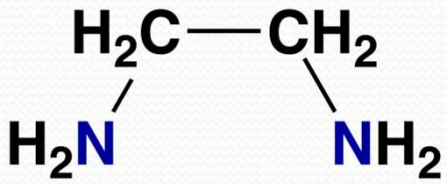
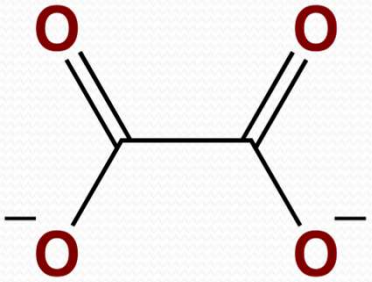
# Bidentate Ligands

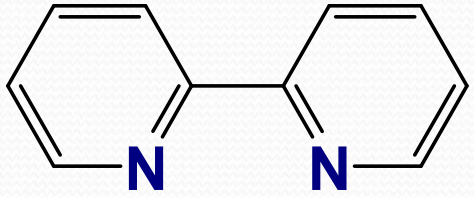
- Two possible sites of attachment
- Two Lewis base sites that can attach to $M^{n+}$
- Part of larger class of chelate



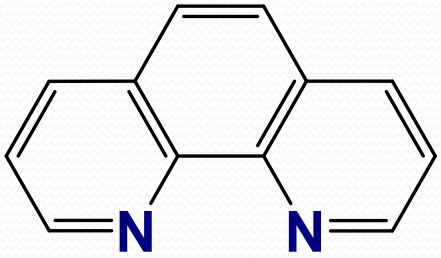

Ethylenediamine
(en)




Oxalate
($ox^{2-}$)

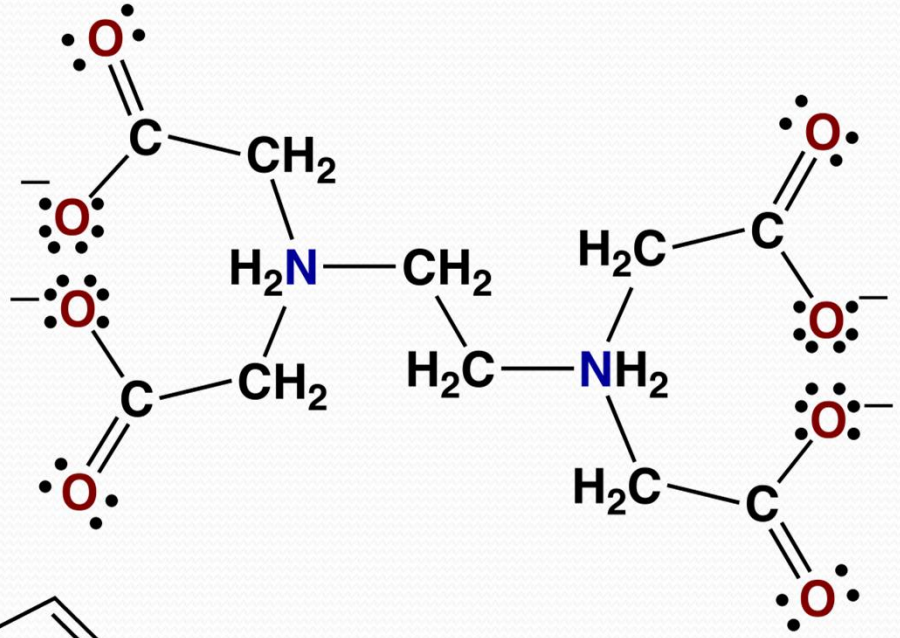



2,2’-bipyridine
(bpy)

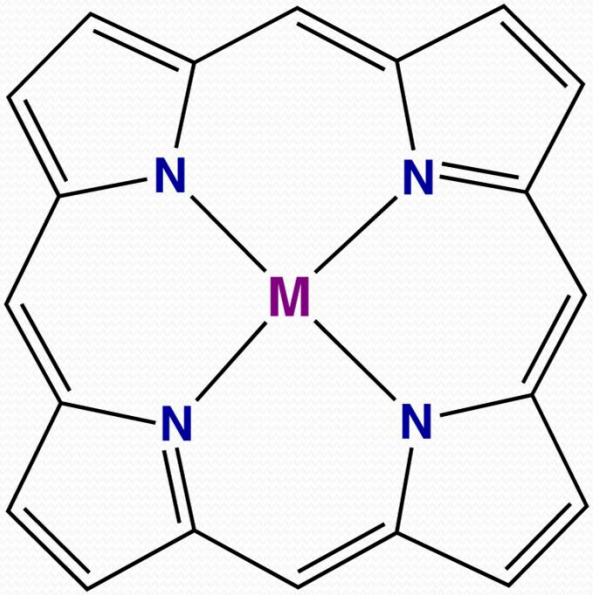



1,10-phenanthroline
(phen)

