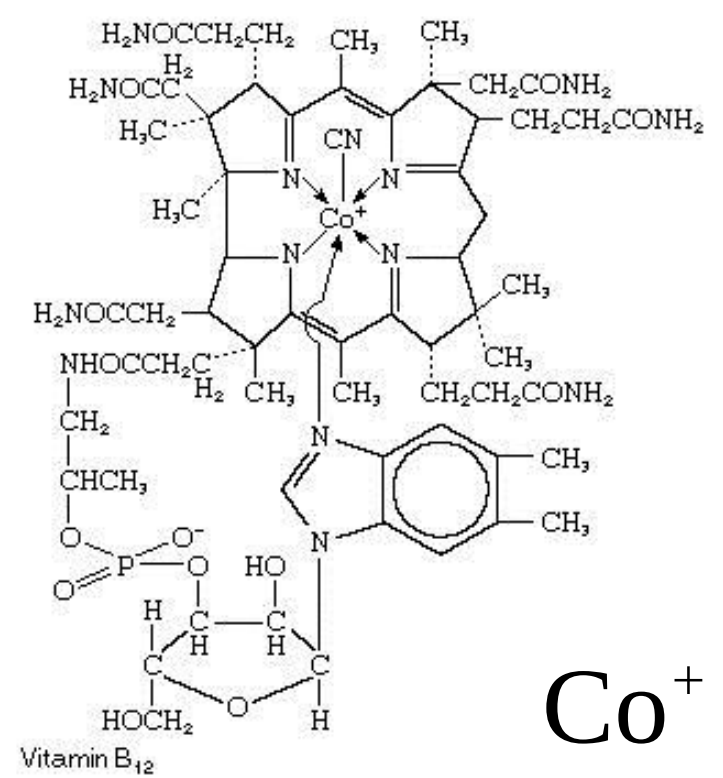
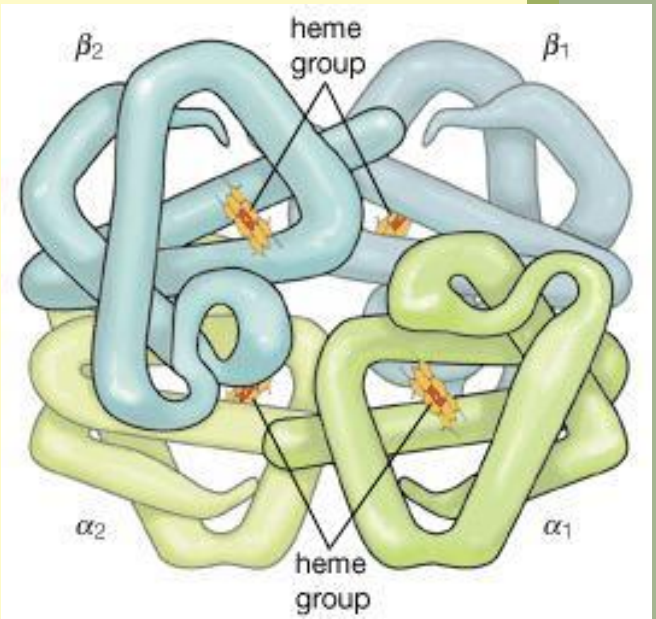
Coordination compounds.

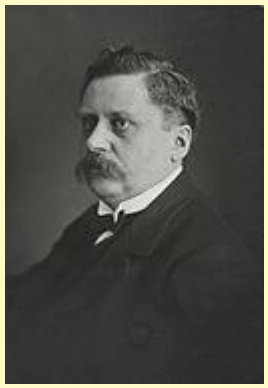
Naturally occurring coordination compounds are vital to living organisms. Metal complexes play a variety of important roles in biological systems.





1 What compounds are called coordination compounds ?

- What is structure of coordination compounds?

