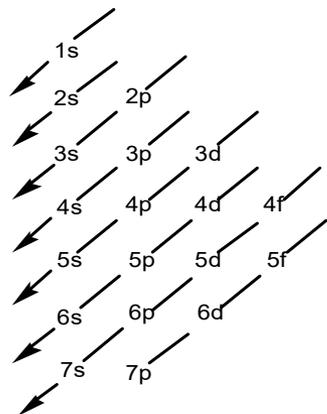




[WWW.CHEMSHEETS.CO.UK](http://www.chemsheets.co.uk)

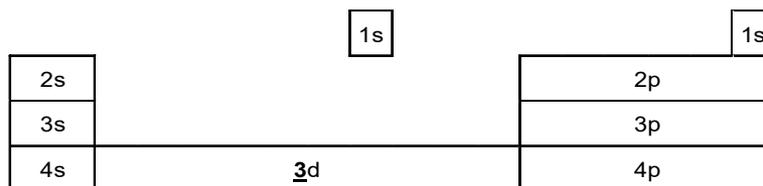
TRANSITION METALS

ELECTRON STRUCTURES



This diagram helps you to work out the order in which orbitals fill:
1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p,

However, it can be easier to read across the periodic table, but remember that the first transition metal row is 3d:



**4s fills and empties
before 3d**



WHAT ARE TRANSITION METALS?

Transition metals are metals that contain an incomplete d sub shell in atoms or ions.

Top row transition metals: Sc – Cu

Zn is not a transition metal (Zn & Zn²⁺)

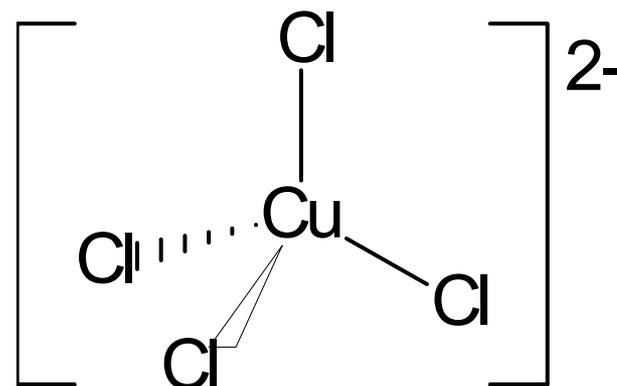
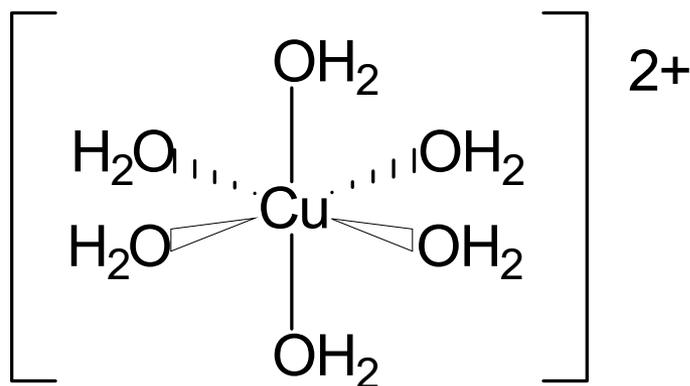
PROPERTIES OF TRANSITION METALS?

1) They form coloured ions.



PROPERTIES OF TRANSITION METALS?

- 2) They form complexes (ligands form co-ordinate bonds to the metal ion).



PROPERTIES OF TRANSITION METALS?

4) They show catalytic activity.

e.g.	Ni	margarine production
	V_2O_5	making SO_3 for H_2SO_4
	Fe	Haber process to make NH_3
	Pt, Pd	catalytic converters

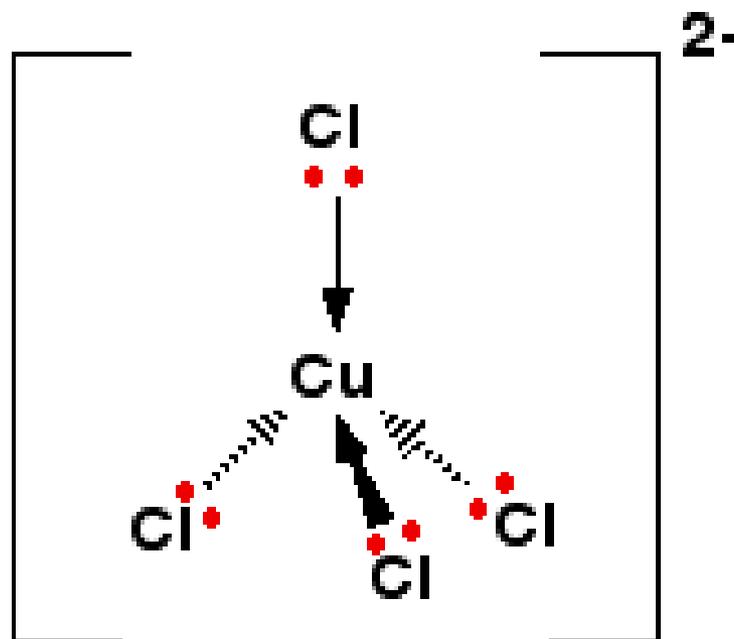
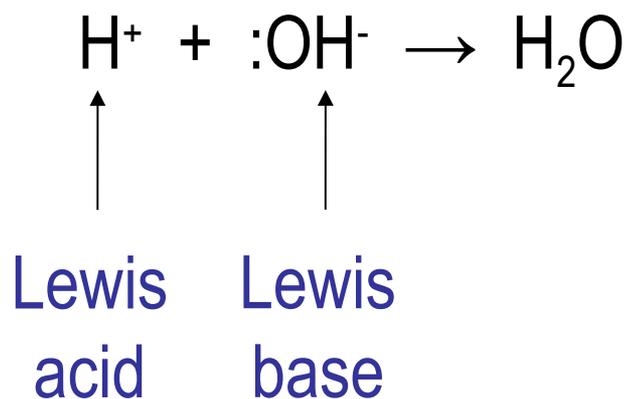
COMPLEX FORMATION

Ligand	particle with a lone pair that forms co-ordinate bond to metal
Complex	metal ion with ligands co-ordinately bonded to it
Co-ordination number	number of co-ordinate bonds from ligand(s) to metal ions
Lewis base	lone pair donor (ligands are Lewis bases)
Lewis acid	lone pair acceptor

COMPLEX FORMATION

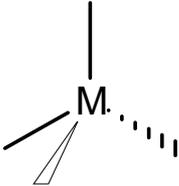
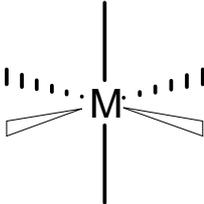
Lewis base lone pair donor (ligands are Lewis bases)

Lewis acid lone pair acceptor

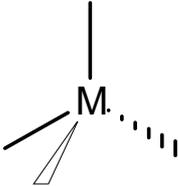
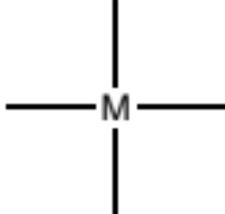
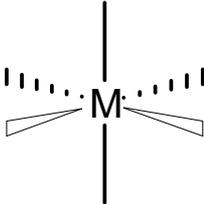


Ligands form co-ordinate bonds via lone pairs

SHAPES OF COMPLEX IONS

Co-ordination number	2	4	4	6
Shape	linear	tetrahedral	square planar	octahedral
				
Bond angles				
Occurrence				
e.g.				

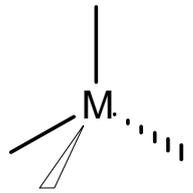
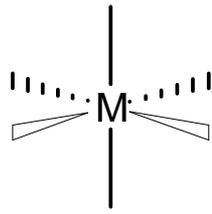
SHAPES OF COMPLEX IONS

Co-ordination number	2	4	4	6
Shape	linear	tetrahedral	square planar	octahedral
				
Bond angles	180°	109½°	90°	90°
Occurrence				
e.g.				