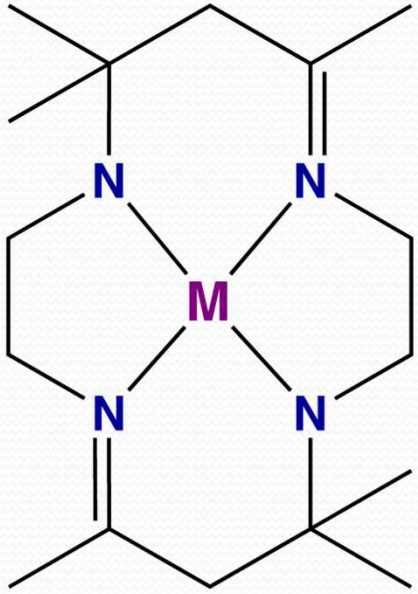
# Important Polydentate Ligands




**EDTA$^{4-}$**




**Porphyrin**




**Corrin ring**



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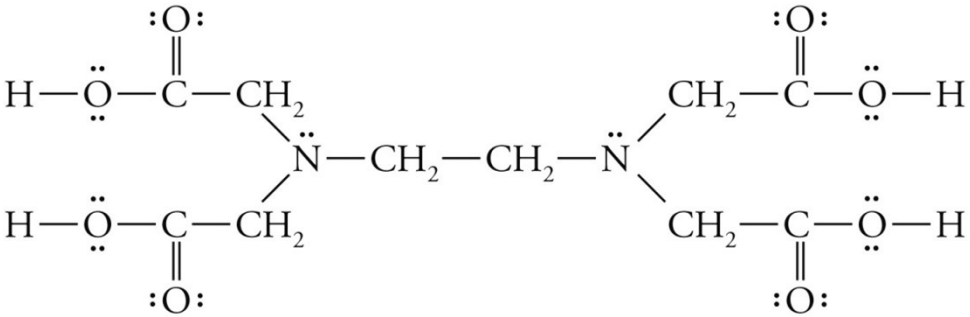
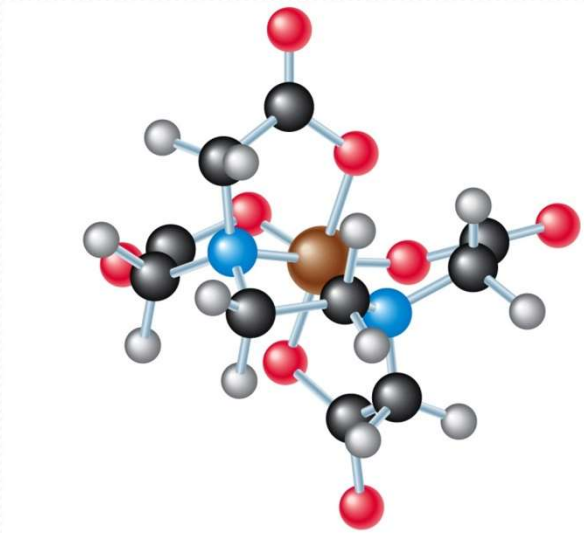
# Structure of EDTA Ligand and Complex

- $H_4EDTA$ common polydentate ligand
- $EDTA^{4-}$ used to complex metal ions
  - 6 donor atoms
  - Wraps around metal ion
  - Forms very stable complexes

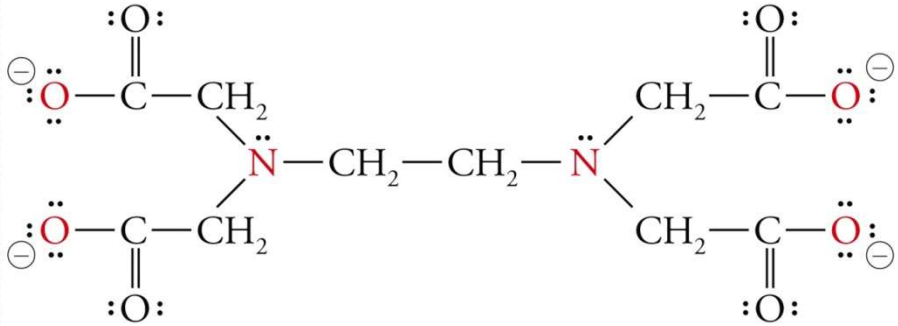


Ethylenediaminetetraacetic acid, $H_4EDTA$)









