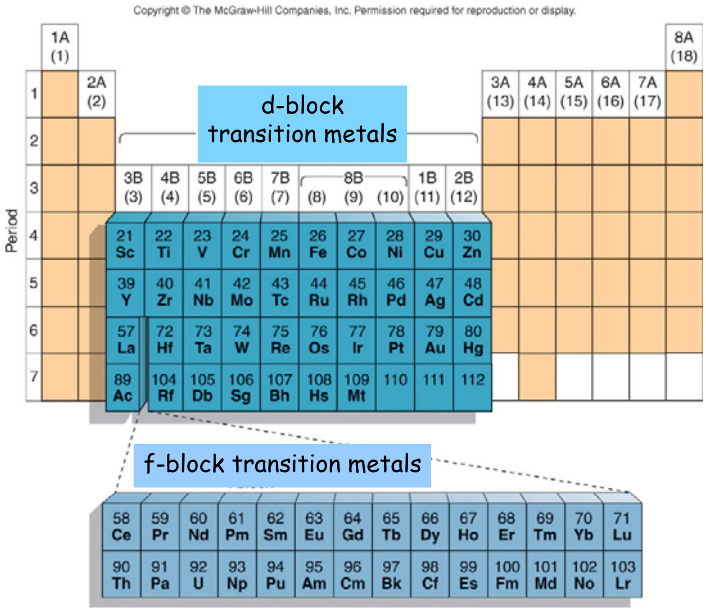
Lecture 8

Coordination Compounds

The d-block elements (Transition Metals)



Properties of the Transition Metals

Malleable, ductile, conducting

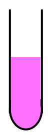
First row transition metals

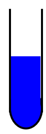
Higher melting and boiling points than main group metals:

m.p. ~ 1 500°C, b.p. ~2 500°C

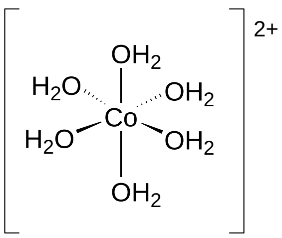
Complexes you will meet…

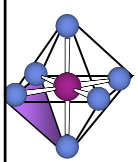
Ligand exchange reaction





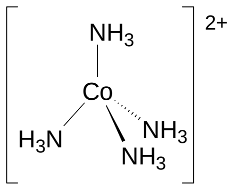
$$Co^{2+}{}_{(aq)} \xrightarrow{conc\ NH_3} [Co(NH_3)_4]^{2+}{}_{(aq)}$$





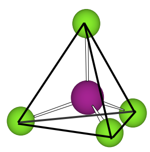
Octahedral complex

Six ligands
Coordination number = 6



Tetrahedral complex

Four ligands
Coordination number = 4



Ions are formed when a transition metal loses electrons

positive ions = cations

Transition metal ions form coordination complexes

with useful and interesting properties

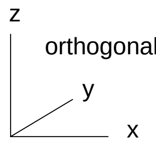
medicine ← colour ← variable oxidation states → magnetism → biology

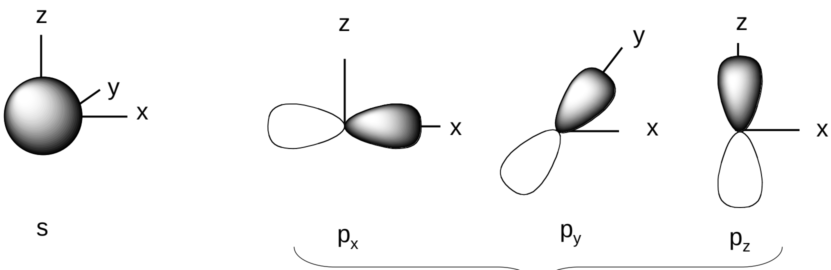
Which orbitals?

The valance electrons in s- and p-block elements occupy s and p-orbitals

s-orbitals: $l = 0$, $m = 0$ — 1 s-orbital per shell

p-orbitals: $l = 1$, $m = +1, 0, -1$ — 3 p-orbitals per shell



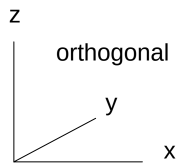


lie along coordinate axes

Two electrons fill 1 s-orbital = 2 elements in each row of the s-block
Six electrons fill 3 p-orbitals = 6 elements in each row of the p-block

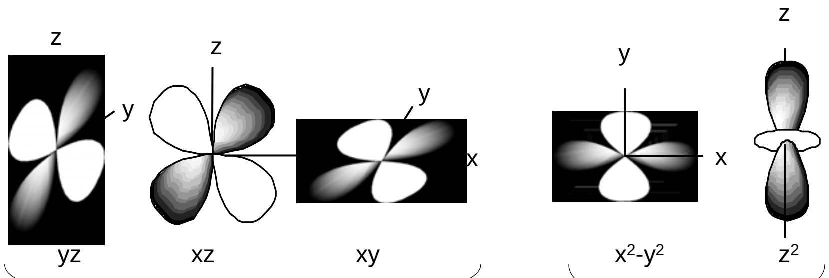
Which orbitals?