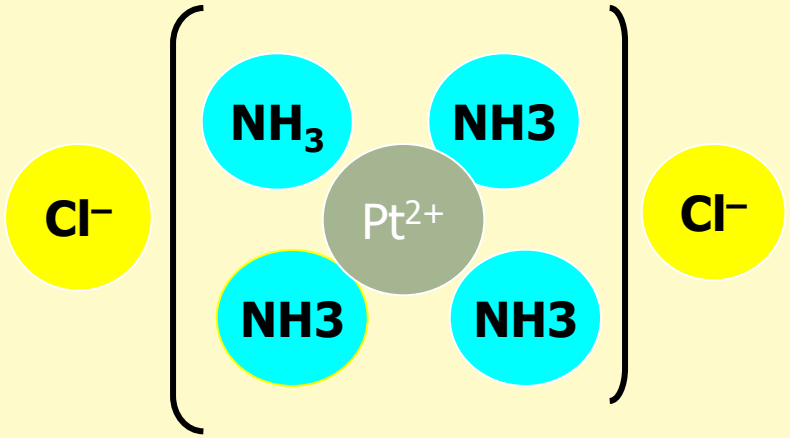


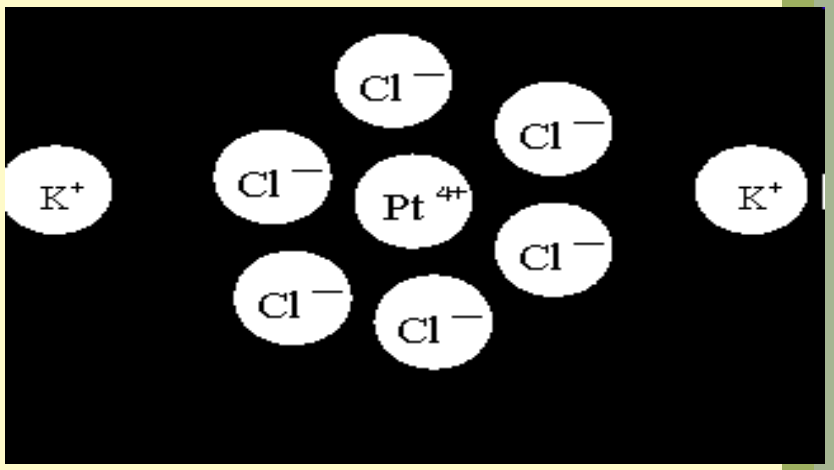
Austrian chemist Alfred Werner developed for the First time the theory and a model of coordination Compounds at the beginning of XX century.

$$K_3[Fe(CN)_6], KCN, [Co(NH_3)_6]Cl_3$$

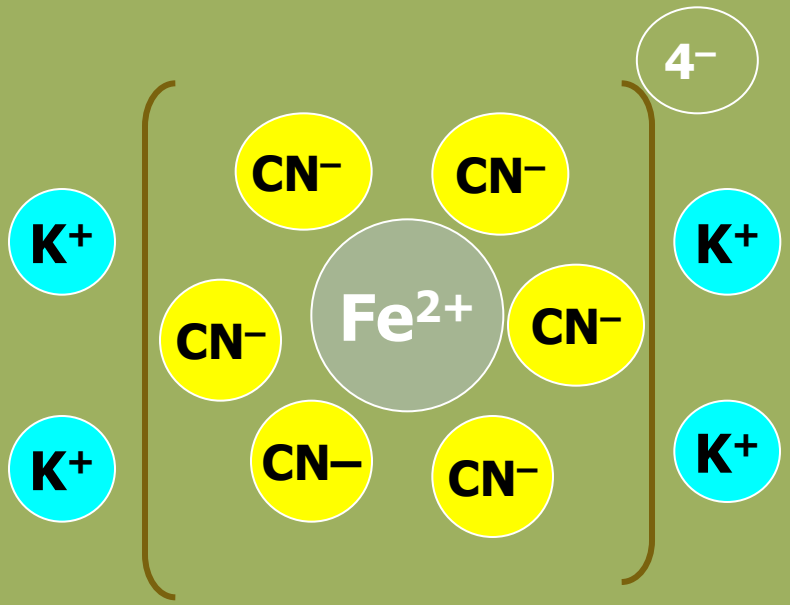
$$Fe(CN)_3, NH_3, [Cu(NH_3)_4]SO_4$$

Coordination compounds (complex) are compounds which contain complex ions.