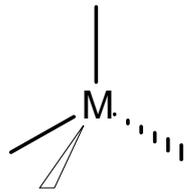
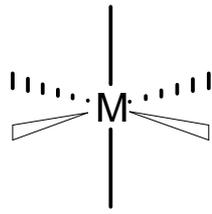
SHAPES OF COMPLEX IONS

Co-ordination number	2	4	4	6
Shape	linear	tetrahedral	square planar	octahedral
Bond angles	180°	$109\frac{1}{2}^\circ$	90°	90°
Occurrence	Ag ⁺ complexes			
e.g.	[Ag(NH ₃) ₂] ⁺			

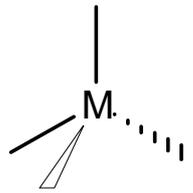
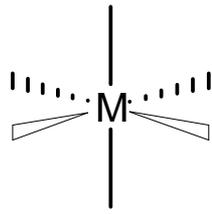
SHAPES OF COMPLEX IONS

Co-ordination number	2	4	4	6
Shape	linear	tetrahedral	square planar	octahedral
				
Bond angles	180°	109½°	90°	90°
Occurrence	Ag ⁺ complexes	Large ligands (e.g. Cl ⁻)		
e.g.	[Ag(NH ₃) ₂] ⁺	[CuCl ₄] ²⁻		

SHAPES OF COMPLEX IONS

Co-ordination number	2	4	4	6
Shape	linear 	tetrahedral 	square planar 	octahedral 
Bond angles	180°	109½°	90°	90°
Occurrence	Ag ⁺ complexes	Large ligands (e.g. Cl ⁻)	Pt ²⁺ complexes	
e.g.	[Ag(NH ₃) ₂] ⁺	[CuCl ₄] ²⁻	[PtCl ₄] ²⁻	

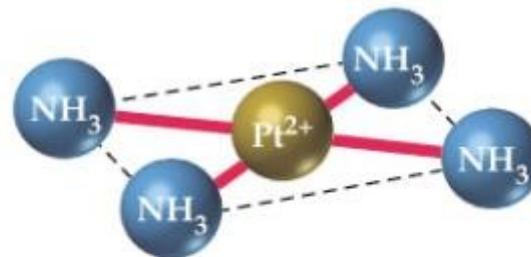
SHAPES OF COMPLEX IONS

Co-ordination number	2	4	4	6
Shape	linear 	tetrahedral 	square planar 	octahedral 
Bond angles	180°	109½°	90°	90°
Occurrence	Ag ⁺ complexes	Large ligands (e.g. Cl ⁻)	Pt ²⁺ complexes	Commonest
e.g.	[Ag(NH ₃) ₂] ⁺	[CuCl ₄] ²⁻	[PtCl ₄] ²⁻	[Cu(H ₂ O) ₆] ²⁺

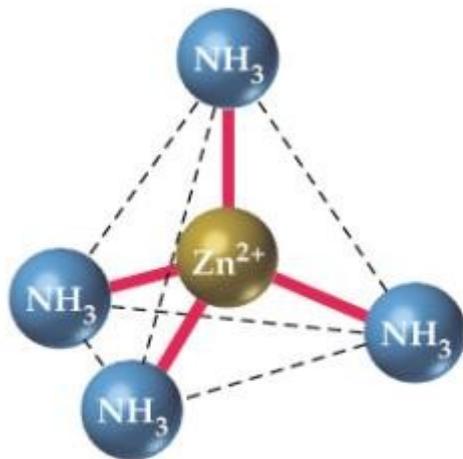
SHAPES OF COMPLEX IONS



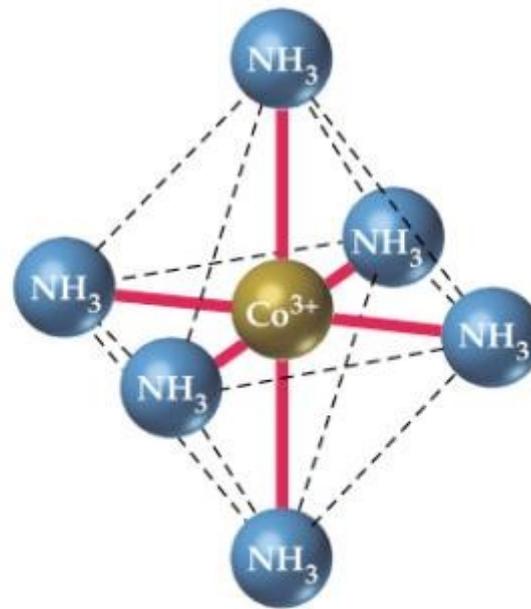
Linear



Square planar



Tetrahedral

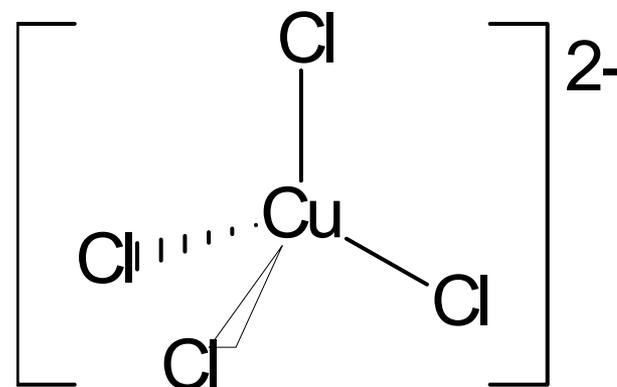
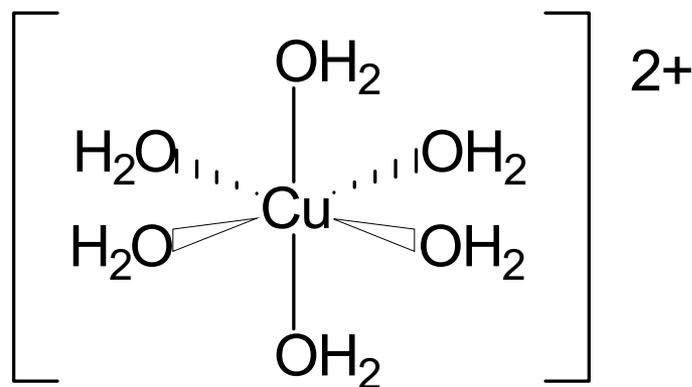


Octahedral

COMPLEX FORMATION

Unidentate ligands – form one co-ordinate bond

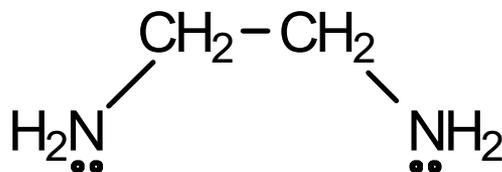
e.g. H_2O , :OH^- , :NH_3 , :CN^- , :Cl^-



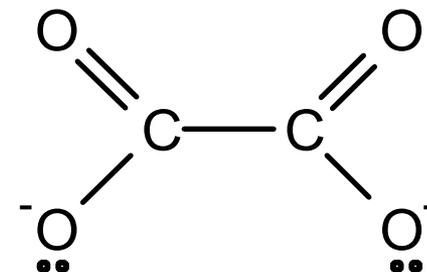
COMPLEX FORMATION

Bidentate ligands – form two co-ordinate bonds

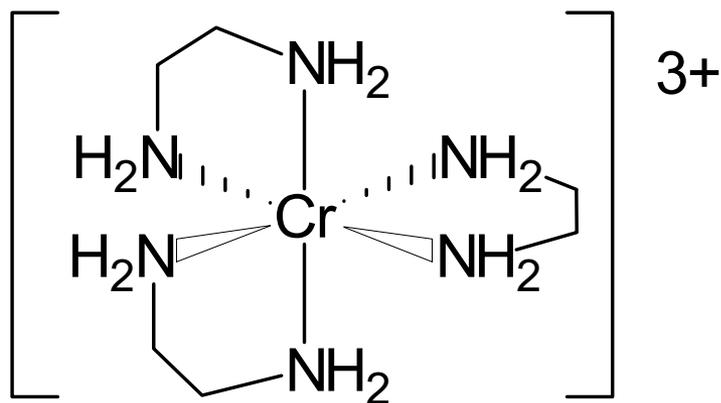
1,2-diaminoethane



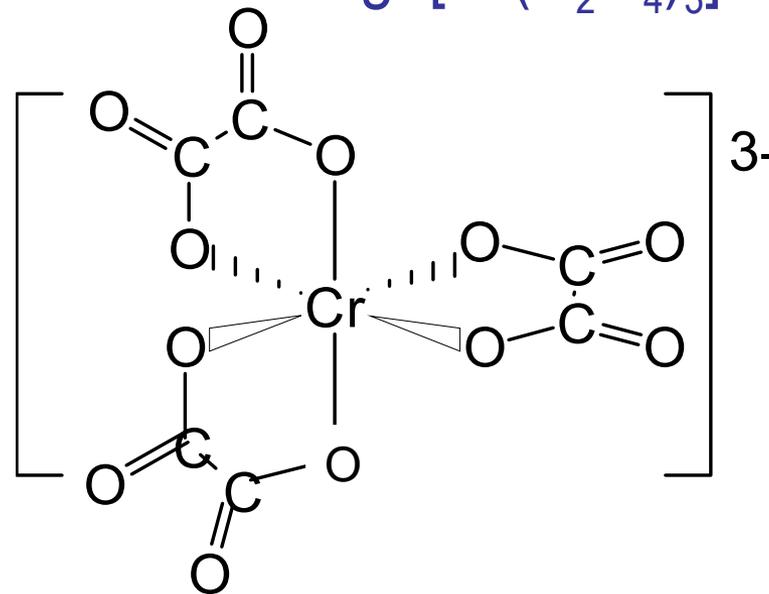
ethanedioate
($\text{C}_2\text{O}_4^{2-}$)



e.g. $[\text{Cr}(\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2)_3]^{3+}$



