**Nomenclature of co-ordination compounds:-** Nomenclature is important in Coordination Chemistry because of the need to have an unambiguous method of describing formulas and writing systematic names, particularly when dealing with isomers. The formulas and names adopted for coordination entities are based on the recommendations of the International Union of Pure and Applied Chemistry (IUPAC). The first 'system' of chemical nomenclature was developed by Guyton de Morveau in 1782.Guyton's statement of the need for a 'constant method of denomination, which helps the intelligence and relieves the memory' is still true today.  
The first comprehensive report of the IUPAC inorganic commission, in 1940, had a major effect on the systematization of inorganic nomenclature and made many chemists aware of the necessity for developing a more fully systematic nomenclature. These IUPAC recommendations were then revised and issued as a small book in 1959followed by a second revision in 1971and a supplement, entitled 'How to Name an Inorganic Substance', in 1977.In 1990 the IUPAC recommendations were again fully revisedin order to bring together the many and varied changes that had occurred in the previous 20 years.   
A revision of this so-called Red Book was initiated in 1998. The latest version of the 'Red Book' was published in Nov 2005 by the Royal Society of Chemistry.

The following rules are used when naming coordination compounds:

(i) The cation is named first in both positively and negatively charged coordination entities. Non-ionic complexes are named in one word. The names of coordination entities of the complexes or non-ionic complexes are written small letters in one word without separation by hyphens.

(ii) The ligands are named in an alphabetical order before the name of the central atom/ion. (This procedure is reversed from writing formula). For example, NH3 (ammine) would be considered an 'a' ligand and come before Cl- (chlorido).

(iii) Names of the anionic ligands end in –o, e.g. Cl1- as chlorido, OH1- as hydroxido, SO42- as sulphato etc. Names of neutral and cationic ligands are the same except aqua for H2O, ammine for NH3, carbonyl for CO and nitrosyl for NO.

(iv) Prefixes mono, di, tri, etc., are used to indicate the number of the individual ligands in the coordination entity. When the names of the ligands include a numerical prefix, then the terms, *bis*, *tris*, *tetrakis* are used, the ligand to which they refer being placed in parentheses. For example, [NiCl2(PPh3)2] is named as dichloridobis(triphenylphosphine)nickel(II).

(v) Oxidation state of the metal in cation, anion or neutral coordination entity is indicated by Roman numeral in parenthesis.

(vi) If the complex ion is a cation, the metal is named same as the element. For example, Co in a complex cation is called 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 [Co(SCN)]4-is called cobaltate. For some metals, the Latin names are used in the complex anions, *e*.g., ferrate for Fe.

(vii) The neutral complex molecule is named similar to that of the complex cation.

(viii) When a ligand can co-ordinate through more than one atom, then the point of attachment of the ligand is indicated by putting the symbol of the atom through which coordination occurs after the name of the ligand.Sometimes, different names are used for alternative modes of attachment. As for example, -NO21- can be named as nitro-N or nitro and -ONO1- as nitro-O or nitrito. Similarly, -NCS1- can be named as isothiocyanato or thiocyanato-N.

(ix)Geometrical isomers are named by the use of the terms ‘cis’ to designate adjacent positions and ‘trans’ to designate opposite positions.

(x) Optically active compounds are designated by the symbols (+)or‘d’ for dextrorotatory and (-) or ‘l’ for laevorotatory.

(xi) For ligands which act as bridge between two or more metal centers, the Greek letter µ (mu) is used before their names. As for example, the complex-

 is named as tetraamminecobalt(III)- µ-amido- µ-nitro tetraamminecobalt(III) or µ-amido- µ-nitro bis{tetraamminecobalt(III)}.

The following examples illustrate the nomenclature for coordination compounds.

**1.** [Cr(NH3)3(H2O)3]Cl3 is named as: triamminetriaquachromium(III) chloride.

*Explanation*: The complex ion is inside the square bracket, which is a cation. The amine ligands are named before the aqua ligands according to alphabetical order. Since there are three chloride ions in the compound, the charge on the complex ion must be +3 (since the compound is electrically neutral). From the charge on the complex ion and the charge on the ligands, we can calculate the oxidation number of the metal. In this example, all the ligands are neutral molecules. Therefore, the oxidation number of chromium must be the same as the charge of the complex ion,+3.