STRUCTURE OF COORDINATION COMPOUNDS



$K_4[Fe(CN)_6]$

- 1. Coordination compounds consist of inner coordination sphere (complex ion) and outer coordination sphere .
- 2 . Complex ion consist of a central ion and ligands.
- 3. The charge of the complex ion = the sum of the charge of the central ion and the charge of the ligands.

As a rule, central ion is d-elements (Cu, Zn, Fe, Co, Ni, Pt, Ag…
But f, p, s elements also can be central ion in the coordination compounds.

Coordination number – the number of ligands bound to the central ion.

$[Fe(CO)_5]$;
$[Pb(H_2O)_4](NO_3)_2$;
$[PtCl_2(NH_3)_2]$

Often Coordination number = oxidation number of the central ion x 2.

$$Ag^{+1} \rightarrow 2, \quad Fe^{+2} \rightarrow 4(6), Al^{+3} \rightarrow 6,$$

Central ion forms bound with ligands.
Ligands can be presented both molecules

$H_2O,\ NH_3, CO, NH_2-CH_2-CH_2-NH_2$

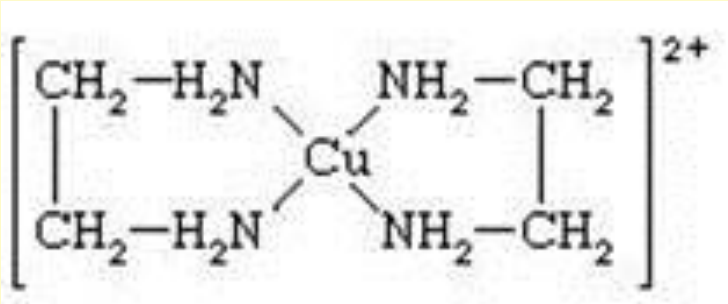
and ions $OH^-,\ CN^-, Cl^-$

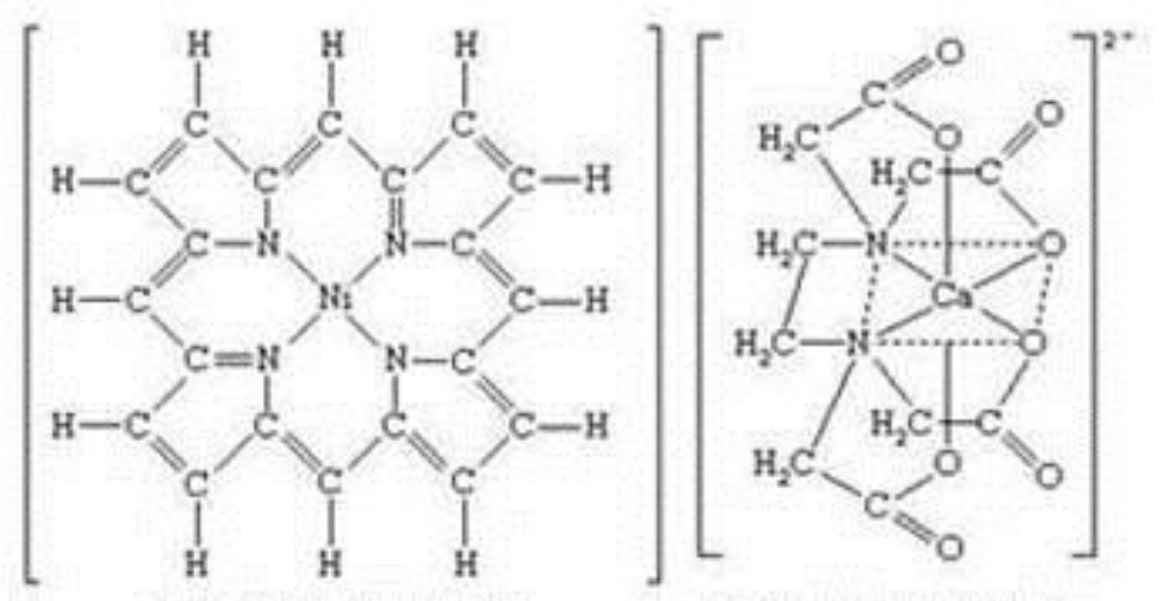
If ligands can forms 1 bound with central Ion, they are called monodentate, 2 bound- didentate, In general, ligands forms more than 1 bond are said to be polydentate. Because a polydentate ligand is joined to the metal atom in more than one place, the resulting complex is said to be cyclic —i.e., to contain a ring of atoms.

