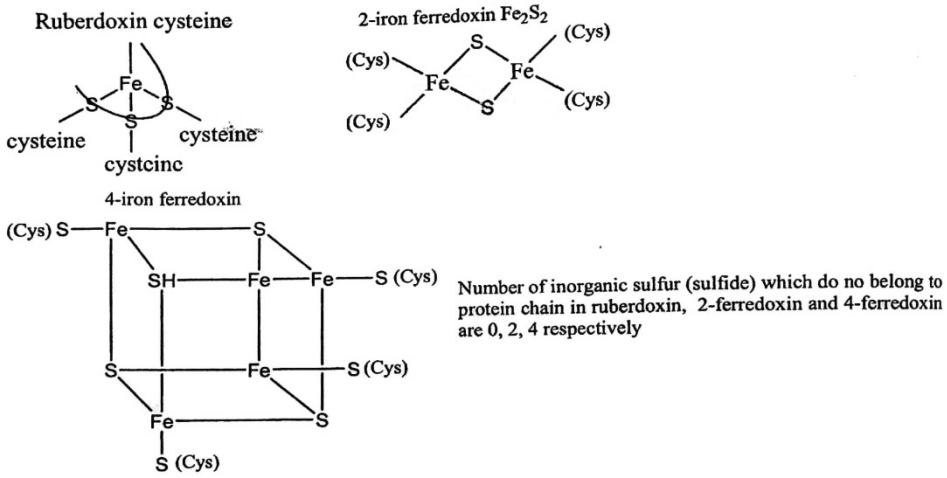
Ans. In carbonic anhydrase OH group first attack on CO_2 and then CO_2 interact with Zn.

Correct option is (a).

Q. The number of inorganic sulphur (or sulphide) atoms present in the metalloprotein active sites of rubredoxin, 2-iron ferredoxin and 4-iron ferredoxin, respectively, are

(a) 0, 2 and 4 (b) 2, 4 and 3 (c) 0, 4 and 2 (d) 0, 2 and 3

Ans.



Number of inorganic sulfur (sulfide) which do no belong to protein chain in ruberdoxin, 2-ferredoxin and 4-ferredoxin are 0, 2, 4 respectively

Correct option is (a).

Q. From the following transformations,

A. Epoxidation of alkene

B. Diol dehydrase reaction

C. Conversion of ribonucleotide-to-deoxyribonucleotide

D. 1, 2-carbon shift in organic substrates

those promoted by coenzyme B12 are

(a) A and B (b) B, C and D (c) A, B and D (d) A, B and C

Ans. Co-enzyme B_{12} catalyzes dehydration, 1,2-carbon shift reaction.

Correct option is (b)

Q. Match the items in column A with the appropriate items in column B

Column A		Column B	
(A)	Metallothioneins	(i)	cis-$[Pt(NH_3)_2Cl_2]$
(B)	Plastocyanin	(ii)	Cystein rich protein
(C)	Ferritin	(iii)	Electron transfer
(D)	Chemotherapy	(iv)	Iron transfer
		(v)	Iron storage
		(vi)	Carboplatin

The correct answer is

(a) (A) – (ii); (B) – (iii); (C) – (v); (D) – (iv)

(b) (A) – (ii); (B) – (iii); (C) – (iv); (D) – (i)

(c) (A) – (ii); (B) – (iii); (C) – (v); (D) – (vi)

(d) (A) – (iii); (B) – (v); (C) – (vi); (D) – (ii)

Ans.

Column A		Column B	
(A)	Metallothioneins	(ii)	Cystein rich protein
(B)	Plastocyanin	(iii)	Electron transfer
(C)	Ferritin	(v)	Iron storage
(D)	Chemotherapy	(vi)	Carboplatin

Correct option is (c)

NET JUNE 2017

Q. The resonance Raman stretching frequencies (in cm^{-1}) of the bound O_2 species in oxy-hemerthyrin and oxy-hemoglobin, respectively, are

(a) ~850 and 1100 (b) ~750 and 850 (c) ~850 and 850 (d) ~1100 and 850

Ans. In oxyhemerythrin $\nu_{O-O} = 850cm^{-1}$

In oxyhemoglobin $\nu_{O-O} = 1100cm^{-1}$

Correct option is (a).

Q. In vitro reaction of an excess of O_2 with free heme B in aqueous medium the end product is

(a) hematin (b) [O_2^- –Fe(III)-protoporphyrin-IX]

(c) heme B(O_2) (d) oxoferrylprotoporphyrin-IX cation radical

Ans.

$$PFe^{II} + O_2 \rightarrow PFe^{II} - O_2 + Fe^{II}P \rightarrow PFe^{III} - O - O - Fe^{III}P$$

$$\leftrightarrow 2PFe^{IV} = O \xrightarrow{PFe^{II}} PFe^{III} - O - Fe^{III}P$$

Correct option is (a).

Q. Consider the following statements for deoxy-hemerythrin and deoxy-hemocyanin:

A. they are involved in O_2 transport in biological systems

B. they contain two metal ions in their active site

C. active site metal centres are bridged by amino acid residues

D. they prefer to bind only one O_2 per active site

The correct statements are

(a) A, B and D (b) A, C and D (c) B, C and D (d) A and C

Ans. Both deoxyhemerythrin and deoxy hemocynanin are O_2 transport protein in biological system. Both contain two metal ion at active site and they bind only O_2 per active site.

Correct option is (a).

NET DEC 2017

Q. The correct statement for cytochrome-C is,

(a) It is a non-heme protein

(b) The coordination number of iron in cytochrome-C is five.