**2.** [Co(H2NCH2CH2NH2)3]2(SO4)3 is named as: tris(ethane-1,2–diammine)cobalt(III) sulphate.

*Explanation*: The sulphate is the counter anion in this molecule. Since it takes 3 sulphates to bond with two complex cations, the charge on each complex cation must be +3. Further, ethane-1,2–diamine is a neutral molecule, so the oxidation number of cobalt in the complex ion must be +3. *Remember that you never have to* *indicate the number of cations and anions in the name of an* *ionic compound.*

**3.** [Ag(NH3)2][Ag(CN)2] is named as: diamminesilver(I) dicyanoargentate(I).

[NiCl4]2− → tetrachloridonickelate(II) ion

[CuNH3Cl5]3− → amminepentachloridocuprate(II) ion

[Cd(en)2(CN)2] → dicyanidobis(ethylenediamine)cadmium(II)

[Co(NH3)5Cl]SO4 → pentaamminechloridocobalt(III) sulfate

Q.Write the IUPAC names of the following coordination compounds:

(i) [Pt(NH3)2Cl(NO2)] (ii) K3[Cr(C2O4)3] (iii) [CoCl2(en)2]Cl (iv) [Co(NH3)5(CO3)]Cl (v) Hg[Co(SCN)4]

(vi) [Co(NH3)6]Cl3 (vii) [Co(NH3)5Cl]Cl2 (viii) K3[Fe(CN)6] (ix) K2[PdCl4] (x)[Pt(NH3)2Cl(NH2CH3)]Cl

**Rules for writing formula**:-The formula of a compound is a shorthand tool used to provide basic information about the constitution of the compound in a concise and convenient manner. Mononuclear coordination entities contain a single central metal atom. The following rules are applied while writing the formulas:

(i) The central atom is listed first.

(ii) The ligands are then listed in alphabetical order. The placement of a ligand in the list does not depend on its charge.

(iii) Polydentate ligands are also listed alphabetically. In case of abbreviated ligand, the first letter of the abbreviation is used to determine the position of the ligand in the alphabetical order.

(iv) The formula for the entire coordination entity, whether charged or not, is enclosed in square brackets. When ligands are polyatomic, their formulas are enclosed in parentheses. Ligand abbreviations are also enclosed in parentheses.

(v) There should be no space between the ligands and the metal within a coordination sphere.

(vi)When the formula of a charged coordination entity is to be written without that of the counter ion, the charge is indicated outside the square brackets as a right superscript with the number before the sign. For example, [Co(CN)6]3–, [Cr(H2O)6]3+, etc. (vii) The charge of the cation(s) is balanced by the charge of the anion(s).

Q.Write down the formulas for the following coordination compounds:

(i) Tetraamineaquachloridocobalt(III) chloride

(ii) Potassium tetrahydroxozincate(II)

(iii) Potassium trioxalatoaluminate(III)

(iv) Dichloridobis(ethane-1,2-diamine)cobalt(III)

(v) Tetracarbonylnickel(0)

(vi) Tetraamminediaquacobalt(III) chloride

(vii) Potassium tetracyanonickelate(II)

(viii) Tris(ethane–1,2–diamine) chromium(III) chloride.

(ix) Amminebromidochloridonitrito-N-platinate(II)

(x) Dichloridobis(ethane–1,2–diamine)platinum(IV) nitrate

(xi) Iron(III) hexacyanoferrate(II)

**Some common ligands**:-

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Ligand** | **Formula** | | | **IUPAC name** | **Remark(s)** | |
| Chloride  Bromide  Thiocyanate  Isothiocyanato  Nitrate  Azide  Hydroxide  Oxalate  Amide  Nitrite  Nitrite  Hydride  Imide  Oxide  Peroxide  Carbonate  Nitrosonium  Nitronium  Hydrazinium  Water  Ammonia  Carbon monoxide  Nitric oxide  Acetonitrile  Pyridine  Ethylenediamine  2,2'-Bipyridine  1,10-Phenanthroline  Triphenylphosphine  Cyanide  Acetate | Cl-  Br-  SCN-  NCS-  O-NO2-  N-N2-  OH-  C2O42-  NH2-  NO2-  ONO-  H-  NH-  O2-  O22-  CO32-  NO+  NO2+  NH2NH3+  H2O  NH3  CO  NO  CH3CN  C5H5N (py)  NH2(CH2)2NH2 (en)  Bipy  Phen  P(Ph)3  CN-  CH3COO- | | | chlorido  bromide  thiocyanato  isothiocyanato  nitrato  azido  hydroxide  oxalate  amido  nitro (N-bonded)  nitrito (O-bonded)  hydrido  imido  oxido  peroxido  carbonato  nitrosonium  nitronium  hydrazinium  aqua  ammine  carbonyl  nitrosyl  acetonitrile  pyridine  ethylenediamine  bipy  phen  triphenylphosphine  cyanide  acetato | Monodentate, bridging  Monodentate  Monodentate, ambidentate  Monodentate, ambidentate  Monodentate  Monodentate  Monodentate, bridging  Bidentate, chelating  Monodentate, bridging  Monodentate  Monodentate  Monodentate  Monodentate, bridging  Monodentate, bridging  Monodentate, bridging  Monodentate,flexidentate  Monodentate  Monodentate  Monodentate  Monodentate  Monodentate  Monodentate, bridging  Monodentate  Monodentate  Monodentate  Bidentate (chelating)  Bidentate  Bidentate  Monodentate  Monodentate  Monodentate | |
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**Other general encountered ligands:**