and the structural formula is

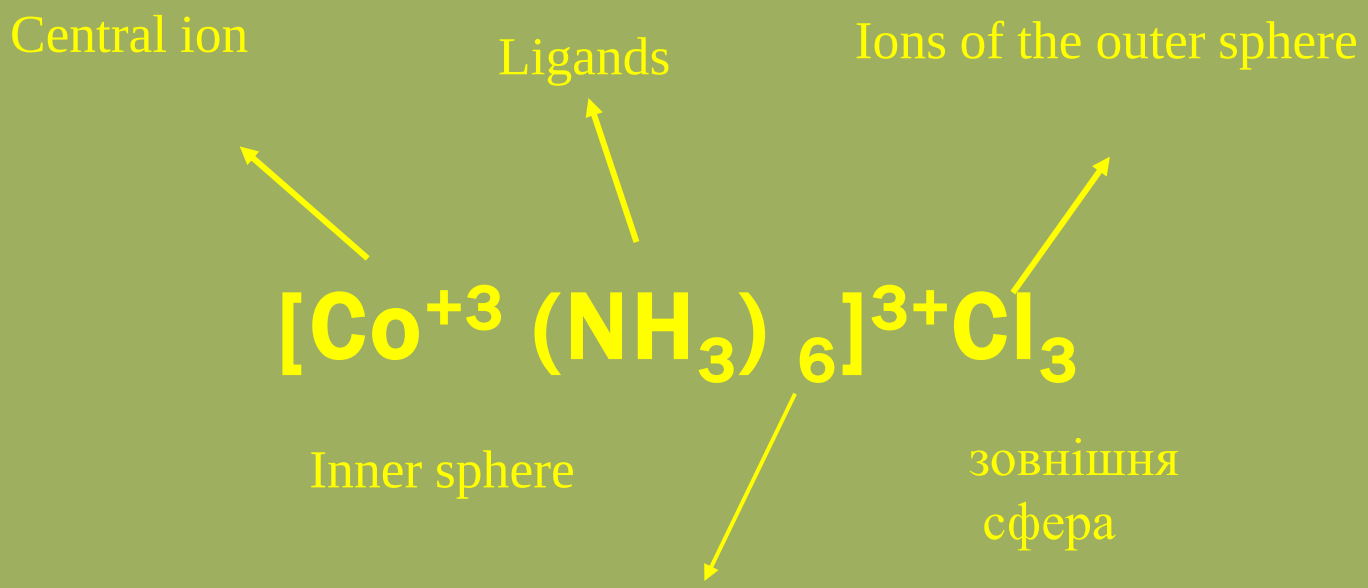
Coordination compounds containing polydentate ligands are called chelates (from Greek *chele*, "claw"), and their formation is termed *chelation*. Chelates are particularly stable and useful.

An example of a typical chelate is bis(1,2-ethanediamine)copper(2+)





These are a nickel complex with a tetradentate large-ring ligand, known as a porphyrin, and a calcium complex with a hexadentate ligand, ethylenediaminetetraacetate (EDTA). Because metal-ligand attachment in such chelate complexes is through several bonds, such complexes tend to be very stable.