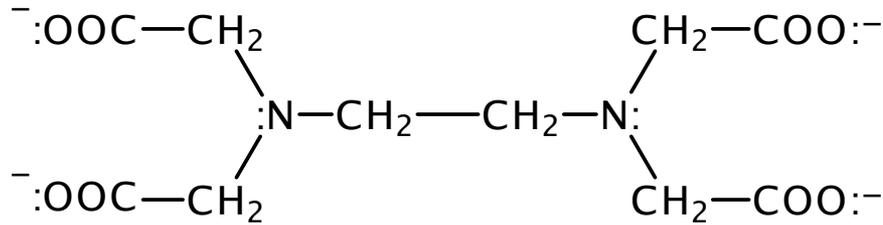
e.g. $[\text{Cr}(\text{C}_2\text{O}_4)_3]^{3-}$



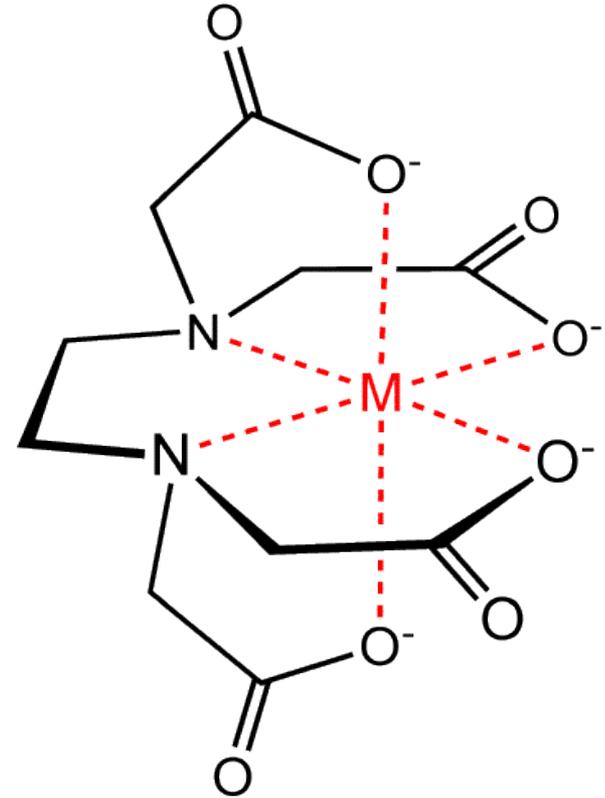
COMPLEX FORMATION

Multidentate ligands – form several co-ordinate bonds

EDTA⁴⁻



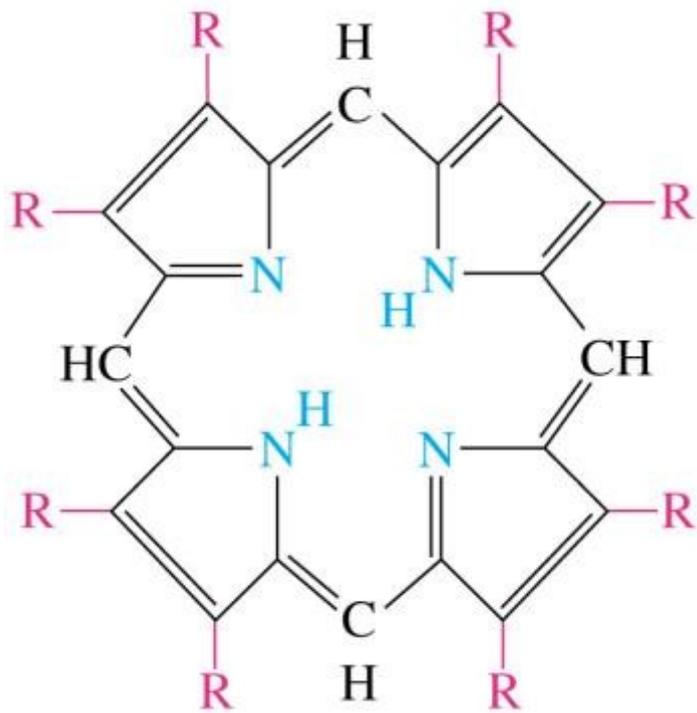
e.g. [Cu(EDTA)]²⁻



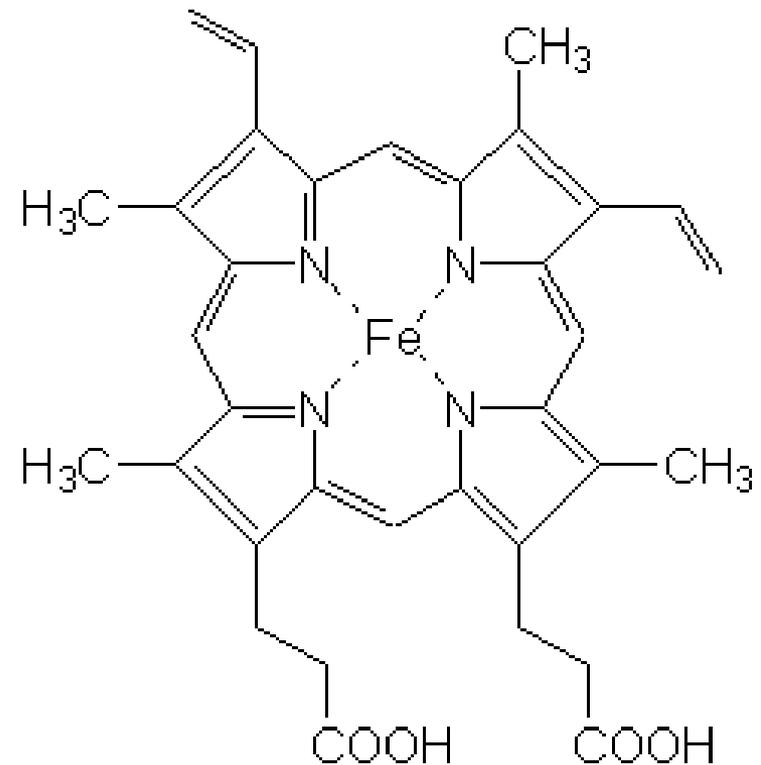
COMPLEX FORMATION

Multidentate ligands – form several co-ordinate bonds

porphyrin



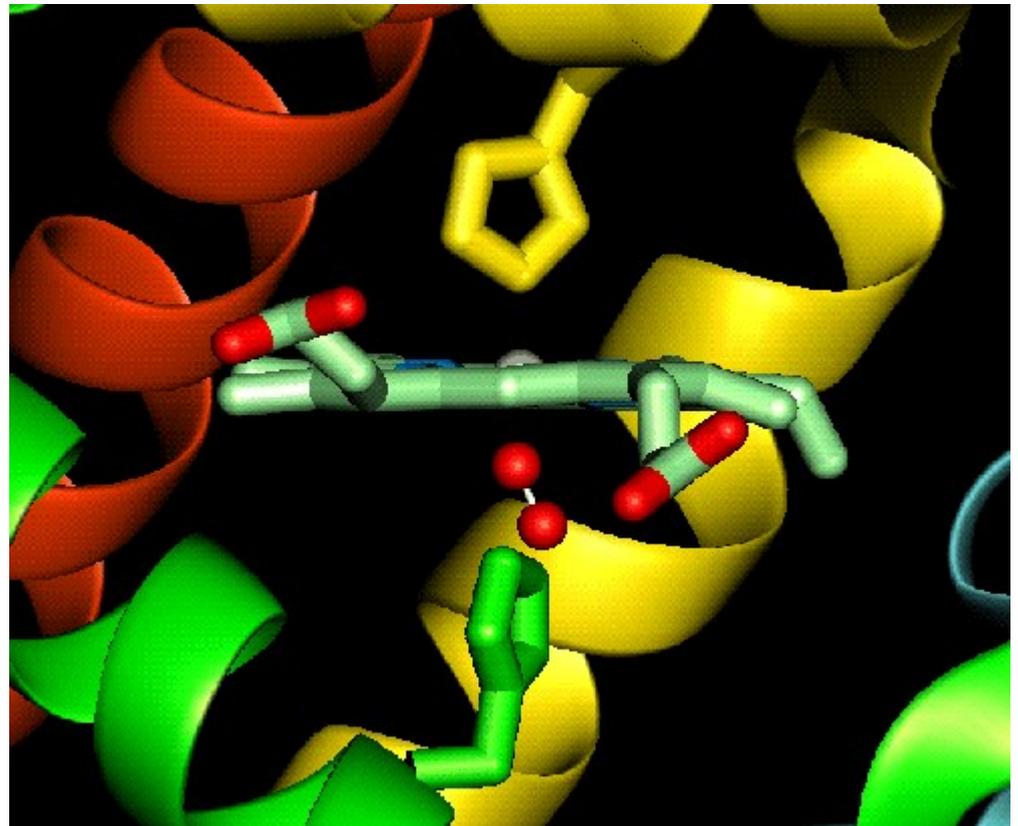