$EDTA^{4-}$





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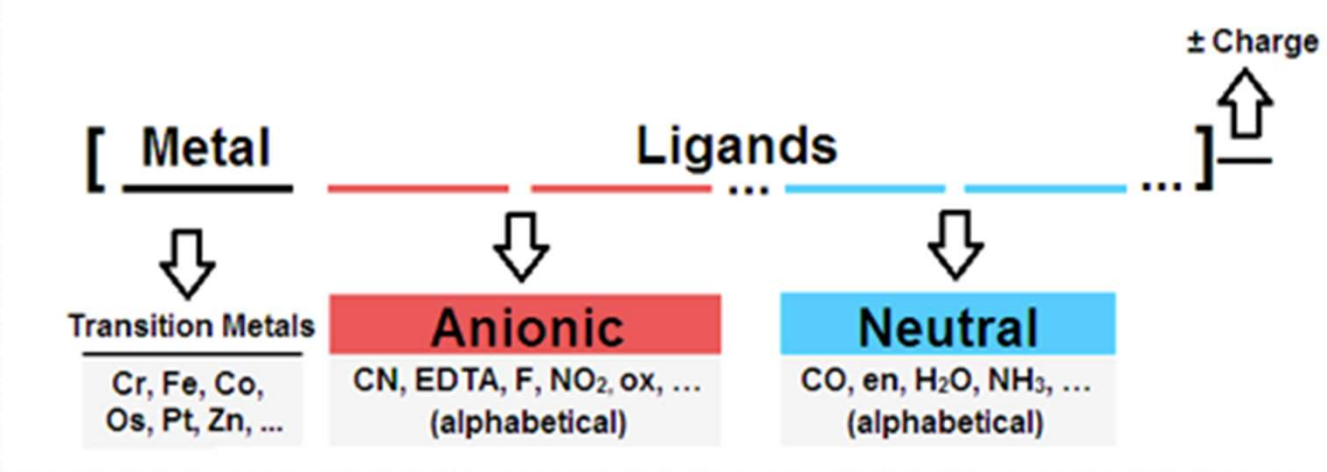
# Formulas of Complex Ions

1. The symbol for the metal ion is always given first, followed by ligands. $[Cu(NH_3)_4]^{2+}$ $[Cr(H_2O)_4(NH_3)]^{+2}$
2. When more than one kind of ligand is present,
   A. **Anionic ligands** are first (in alphabetical order)
   B. **Neutral ligands** are next (in alphabetical order)
3. Charge on complex is algebraic sum of charge on metal ion and charges on ligands
4. The formula is placed inside of square brackets with the charge of the complex as a superscript outside the brackets, if it is not zero.

# Formulas of Complex Ions




$[Cu(NH_3)_4]^{2+}$ $[Cr(H_2O)_4(NH_3)]^{2+}$

1. What is the formula for the complex made by $Cu^{2+}$ and four ammonia ($NH_3$) molecules? Decide if the complex could be isolated as a chloride salt or a potassium salt. Write the formula of the appropriate salt.
   - $Cu^{2+}$ has +2 charge
   - $NH_3$ is neutral
   - So overall charge of ion is +2 + 4(0) = +2
- $[Cu(NH_3)_4]^{2+}$
   - Need two $Cl^-$ to make neutral complex
- **$[Cu(NH_3)_4]Cl_2$**

# Learning Check

2. What is the formula for the complex made by $Ag^+$ and two cyanide ($CN^-$) ions? Decide if the complex could be isolated as a chloride salt or a potassium salt. Write the formula of the appropriate salt.
   - $CN^-$ is negative one charge
   - So overall charge of ion is +1 + 2(–1) = –1
- $[Ag(CN)_2]^-$
  - Need +1 to make neutral complex
  - So add one $K^+$ ion
- **$K[Ag(CN)_2]$**

# Coordination Number

- Number of bonds formed by metal ions to ligands in complex ions
- Varies from 2 to 8
- Depends on:
  1. Size of central atom
  2. Steric interactions of ligands
  3. Electrostatic interactions

**e.g.** $[Co(NH_3)_6]^{3+}$ CN = 6

$[PtCl_4]^{2-}$ CN = 4

$Ni(CO)_4$ CN = 4

4 and 6 most common

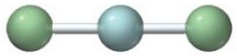
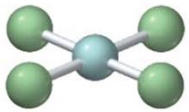
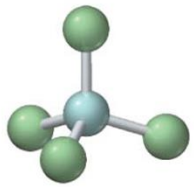
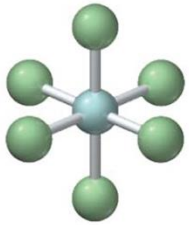
# Some Common Coordination Numbers of Metal Ions

**Table 22.2** Some Common Coordination Numbers of Metal Ions

| Metal Ion | Coordination Number | Metal Ion | Coordination Number |
|---|---|---|---|
| $Al^{3+}$ | 4, 6 | $Ni^{2+}$ | 4, 6 |
| $Sc^{3+}$ | 6 | $Cu^{+}$ | 2, 4 |
| $Ti^{4+}$ | 6 | $Cu^{2+}$ | 4, 6 |
| $V^{3+}$ | 6 | $Zn^{2+}$ | 4 |
| $Cr^{3+}$ | 6 | $Pd^{2+}$ | 4 |
| $Mn^{2+}$ | 6 | $Ag^{+}$ | 2 |
| $Fe^{2+}$ | 6 | $Pt^{2+}$ | 4 |
| $Fe^{3+}$ | 6 | $Pt^{4+}$ | 6 |
| $Co^{2+}$ | 4, 6 | $Au^{+}$ | 2, 4 |
| $Co^{3+}$ | 6 | $Au^{3+}$ | 4 |

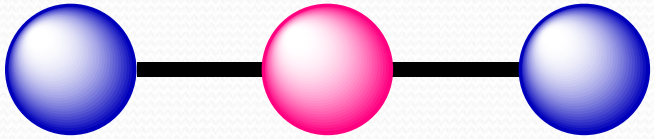
# Molecular Geometry

**TABLE 24.3 Common Geometrics of Complex Ions**

| Coordination Number | Shape | Model | Example |
|---|---|---|---|
| 2 | Linear |  | $[Ag(NH_3)_2]^+$ |
| 4 | Square planar |  | $[PdCl_4]^{2-}$ |
| 4 | Tetrahedral |  | $[Zn(NH_3)_4]^{2+}$ |
| 6 | Octahedral |  | $[Fe(H_2O)_6]^{3+}$ |

# Structures

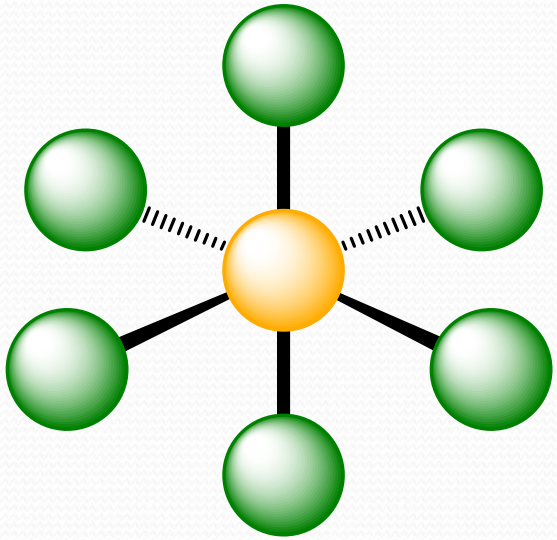
= 2 $ML_2$ Linear

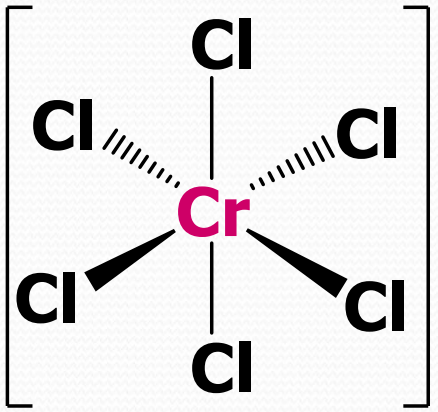


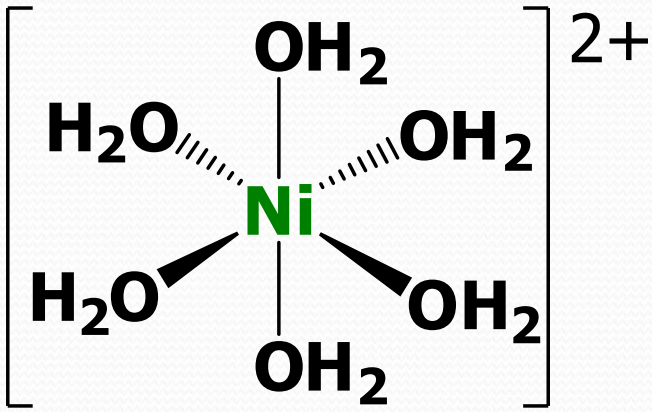
$[H_3N—Ag—NH_3]^+$

$[NC—Ag—CN]^-$

= 6 $ML_6$ Octahedral

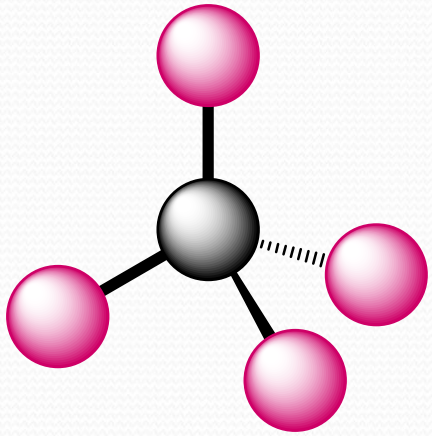


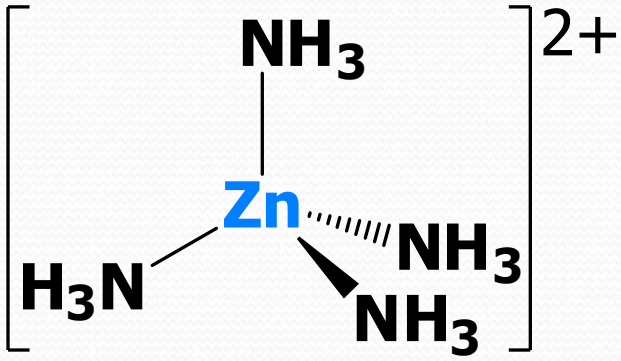


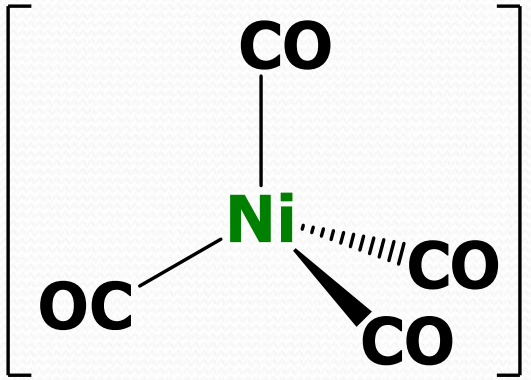



# Structures

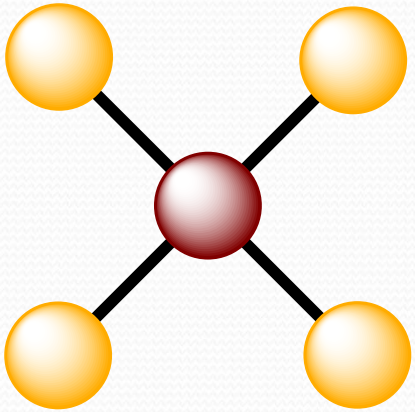
## 4 $ML_4$ Tetrahedral

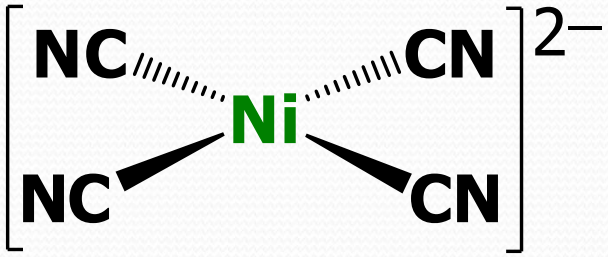


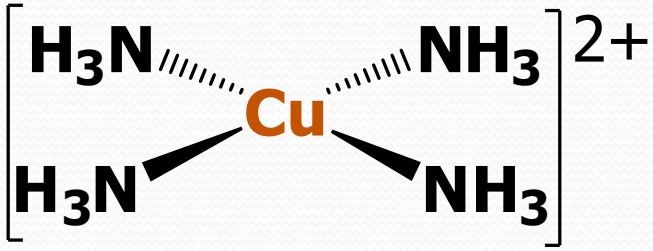



## 4 $ML_4$ Square Planar





# Metal Complex Nomenclature

1. Cation (PART)named first, then anion (PART)
2. Ordering of ligands

$K[Ag(CN)_2]$ $[Cu(NH_3)_4]Cl_2$

   a. **In formula**, symbol of metal first followed by ligands

      Ligands order

      I. Anionic ligands first in alphabetical order

      II. Neutral ligands next also in alphabetical order

   b. **In the name** of the complex,

      I. Ligands named first in alphabetical order *without regard to charge*

      II. Metal named last

$K_3[Fe(CN)_6]$ → potassium hexa**cyano**ferrate(III)

$[Co(H_2O)_6]^{2+}SO_4$ → Hexaaqua**cobalt**(II) sulphate

# Metal Complex Nomenclature

IUPAC Rules for naming Coordination Compounds

3. Names of anionic ligands always end in suffix –*o*

   a) Ligands whose names end in –*ide* have suffix changed to –*o*

$K_3[Fe(CN)_6]$ → potassium hexa**cyano**ferrate(III)

$[Co(H_2O)_6]^{2+}SO_4$ → Hexaaqua**cobalt**(II) sulphate

| Anion | | Ligand |
|---|---|---|
| chloride | $Cl^-$ | chloro- |
| bromide | $Br^-$ | bromo- |
| cyanide | $CN^-$ | cyano- |
| oxide | $O^{2-}$ | oxo- |

# Metal Complex Nomenclature

Rules for naming Coordination Compounds

b) Ligands whose names end in *–ite* or *–ate* become *–ito* and *–ato* respectively

| Anion | | Ligand |
|---|---|---|
| carbonate | $CO_3^{2-}$ | carbonato- |