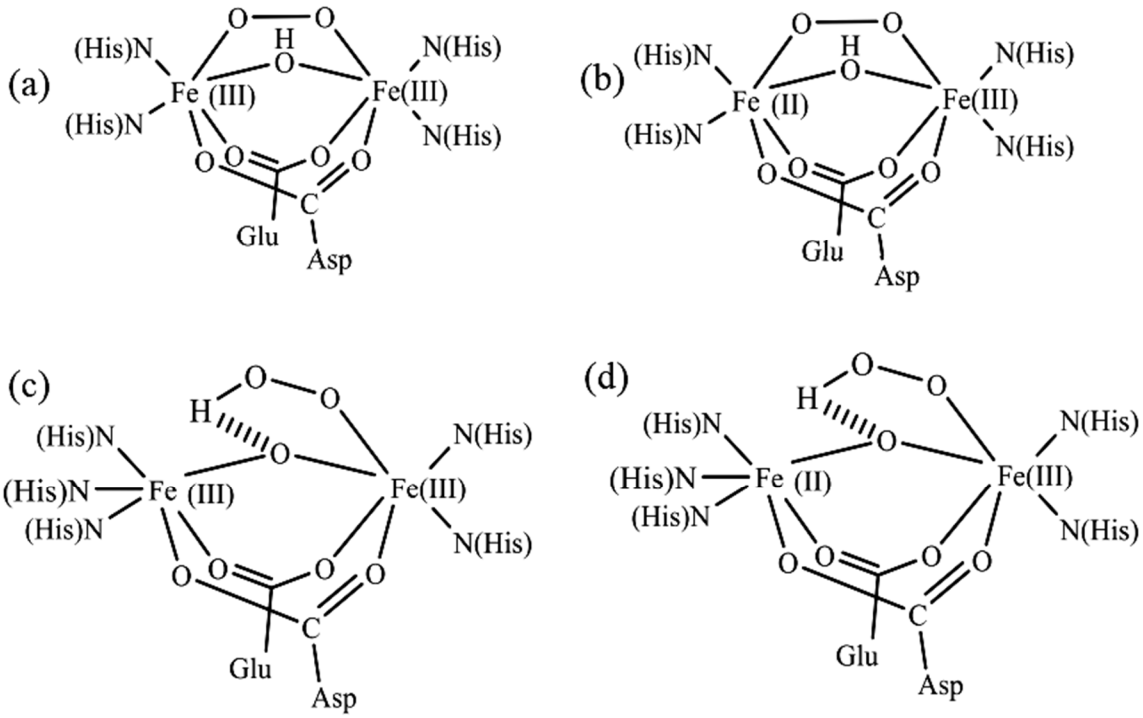
(c) It is a redox protein and an electron carrier

(d) It can store or carry dioxygen

Ans. Cytochrome-C shows redox reaction and it is an essential component of electron transport chain, whereas it is carriers of one electron and does not bind oxygen.

Correct option is (c).

Q. The active site structure for oxy- hemerythrin is:



Ans. In oxyhemerythrin, both the Fe are present as Fe(III) and there is presence of H-bonding and dioxygen bind to only one Fe.

Correct option is (c).

Q. The number of inorganic sulfides in cubane like ferredoxin and their removal method, respectively, are,

(a) Eight and washing with an acid (b) Four and washing with a base

(c) Eight and washing with a base (d) Four and washing with an acid

Ans. Cubane like ferredoxin is Fe_4S_4.

It has four inorganic sulfide which can be removed by the treatment with acid.

Correct option is (d).

NET JUNE 2018

Q. For the catalytic activity of Cu and Zn containing enzyme, superoxide dismutase, what is /are the correct statement (S)?

(A) Cu and Zn both are essential

(B) Only Cu is essential

(C) Zu is essential and Cu may be replaced by any other divalent metal atom

(D) Zn may be replaced by any other divalent metal atom

(a) (A) only (b) (C) Only (c) (D) Only (d) (B) and (D)

Ans. The Cu^{+2} ion is essential that cannot be replaced by other metal atom while retaining activity. On other hand, the Zn^{+2} ion can be replaced by other divalent metals such as Co or Cd with retention of most of the activity.

Correct option is (d)

Q. Consider the following statements for the oxygenation of hemocyanine:

(A) Oxidation state of both copper atoms changes by two

(B) It becomes intense blue from colorless

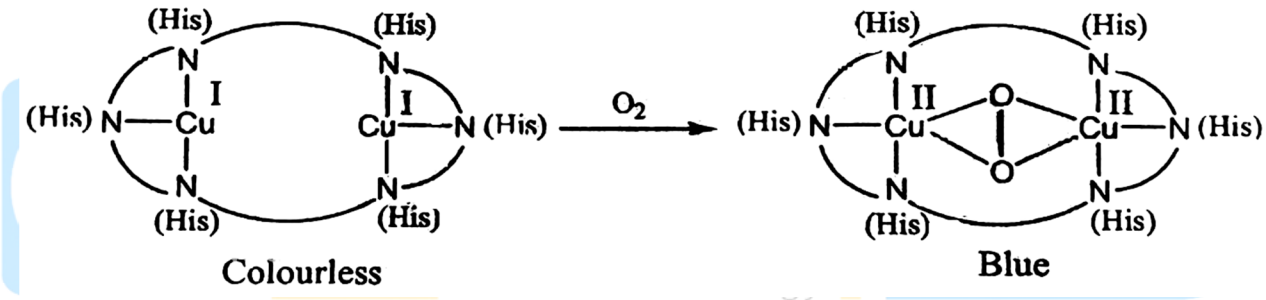
(C) Dioxygen is reduced to O_2^{2-} .

(D)The $\mu-\eta^2:\eta^2$ bond forms between each oxygen and copper atoms.

The correct statements are:

(a) (A) and (C) (b) (B) and (C) (c) (A),(B) and (C) (d) (B),(C) and (D)

Ans.



Correct option is (d).