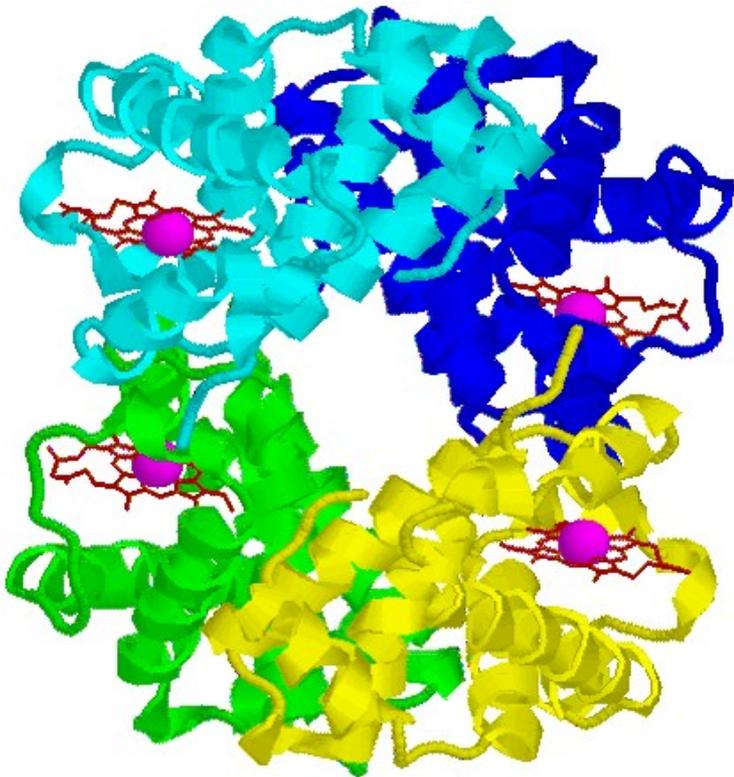
e.g. haem



COMPLEX FORMATION

Multidentate ligands – form several co-ordinate bonds

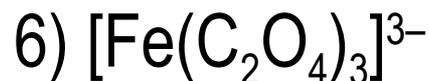
haemoglobin



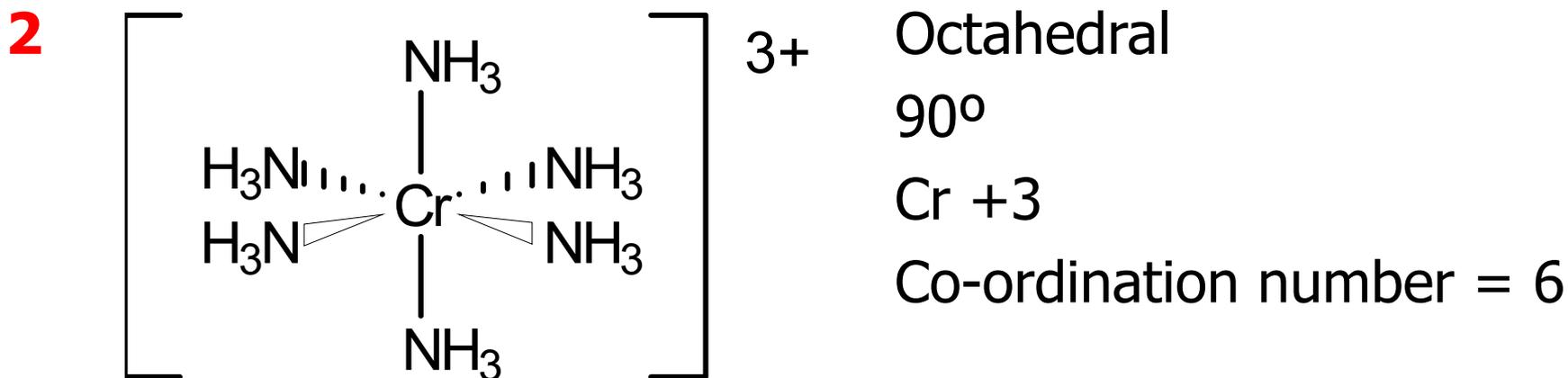
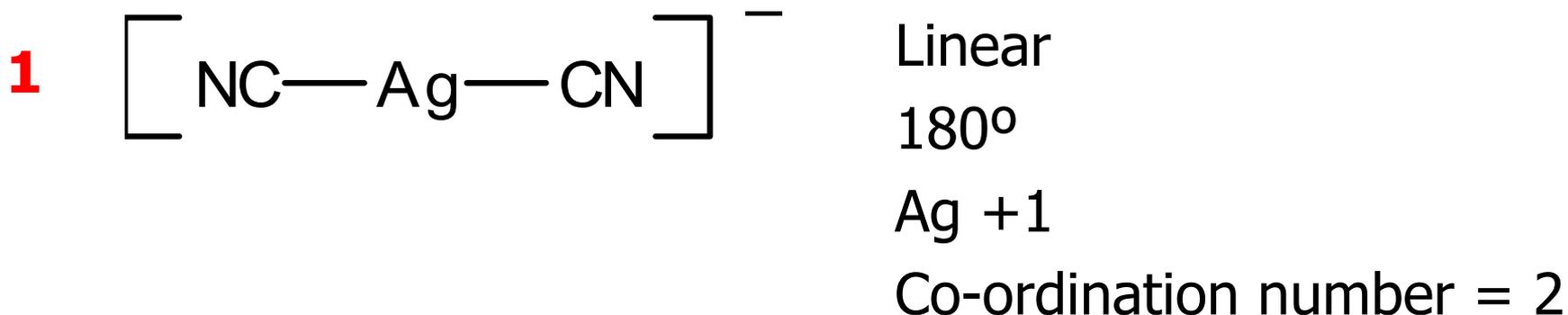
SHAPES OF COMPLEX IONS

For each of the following complexes:

- Draw the complex.
- Name the shape.
- Show bond angles.
- Give the metal oxidation state.
- Give the co-ordination number.

