Chapter 8

Elemental Chemistry in Biological System

1. INTRODUCTION: Bio-inorganic chemistry is a field that examines the role of metals in biology. It is the gateway of inorganic chemistry and biochemistry, i.e., it describes the mutual relationship between these two sub-disciplines, with focus upon the function of inorganic substances in living systems, including the transport, speciation and eventually, mineralisation of inorganic materials, and including the use of inorganics in medicinal therapy and diagnosis. These substances can be metal ions, composite ions, coordination compounds or inorganic molecules:

OR

Bio-inorganic chemistry is a multi-disciplinary field which draws on expertise in biochemistry, chemistry, crystallography, genetics, medicine, microbiology together with the effective application of advanced physical methods.

2. CLASSIFICATION OF ELEMENTS ACCORDING TO THEIR ACTION IN THE BIOLOGICAL SYSTEM:

Of the 100 plus known elements, two to three dozen can be found in most organisms. Most are found in trace amounts, but five are found bulk amounts, carbon, hydrogen, oxygen, nitrogen and phosphorus.

Carbon is in every organic compound. It forms the backbone of carbohydrates, proteins, lipids and nucleic acids such as DNA. Carbon's unique ability to form four stable bonds means it can form more molecular structures than any other atom.

Hydrogen and oxygen, bound as water, play an essential role in living cells. Water is the primary solvent in which organic molecules are sustained in cells. Most biochemical reactions occur in the watery, or aqueous, phase. Hydrogen and oxygen also play vital roles in producing energy in most cells.

Carbon, hydrogen and oxygen are abundant in living matter; nitrogen and phosphorus are more rare. Every protein has nitrogen in its molecular backbone. Phosphorus plays a key role in the energy and information systems of the cell.

Consider the content of the elements in the body of an average healthy person (weighing 70 kg). It has been established that out of 70 kg man's weight

Non-Metals Distribution

O	45.5 kg
C	12.6 kg
H	7.0 kg
N	2.1 kg
P	0.7 kg

Metals Distribution

Ca	1050 gm
K	140 gm
Na	105 gm
Mg	35 gm
Fe	4.2 gm
Zn	2.3 gm
Cu	0.11 gm
Mn	0.02 gm
Mo	0.005 gm
Co	0.003 gm
Cr	0.0014 gm

Data shows that abundance of Cu, Mn, Mo, Co, Cr etc metals is < 1.0 gm but those are highly significant for biological system. This partial data helps to predict the order of abundance of metal ions in human body. It is showing a qualitative correlation with order of natural abundance of metals in geochemical distribution and seems that life evolved utilizing only those elements which are readily occur in earth crust.

Biological functions of selected metal ions

Metal	Function
Na, K	Charge carrier, osmotic balance
Mg, Zn	Structural, hydrolase, isomerase
Ca	Structural, charge carrier, blood clotting, gene regulation
V, Mo	Nitrogen fixation, oxidase
Mn	Photosynthesis, structural, oxidase
Fe, Cu	Di-oxygen transport and storage, electron transfer, oxidase
Ni	Hydrogenase, hydrolase

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

1. Essential (O, C, H, N, P, Na, K, Mg, Cl, Ca, S etc.)
2. Trace (I, Fe, Cu, Zn, Mn, Co, Mo, F etc.)
3. Non-Essential (Al, Sr, Ba, Sn etc.)
4. Toxic (Cd, Pb, Hg etc.)
5. Medicinally important element (Li, Ba, Gd, Tc, Pt, Au, Sb, Bi)

- Essential elements are absolutely necessary for running the life processes.
- Trace elements are also essentially required for life processes but exists in low concentrations.
- Non-essential elements are not essential. If they are not present, other elements may serve their function.
- Toxic elements are those elements which disturb the natural functions of the biological system. They are not required in biological system.

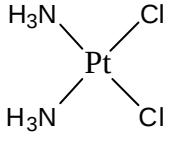
Some metal dependent human systems.

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
Digestive (stomouch liver)	Zn, Fe	Liver cirrosis
	Cu	Wilson's disease
Urinary	K, Mg, Ca	Renal insufficiency
Bone and skeleten	Ca, Mg	Osteoporosis.

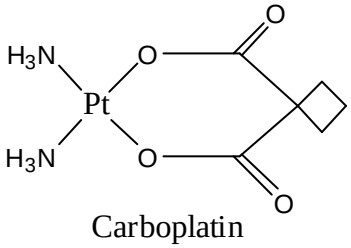
Application of Metal for Medicinal use:

Pt – Anti cancer agent.

Pt (II) complexes are most widely used for the treatment of cancer (cis-platin).



Cisplatin

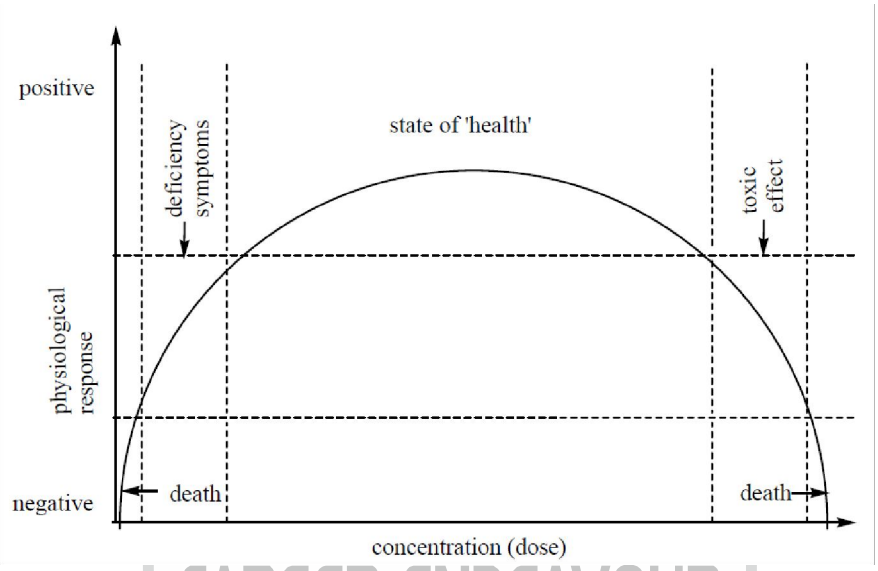


Carboplatin

Metals	Applications
Li^+	Treatment of depression
Gd^{3+}	Contrast agent (NMR)
$BaSO_4$	Contrast agent (radiography)
Tc	Radio diagnostic (Thyroid)
Au(I)	Rhemation
Sb(III)	EC Zema
Bi(III)	Gastric ulcer
Cd	Carbo anhydrase

3. DEFICIENCY AND TOXICITY:

Concentration of metal ions in body exists in fine limit and this is controlled by several biological complexes. When concentration 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 metals remains in confined limit.



Descriptive study of some common metals in biological system:

Calcium:

- About 99% of Ca exists in human body as phosphates resembling the mineral hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$ in bones and teeth.
- Remaining amount found in cellular fluids, existing in partly ionized, or in protein bound forms.
- Deficiency causes thinning and weakening of the bones, osteoporosis and hypocalcaemia.
- Excess of Ca leads to the formation of stones, hardening of arteries, and cataracts in the eye.
- Important for blood clotting.

Magnesium:

- Chlorophyll pigment in plants is a complex of Mg with porphyrin. It has good ability as a +2 cation to form octahedral geometry and can stabilize a structure without promoting energy loss by fluorescence.
- All enzymatic reaction in animals and human body are catalyzed by ATP. Mg acts as a cofactor for ATP.
- Number of biological process such as oxidative phosphorylation, DNA transcription, RNA function, protein synthesis and critical cell membrane functions are all require optimal concentrations of Mg.
- About 99% Mg in human body exits in intracellular region and bones.