| thiosulfate | $S_2O_3^{2-}$ | thiosulfato- |
| thiocyanate | $SCN^-$ | thiocyanato- (when bonded through sulfur) |
| | | isothiocyanato- (when bonded through nitrogen) |
| oxalate | $C_2O_4^{2-}$ | oxalato- |
| nitrite | $NO_2^-$ | nitrito- (when bonded through oxygen; written ONO in the formula for the complex)[a] |

[a]An exception to this is when the nitrogen of the $NO_2^-$ ion is bonded to the metal, in which case the ligand is named nitro-.

# Metal Complex Nomenclature

4. Neutral ligands given same name as used for molecule except:
   - $H_2O$ aqua $NH_3$ ammine
5. When there is more than one of a given ligand, specify number of ligands by prefixes.

| Number of same ligand | Simple ligand prefix | Complicated ligand prefix |
|---|---|---|
| 2 | di- | bis- |
| 3 | tri- | tris- |
| 4 | tetra- | tetrakis- |
| 5 | penta- | |
| 6 | hexa- | |

# Nomenclature

6. If the complex ion has a negative charge, the suffix –*ate* is added to the name of the metal.

| Metal | As Named in Anionic Complex |
|---|---|
| Aluminum | Aluminate |
| Chromium | Chromate |
| Manganese | Manganate |
| Nickel | Nickelate |
| Cobalt | Cobaltate |
| Zinc | Zincate |
| Platinum | Platinate |
| Vanadium | Vanadate |

# Latin Names of Metals

7. Sometimes the Latin name of the metal is used.

| Metal | Stem | Metal as Named in an Anionic Complex |
|---|---|---|
| iron | ferr- | ferrate |
| copper | cupr- | cuprate |
| lead | plumb- | plumbate |
| silver | argent- | argentate |
| gold | aur- | aurate |
| tin | stann- | stannate |



8. Oxidation state of the metal is designated by Roman numeral in parentheses

Name the Following:

- $[Ag(CN)_2]^-$
- dicyanoargentate(I) ion
- $[Zn(OH)_4]^{2-}$
- tetrahydroxozincate(II) ion
- $[Co(NH_3)_6]^{3+}$
- hexamminecobalt(III) ion
- $[Mn(en)_3]Cl_2$
- tris(ethylenediamine)manganese(II) chloride