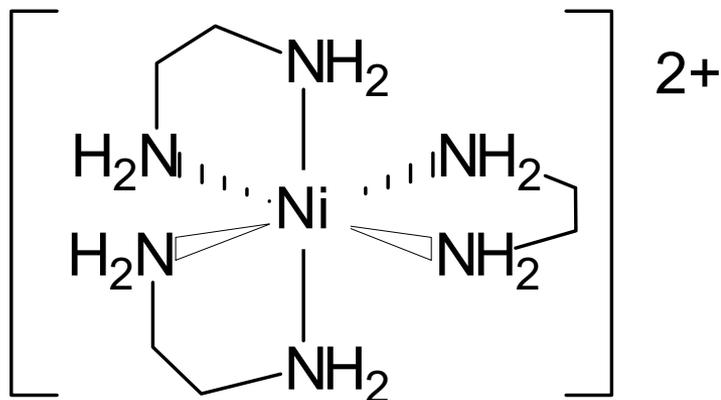


SHAPES OF COMPLEX IONS



SHAPES OF COMPLEX IONS

3



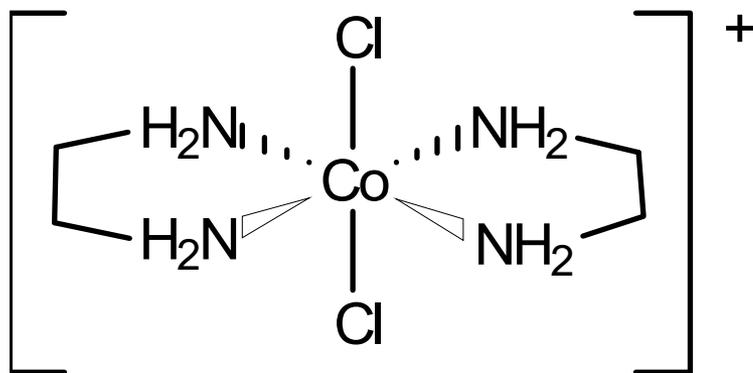
Octahedral

90°

Ni +2

Co-ordination number = 6

4



Octahedral

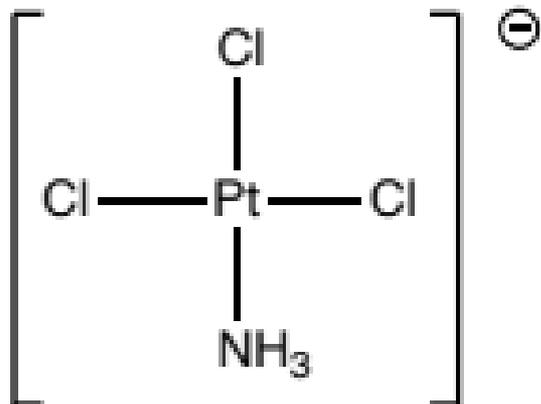
90°

Co +3

Co-ordination number = 6

SHAPES OF COMPLEX IONS

5



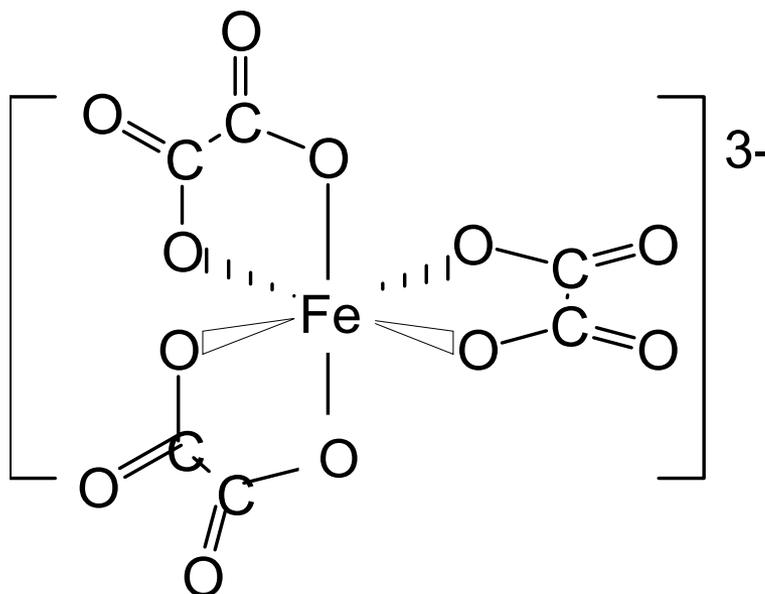
Square planar

90°

Pt +2

Co-ordination number = 4

6



Octahedral

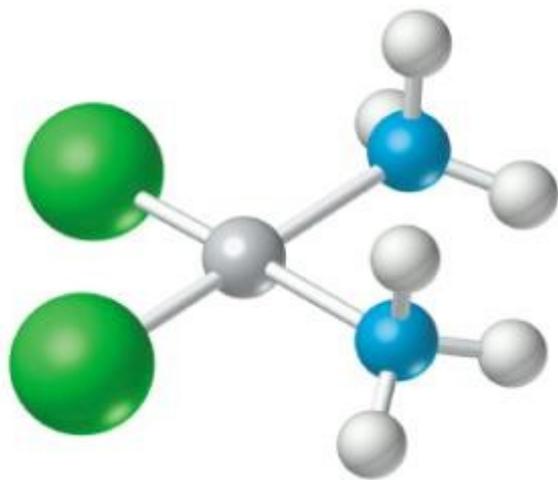
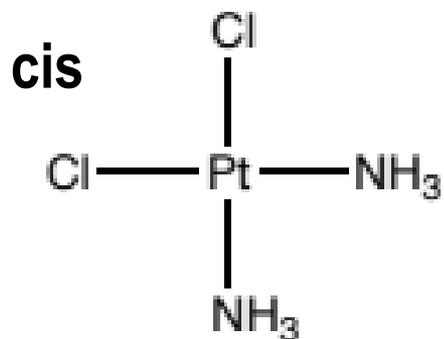
90°

Fe +3

Co-ordination number = 6

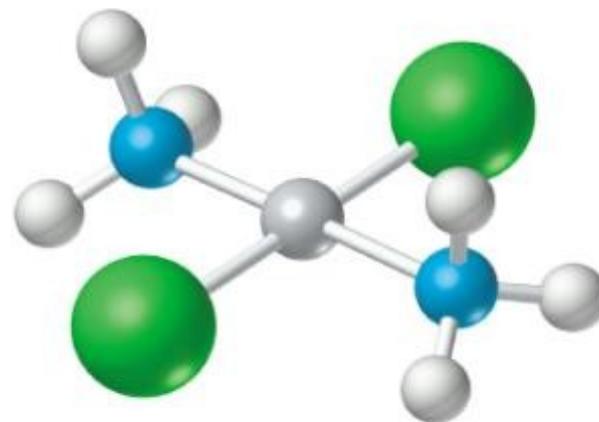
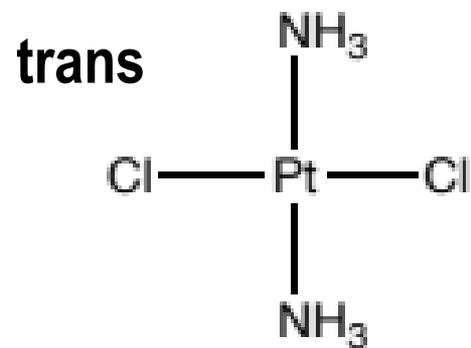
STEREISOMERISM IN COMPLEXES

E-Z Isomerism



cis-[PtCl₂(NH₃)₂]

e.g. [PtCl₂(NH₃)₂]

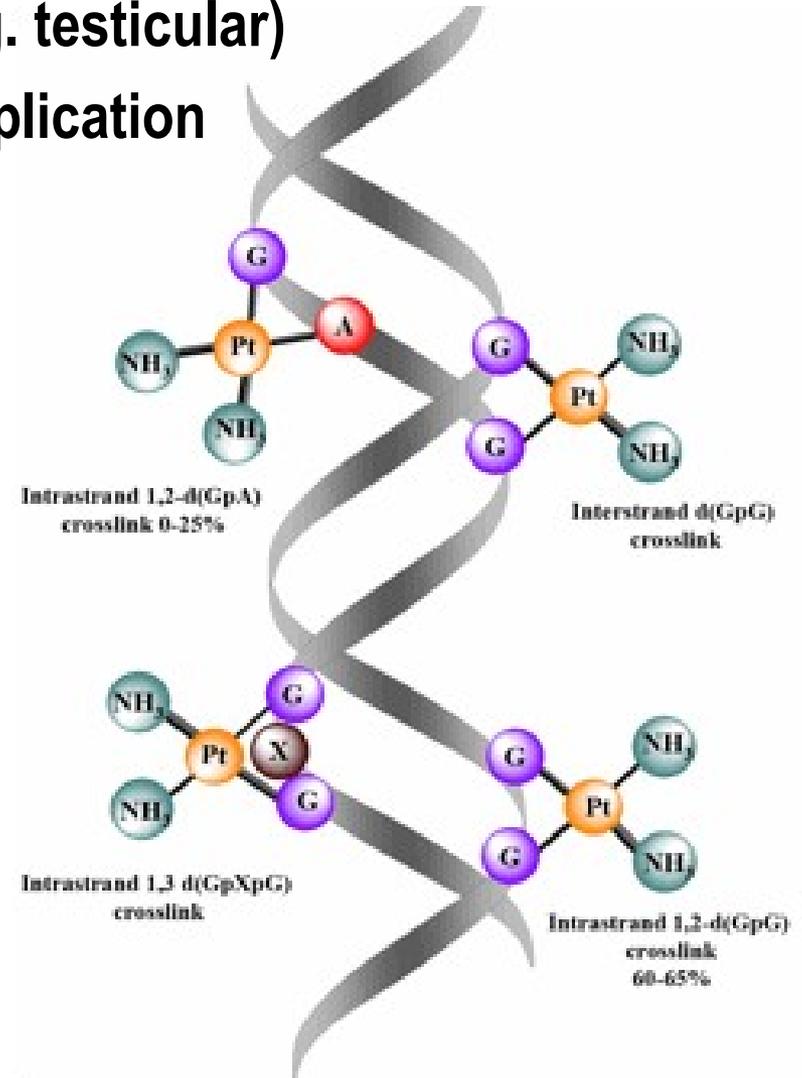
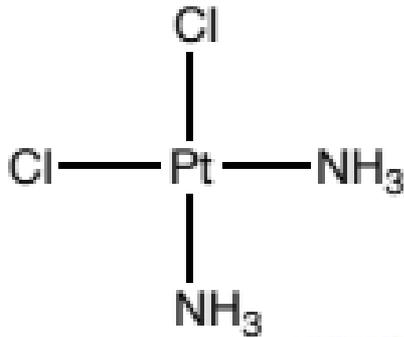


trans-[PtCl₂(NH₃)₂]