The valance electrons occupy d-orbitals in transition metals



d-orbitals: l = 2, m = +2, +1, 0, -1, -2

therefore there are 5 d-orbitals



lie between coordinate axes

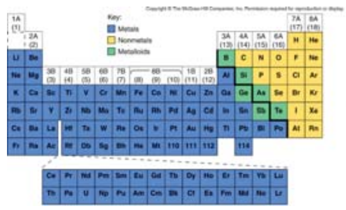
lie along coordinate axes

Ten electrons fill 5 d-orbitals so there are ten elements in each row of the d-block

Electron configurations of transition metal atoms

	4s	3d	4p	
K	↑	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐	[Ar] $4s^1$
Ca	↑↓	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐	[Ar] $4s^1$
Sc	↑↓	↑ ☐ ☐ ☐ ☐	☐ ☐ ☐	[Ar] $4s^2\ 3d^1$
Ti	↑↓	↑ ↑ ☐ ☐ ☐	☐ ☐ ☐	[Ar] $4s^2\ 3d^2$
V	↑↓	↑ ↑ ↑ ☐ ☐	☐ ☐ ☐	[Ar] $4s^2\ 3d^3$
The element gains stabilisation from having a half-filled d-shell				[Ar] $4s^1\ 3d^5$
Mn	↑↓	↑ ↑ ↑ ↑ ↑	☐ ☐ ☐	[Ar] $4s^2\ 3d^5$
Fe	↑↓	↑↓ ↑ ↑ ↑ ↑	☐ ☐ ☐	[Ar] $4s^2\ 3d^6$
Co	↑↓	↑↓ ↑↓ ↑ ↑ ↑	☐ ☐ ☐	[Ar] $4s^2\ 3d^7$
Ni	↑↓	↑↓ ↑↓ ↑↓ ↑ ↑	☐ ☐ ☐	[Ar] $4s^2\ 3d^8$
The element gains stabilisation from having a filled d-shell				[Ar] $4s^1\ 3d^{10}$
Zn	↑↓	↑↓ ↑↓ ↑↓ ↑↓ ↑↓	☐ ☐ ☐	[Ar] $4s^2\ 3d^{10}$

Working out numbers of d-electrons from oxidation states:



1st: how many electrons are there in the shell?

- count along the periodic table

e.g. Mn = 7 electrons   Cu = 11 electrons

2nd: how many electrons are lost?

- oxidation state

e.g. Mn(VII) = 7 electrons lost   Cu(II) = 2 electrons lost

3rd: how many electrons left over?

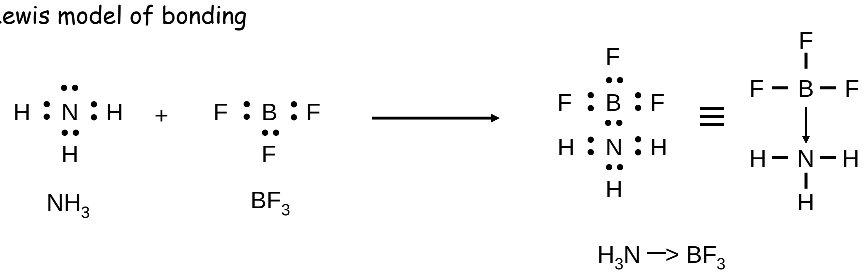
- subtract

e.g. Mn(VII) = no d-electrons, d^0 Cu(II) = 9 d-electrons = d^9

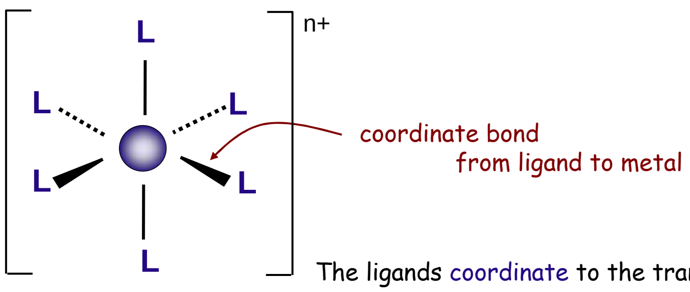
Rule: The electrons in the s-orbital are the first to be lost

Hence the only valance electrons available in a transition metal ion are d-electrons

Lewis model of bonding



Each ligand donates both electrons in the bond to the metal centre

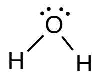


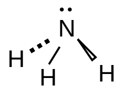
The ligands coordinate to the transition metal ion

Ligands

A ligand is Lewis base which donates an electron pair to a metal ion in a complex to form a coordinate bond

Neutral ligands





Anionic ligands OH^- CN^-

cyano-

Monodentate ligands = "one tooth"

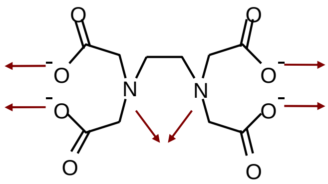
one electron pair to donate

mondentate ligands occupy one coordination site about the metal centre

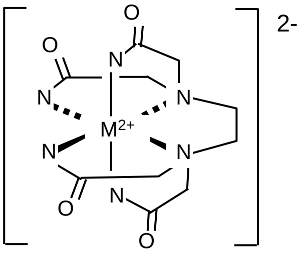
Denticity = number of donor atoms with which one ligand can coordinate to a metal centre

Polydentate Ligands

Hexadentate ligand



tetraanion of ethylenediaminetetraacetic acid, $EDTA^{4-}$



Octahedral complex