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| --- | --- | --- | --- | --- | --- | --- | --- |
| **Ligand** | **Formula** | **Iupac name & abbrevations** | | **Remark(s)** | | | |
| Acetylacetonate  Alkenes  Benzene  Cyclopentadienide  Diethylenetriamine  Dimethylglyoximate  Ethylenediaminetetraacetate  Glycinte  Triethylenetetramine | CH3-C(**O**)-CH2-C(**O**)-CH3  R2**C=C**R2  **C**6H6  [C5H5]−  C4H13N3 | acetylacetonato (acac)  alkene  benzene  cyclopentadienyl  dien  dimethylglyoximato (dmg)  edta  gly  trien | | Bidentate  Pi-complex  Arene complex  Tridentate  Bidentate (chelating)    Tetra-anionic hexadentate  Bidentate (chelating)  tetradentate | | | |
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**Flexidentate ligand**:-The plydentate ligands are said to be flexidentate character if they do not use all its donor atoms to get coordinated to the metal. An interesting example is ethylenediaminetetraacetic acid (edtaH2). This ligand generally hexadentate but it can acts as pentadentate e.g. [Cr(OH)(edtaH)]2-, [Co(Br)(edtaH)]2- or as tetradentate e.g. [Pd(edtaH2)].Another example is SO4-2 ion, which may acts as mono, bi or bridging ligands.



Q. Explain Werner’s theory on coordination compounds by taking an example K4[Fe(CN)6]. A. (a) In the complex K4[Fe(CN)6], the oxidation no. of Fe is +2. This is, according to Werner’s theory the primary valency of Fe. These are satisfied by two CN- ions in this given complex. (b) The no. of CN- ions around the Fe(II) ion is six. This means the no. of secondary valency of Fe(II) in this complex is six. Each CN- ion has a lone pair of electrons on its C atom. Thus the secondary valencies are satisfied by six CN- ions by donating their lone pair of electrons.Two of the six CN- ligands. At the same time, two of the six CN- ligands also satisfied the primary valencies of Fe(II) i.e. two CN- ions exhibit their dual nature.

(c) The six CN- ligands are directed towards fixed positions in space around Fe(II).The fixed positions are located at the corners of an octahedron. (d) The charged on [Fe(CN)6]4- is satisfied by four K+ ions.

The Werner’s formulation of the complex K4[Fe(CN)6] is shown in the below figure.In the figure the coordinate bonds are shown by marked line and the ionic bonds are shown by dotted lines.



Q. Name four methods for detecting complex compounds.

A. The methods for detecting complex compounds are-

1. Qualitative tests for the presence of individual ions in the complex compounds. 2. Conductivity measurements:-The conductivity of the solution of an ionized compound is dependent upon no. of ions formed. Therefore, by measuring the conductivity of a molecular compound can be used to differentiate between a complex compound and a double salt. 3. Visible and uv absorption spectrum analysis is also helpful in detecting a complex compound. 4. Optical activity measurement can be used to detect a complex compound.

Q. A monomeric compound of cobalt gives the following data:- Co = 21.27%, NH3 = 24.77%, Cl- = 12.81%, H2O = 6.53% and SO42- = 34.65% .Find out the empirical formula of the compound. Hints:- Relative ratio Co: NH3: Cl- : H2O: SO42- = 21.24/58.93 : 24.77/17 : 12.81/35.5 :6.53/18 : 34.65/96 = 0.36:1.46:0.36:0.36:0.36 and actual ratio = 1:4:1:1:. Hence, empirical formula is [Co(NH3)4Cl(H2O)]SO4 Q. How does an ambidentate ligand form a complex .Illustrate with an example? Q. Explain “Carnalite is a double salt whereas 2KCl,HgCl2 is a complex compound.” Q Explain why AgCl is dissolved in ammonia solution? Q.What are Werner’s secondary valencies? Explain with structural formula of dichloridotetraamminecobalt(III) chloride.