CIS-PLATIN

Very effective drug to fight cancer (e.g. testicular)

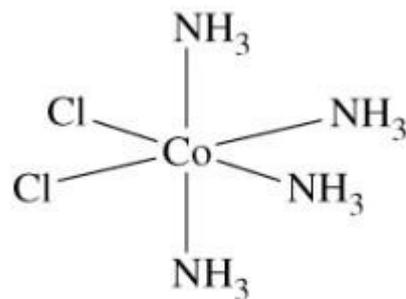
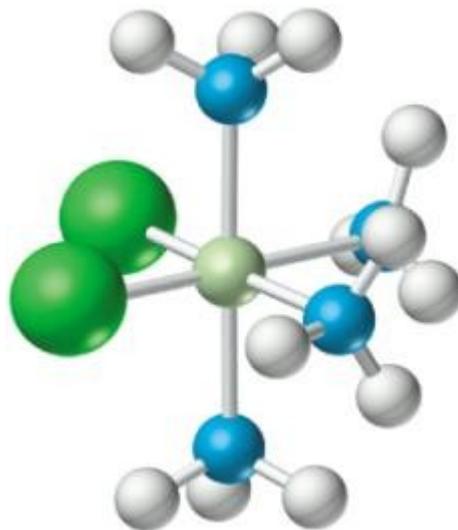
Binds to guanine in DNA and stops replication



STEREISOMERISM IN COMPLEXES

E-Z Isomerism

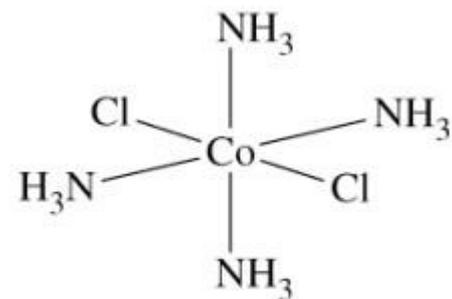
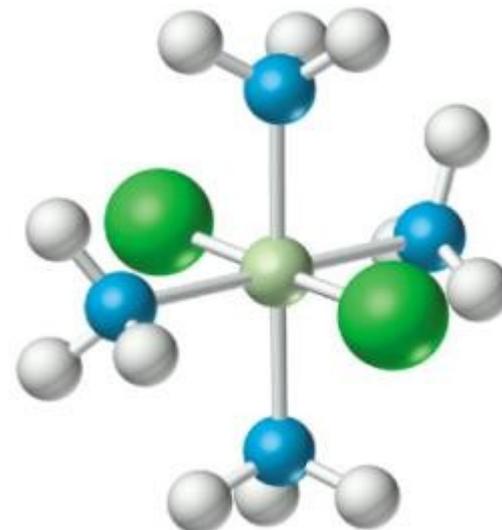
e.g. $[\text{CoCl}_2(\text{NH}_3)_4]^+$



cis- $[\text{CoCl}_2(\text{NH}_3)_4]^+$

(purple)

(a)



trans- $[\text{CoCl}_2(\text{NH}_3)_4]^+$

(green)

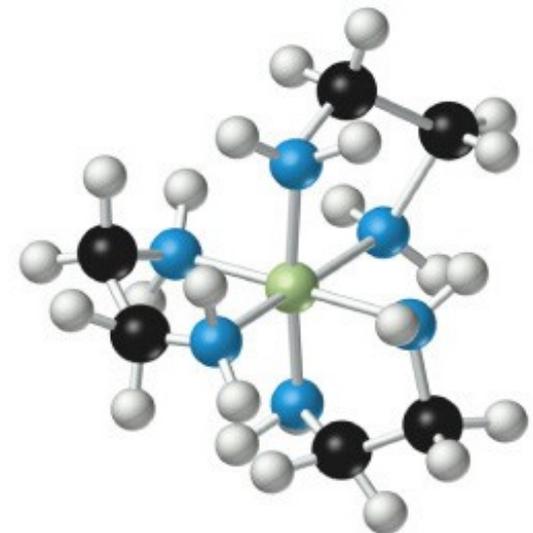
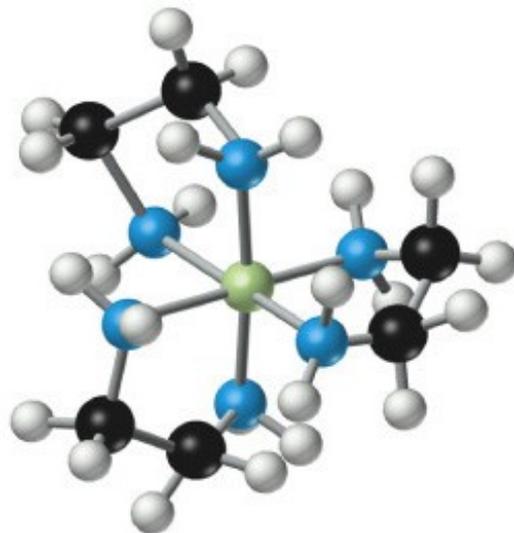
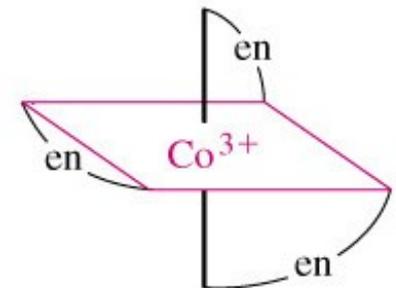
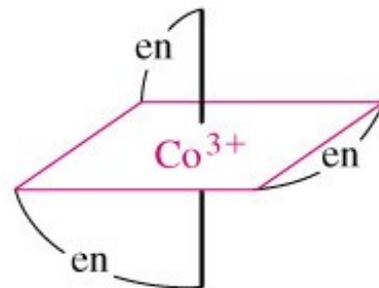
(b)

STEREISOMERISM IN COMPLEXES

Optical Isomerism

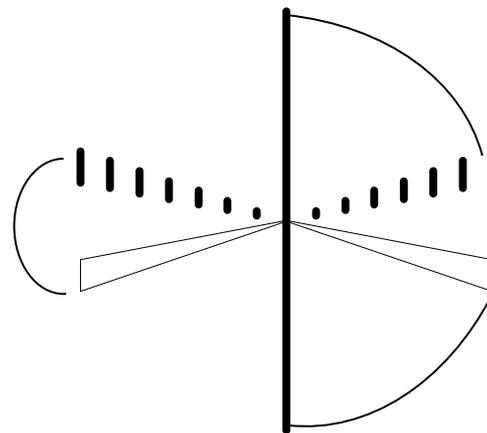
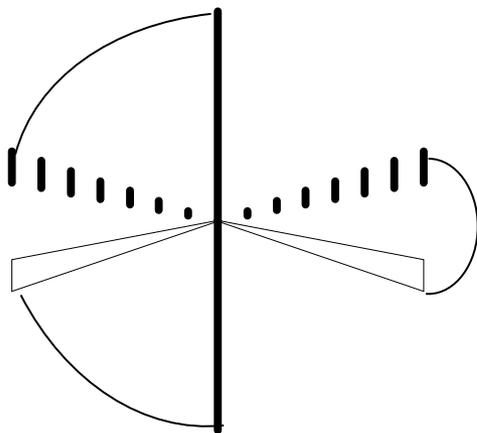
e.g. $[\text{Co}(\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2)_3]^{3+}$

Mirror

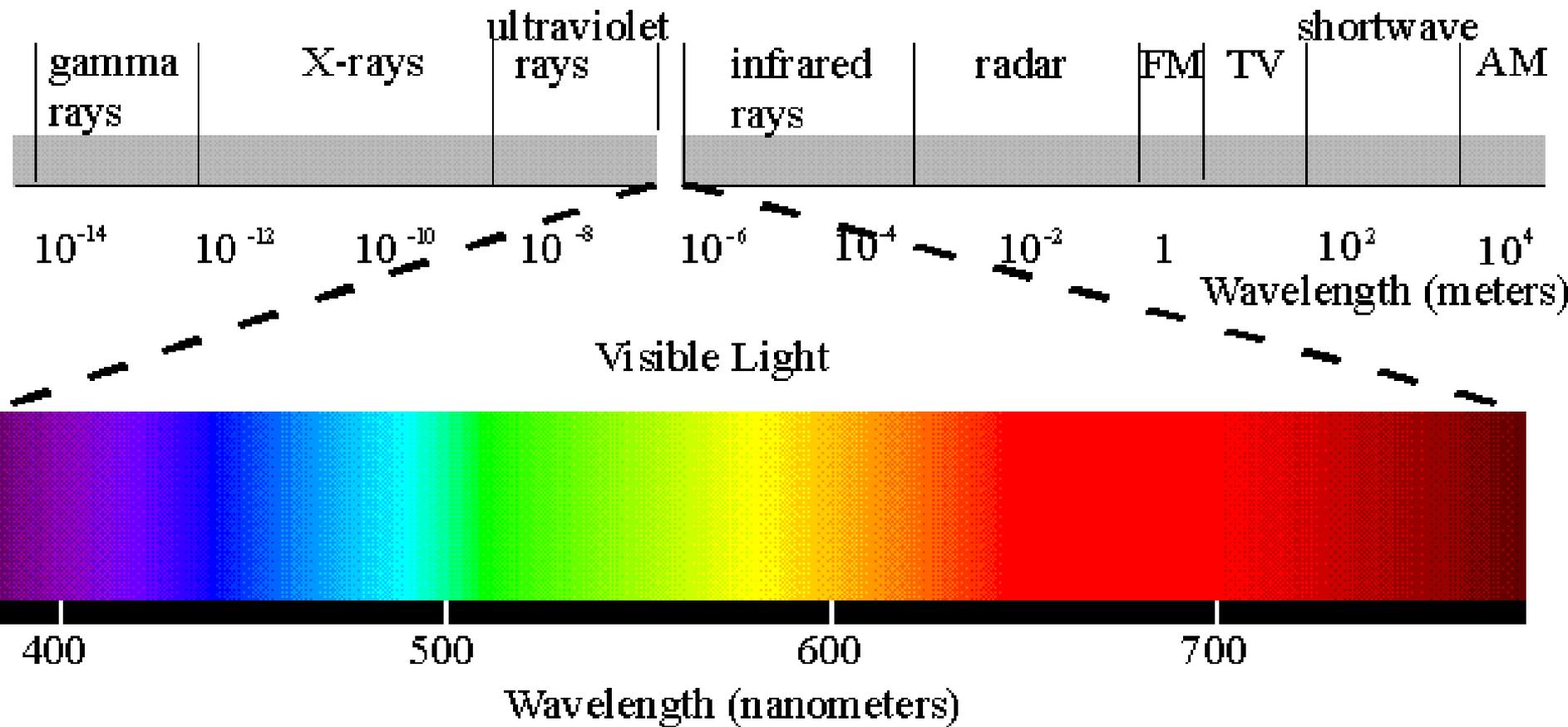


STEREISOMERISM IN COMPLEXES

Optical Isomerism

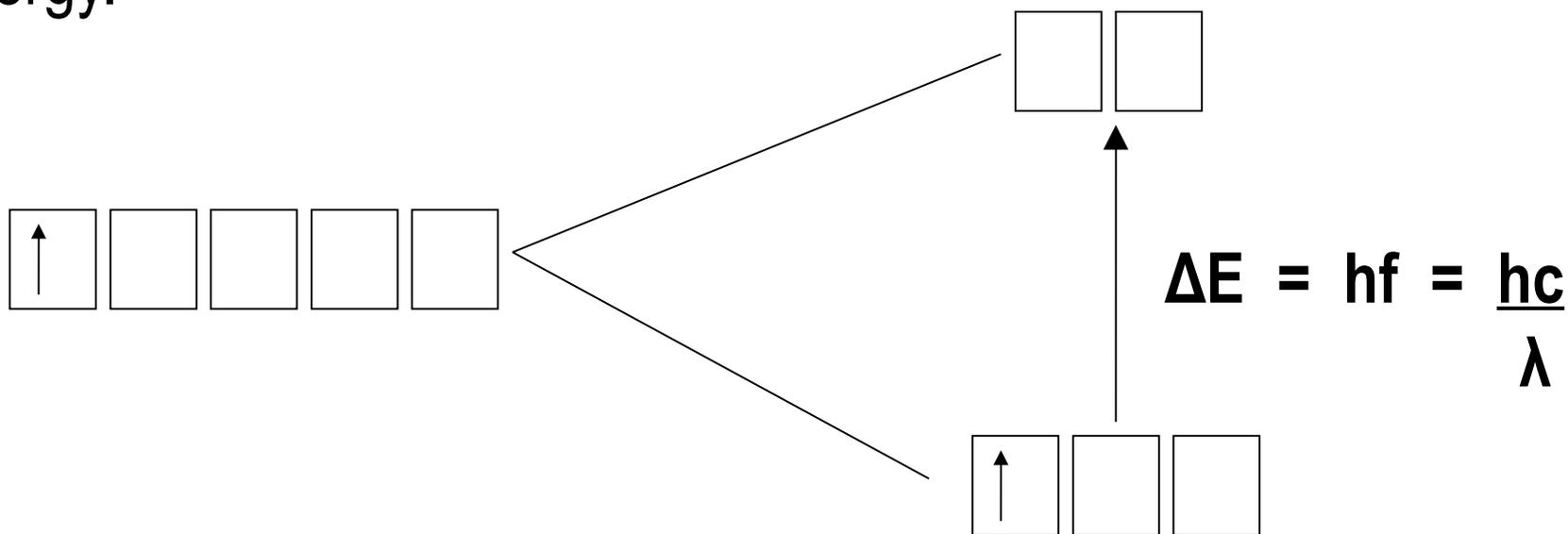


FORMATION OF COLOURED IONS



FORMATION OF COLOURED IONS

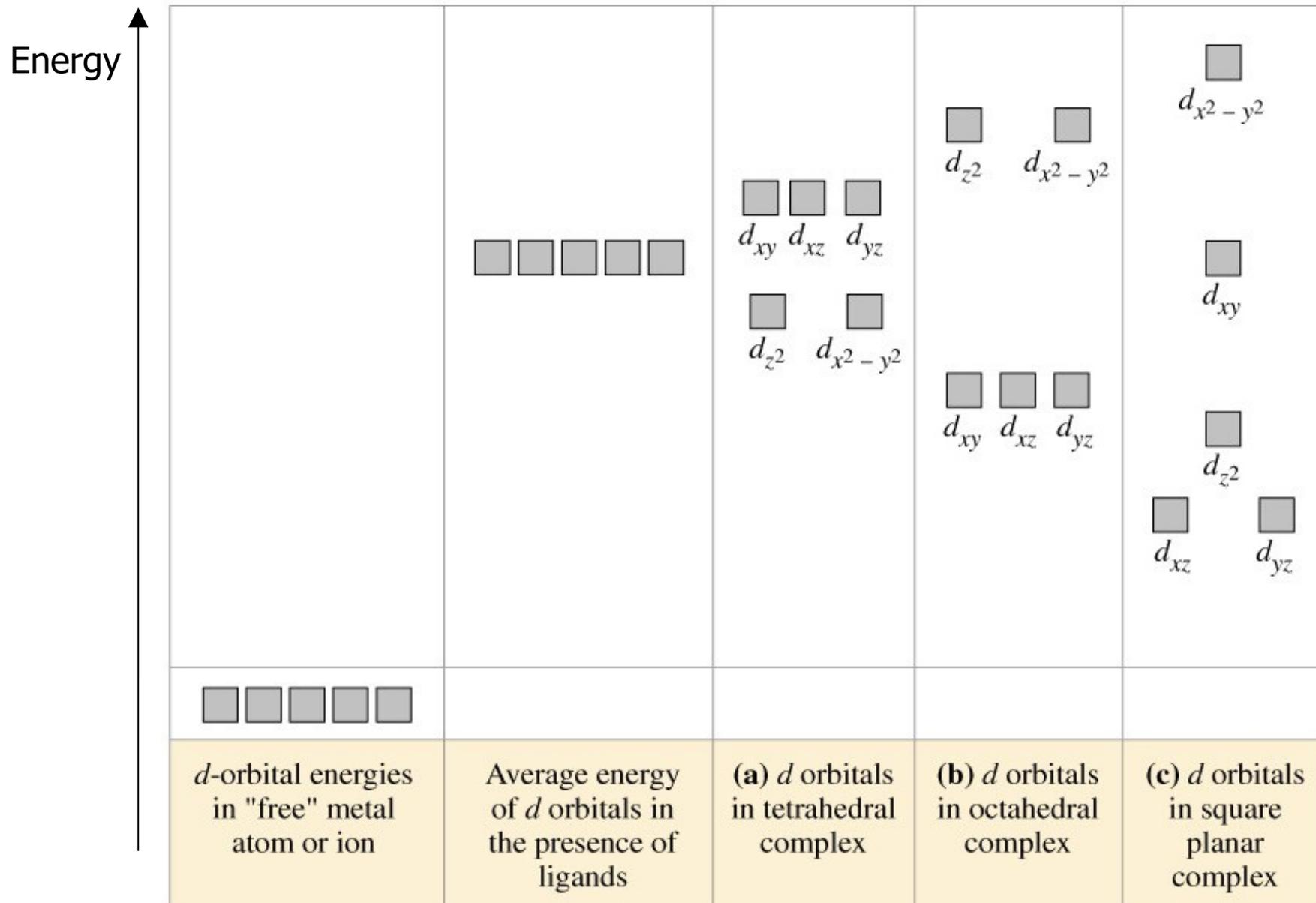
Once ligands bond, the five d orbitals are no longer have the same energy.



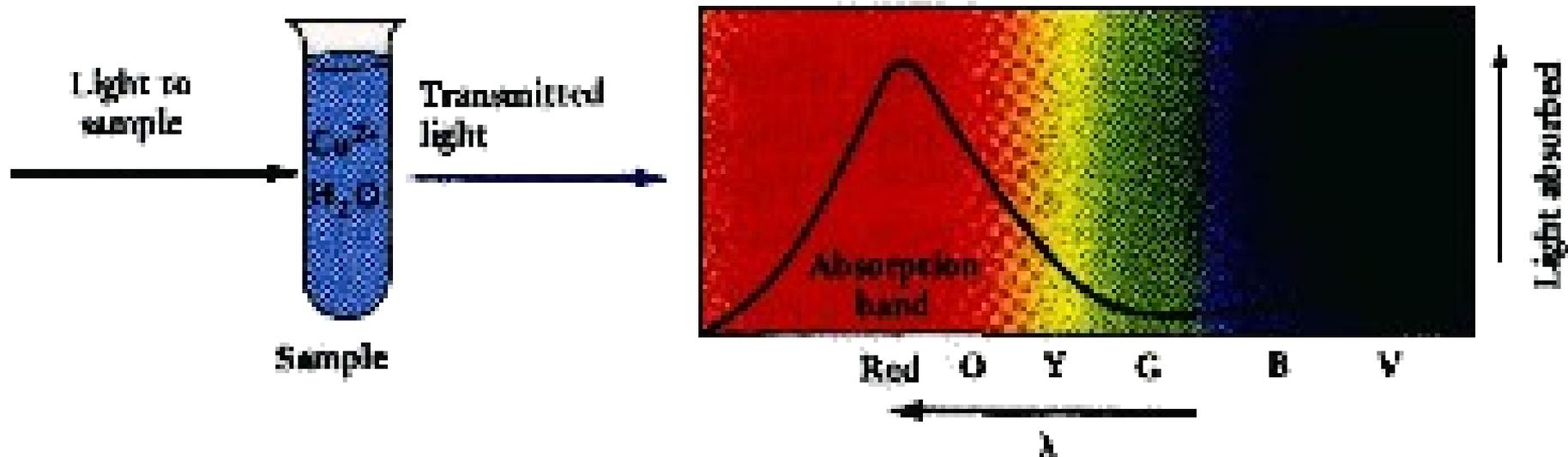
Energy is absorbed to excite electrons from the lower d orbitals to the higher d orbitals.

This energy is in the uv/visible region.

FORMATION OF COLOURED IONS



FORMATION OF COLOURED IONS



The colour you see is what is left after some colours are absorbed by the metal to excite electrons.

FORMATION OF COLOURED IONS

The size of the energy gap between the d-orbitals, and so the colour is affected by changes in:

1) the metal



blue

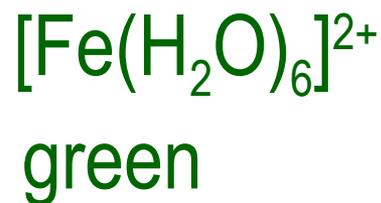
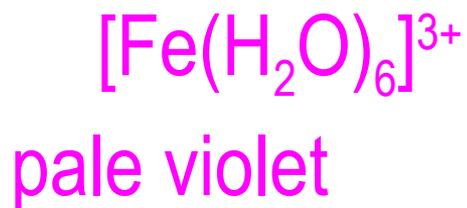


green

FORMATION OF COLOURED IONS

The size of the energy gap between the d-orbitals, and so the colour is affected by changes in:

2) the oxidation state



FORMATION OF COLOURED IONS

The size of the energy gap between the d-orbitals, and so the colour is affected by changes in:

3) the ligands



blue



deep blue

FORMATION OF COLOURED IONS

The size of the energy gap between the d-orbitals, and so the colour is affected by changes in:

4) the co-ordination number



blue



yellow

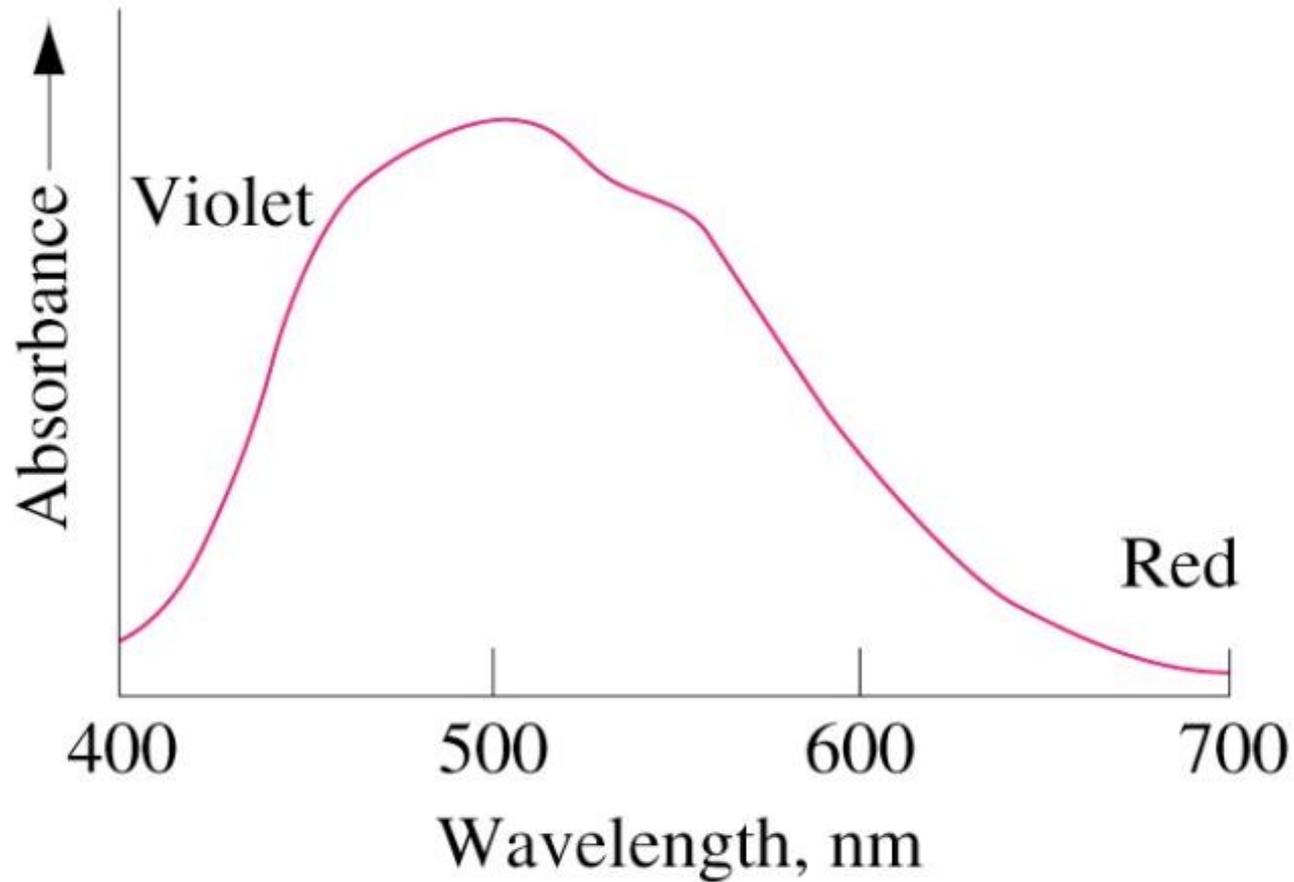
FORMATION OF COLOURED IONS

UV/Visible spectroscopy

- Frequencies at which complexes absorb can be measured by uv/visible spectroscopy.
- Light is passed through complex and the amount passing through measured.



FORMATION OF COLOURED IONS



FORMATION OF COLOURED IONS

Colorimetry

- The more concentrated the solution, the more it absorbs.
- This can be used to find the concentration of solutions – this is done in colorimeters.
- For some ions, a ligand is added to intensify the colour.
- The strength of absorption of solutions of known concentration is measured and a graph produced.
- The concentration of a solution of unknown concentration can be found by measuring the absorption and using the graph.

FORMATION OF COLOURED IONS

Colorimetry

