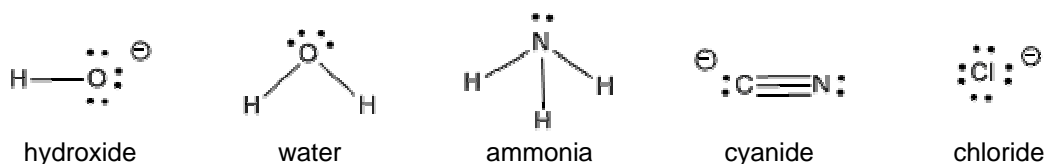
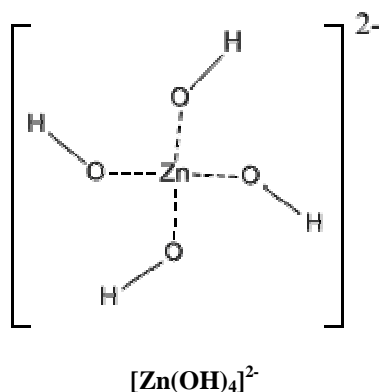


E16 THE COPPER(II) SULFATE/AMMONIA COMPLEX

A *complex* normally consists of a monatomic positive ion (*ie* a metal ion) surrounded by a number of *ligands*. Each ligand is a molecule or ion, generally containing at least one atom with an unshared pair of electrons. Such an electron pair permits the formation of a metal-ligand bond with partial covalent character. The atom of the ligand that is involved in this interaction is the *donor atom*. The function of the unshared pair is to allow for the partial covalent character of the metal-ligand bond. Common ligands include the hydroxide ion (OH^-), water molecule (H_2O), ammonia molecule (NH_3), cyanide ion (CN^-) and halide ions (F^- , Cl^- , Br^- and I^-).



Most complexes carry a positive or negative charge, and are called *complex ions*. An example of a complex-ion is the following, in which because the ligands are negatively charged, the charge of the complex-ion is negative.



One unshared pair from the O atom of each OH^- ion is directed towards the Zn^{2+} ion, the O atoms being arranged tetrahedrally about Zn^{2+} . Due to repulsion of the electron pairs of the donor-atoms, the arrangement of ligands in a complex ion is symmetric.

The following arrangements of donor-atoms commonly occur.

Number of donor atoms	Arrangement of donor atoms around the metal ion:
2	linear
4	tetrahedral
6	octahedral

The number of donor-atoms bound to the metal ion is called the *co-ordination number* or C_N .

Examples

Name of Complex	Formula	Metal Ion	Ligand	C _N	Geometry
tetrahydroxozincate(II) ion	[Zn(OH) ₄] ²⁻	Zn ²⁺	OH ⁻	4	tetrahedral
hexaamminecobalt(III) ion	[Co(NH ₃) ₆] ³⁺	Co ³⁺	NH ₃	6	octahedral
hexaaquanickel(II) ion	[Ni(H ₂ O) ₆] ²⁺	Ni ²⁺	H ₂ O	6	octahedral
tetrachloromercurate(II) ion	[HgCl ₄] ²⁻	Hg ²⁺	Cl ⁻	4	tetrahedral
hexacyanoferrate(II) ion	[Fe(CN) ₆] ⁴⁻	Fe ²⁺	CN ⁻	6	octahedral
hexacyanoferrate(III) ion	[Fe(CN) ₆] ³⁻	Fe ³⁺	CN ⁻	6	octahedral
triamminetrichlorocobalt(III) ion	[Co(NH ₃) ₃ Cl ₃]	Co ³⁺	NH ₃ , Cl ⁻	6	octahedral
dicyanoargentate(I) ion	[Ag(CN) ₂] ⁻	Ag ⁺	CN ⁻	2	linear

Many complexes of transition metal ions are coloured. For example, when a solution containing Cu²⁺ is added to NH₃ solution, an intense purple solution forms. This indicates the probable formation of a complex ion. Complex ions can be isolated as salts. In this case, the sulfate salt of the copper(II)/ammonia complex is soluble in water but insoluble in ethanol. It is therefore convenient to isolate the salt from water solution by the addition of ethanol.

The number of donor atoms that group themselves around a metal ion of charge 2+ is usually 4 or 6. Since NH₃ molecules have no charge the NH₃ complex of Cu²⁺ will have a charge of 2+. In this case, there are four NH₃ groups coordinated to the Cu²⁺ ion. This ion tends to have a co-ordination number of 6, so there may also be two water molecules co-ordinated to the Cu²⁺ ion, thus the complex ion may be formulated as [Cu(NH₃)₄(H₂O)₂]⁺.

When the complex ion is isolated as the sulfate salt, some H₂O molecules may also be contained in the crystal lattice as the complex sulfate salt is allowed to crystallise. Therefore, the isolated complex salt may be formulated as [Cu(NH₃)₄(H₂O)₂]₂SO₄·xH₂O, where x is the number of H₂O molecules in the crystal lattice.