Central ion
Ligands
Ions of the outer sphere
$[Co^{+3}(NH_3)_6]^{3+}Cl_3$
Inner sphere
зовнішня сфера
Coordination number
(= subscript of the monodentate ligands)

Chemical bound between central ion and ligands=coordination bound

A coordinate bond may also be denoted by an arrow pointing from the donor to the acceptor.

$K_4[FE(CN)_6]$

Chemical bound between ions inner sphere and ions outer sphere=ionic

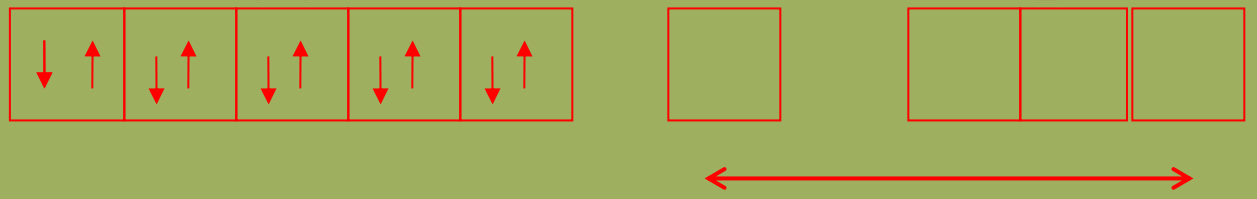
$K_4[Fe(CN)_6] \rightarrow 4K^+ + [Fe(CN)_6]^{4-} \rightleftharpoons Fe^{2+} + 6CN^-$

$ZN^0 : 3D^{10}\ 4S^2 4P^0$

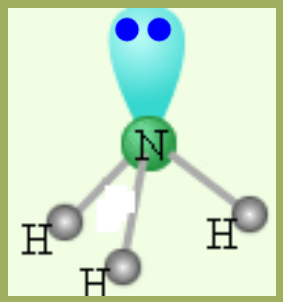
$ZN^{2+}: 3D^{10}\ 4S^0 4P^0$

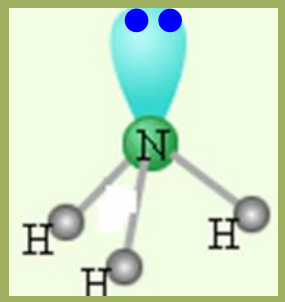
$[\ Zn\ (NH_3)_4]^{2+}$

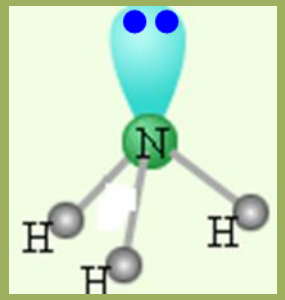
Zn^{2+}:

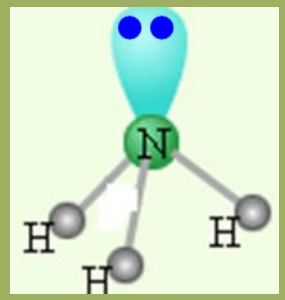


sp^3 - hybridization

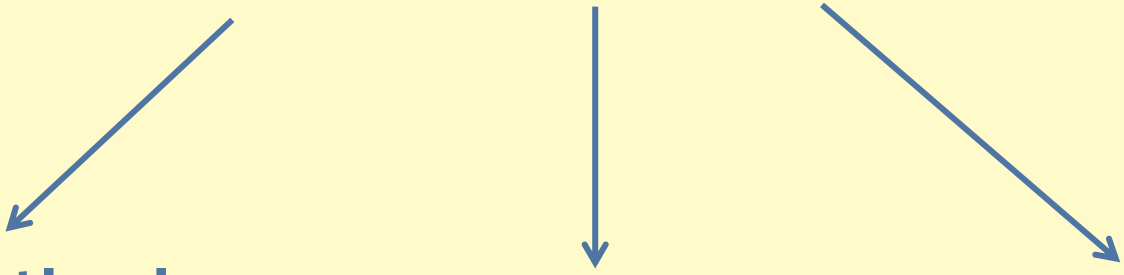








Classification of coordination compounds



cationic

$[Cu(NH_3)_4]SO_4$

anionic

$K_3[Al(OH)_6]$

neutral

$Fe(CO)_5$

Rules for naming coordination compounds

The coordination compounds are named in the following way.

A. To name a coordination compound, no matter whether the complex ion is the cation or the anion, **always name the cation before the anion**. (This is just like naming an ionic compound.)
B. In naming the complex ion:

1. **Name the ligands first, in alphabetical order, then the metal atom or ion. Note:** The **metal atom or ion** is written **before** the **ligands** in the **chemical formula**.
2. The names of some common ligands are listed in Table .

Anionic Ligands	Names		Neutral Ligands	Names
Br^-	bromo		NH_3	ammine
F^-	fluoro		H_2O	aqua
O^{2-}	oxo		NO	Nitrosyl
OH^-	Hydroxo		CO	Carbonyl
CN^-	cyano		O_2	dioxygen
$C_2O_4^{2-}$	oxalato		N_2	dinitrogen
CO_3^{2-}	carbonato		C_5H_5N	pyridine
CH_3COO^-	acetato		$H_2NCH_2CH_2NH_2$	ethylenediamine

. Greek prefixes are used to designate the number of each type of ligand in the complex ion, e.g. di-, tri- and tetra-. If the ligand already contains a Greek prefix (e.g. ethylene**di**amine) or if it is polydentate ligands (ie. can attach at more than one binding site) the prefixes bis-, tris-, tetrakis-, pentakis-, are used instead. The numerical prefixes are listed in Table

Number	Prefix	Number	Prefix	Number	Prefix
1	mono	5	penta (pentakis)	9	nona (ennea)
2	di (bis)	6	hexa (hexakis)	10	deca
3	tri (tris)	7	hepta	11	undeca
4	tetra (tetrakis)	8	octa	12	dodeca

After naming the ligands, name the central metal. If the complex ion is a cation, the metal is named same as the element. For example, Co in a complex cation is call cobalt and Pt is called platinum. If the complex ion is an anion, the name of the metal ends with the suffix –ate. For example, Co in a complex anion is called cobaltate and Pt is called platinate.

Name of Metal	Name in an Anionic Complex
Iron	Ferrate
Copper	Cuprate
Lead	Plumbate
Silver	Argenate
Gold	Aurate
Tin	Stannate

$[Cr(NH_3)_3(H_2O)_3]Cl_3$

triamminetriaquachromium(III) chloride

$Na_2[NiCl_4]$

sodium tetrachloronickelate(II)

$Fe(CO)_5$

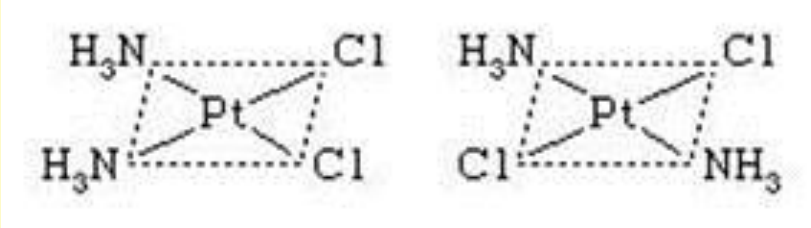
pentacarbonyliron(0)

Isomerism

Coordination compounds often exist as isomers—i.e., as compounds with the same chemical composition but different structural formulas. Many different kinds of isomerism occur among coordination compounds. The following are some of the more common types.

CIS-TRANS ISOMERISM

Cis-trans (geometric) isomers of coordination compounds differ from one another only in the manner in which the ligands are distributed spatially; for example, in the isomeric pair of diamminedichloroplatinum compounds



the two ammonia molecules and the two chlorine atoms are situated next to one another in one isomer, called the *cis* (Latin for "on this side") isomer, and across from one another in the other, the *trans* (Latin for "on the other side") isomer. A similar relationship exists between the *cis* and *trans* forms of the tetraamminedichlorocobalt(1+) ion: