

Optical Properties of Coordination Complexes:

The striking colors exhibited by transition metal complexes are caused by excitation of an electron from a lower-energy 'd' orbital to a higher-energy 'd' orbital, which is called a d-d transition.

For a photon to effect such a transition, its energy must be equal to the difference in energy between the two 'd' orbitals, which depends on the magnitude of Δ_o .

The magnitude of Δ_o depends on the type of ligands coordinated to the metal center, which influence the color of coordination complexes.

For example:

The complex $[\text{Cr}(\text{NH}_3)_6]^{3+}$ has strong-field ligands and a relatively large Δ_o . Consequently, it absorbs relatively high-energy photons, corresponding to blue-violet light, which gives it a yellow color.

A related complex with weak-field ligands, the $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$ ion, absorbs lower-energy photons corresponding to the yellow-green portion of the visible spectrum, giving it a deep violet colour.

$[\text{Fe}(\text{H}_2\text{O})_6]\text{SO}_4$ appears blue-green

\Rightarrow weak field ligand (or) high spin complex

\Rightarrow Absorbs photons in the lower-energy or higher wavelength (Red wavelength).

$\text{K}_4[\text{Fe}(\text{CN})_6]$ appears pale yellow.

\Rightarrow strong field ligand (or) low spin complex

\Rightarrow Absorbs photons in the higher-energy or lower wavelength (Blue wavelength)

In general,

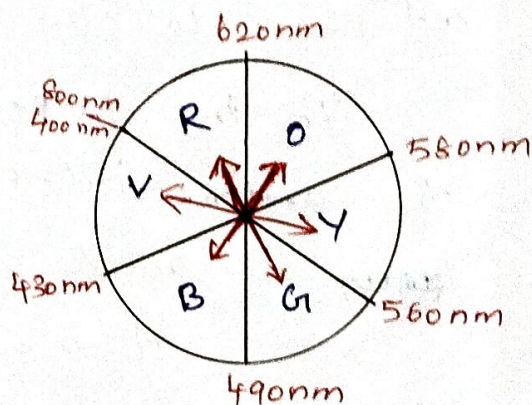
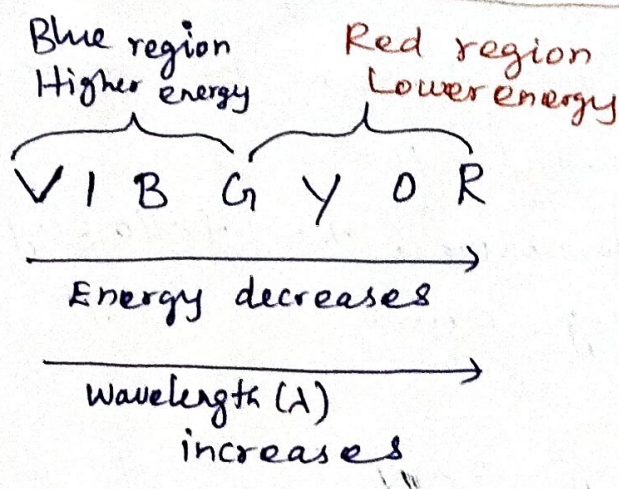
* Strong-field ligands cause a large split in the energies of d orbitals of the central metal atom (large Δ_0).

* Transition metal Coordination Compounds with these ligands are yellow, orange or red because they absorb higher-energy violet or blue light.

* On the other hand, Coordination Compounds of transition metals with weak-field ligands are often blue-green, blue or indigo because they absorb lower-energy yellow, orange or red light.

The relationship between the Δ_0 and the energy of the photons are absorbed in the d-d transition is given by equating Planck's equation to the crystal field splitting parameter:

$$E = h\nu = \frac{hc}{\lambda} = \Delta_0$$

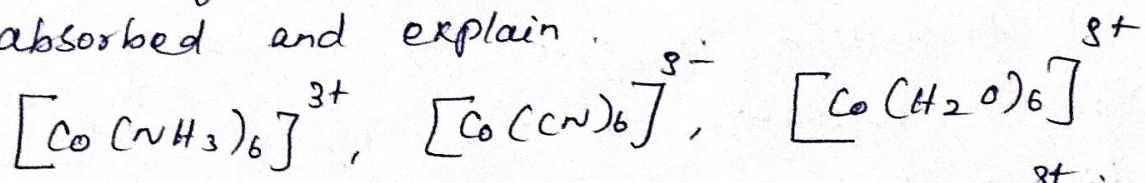


Complementary Colour wheel.

[Consider, relative correlation between Observed color (to the eye) and the wavelength of the light that is absorbed.]

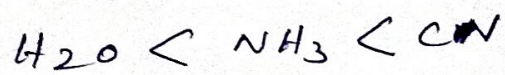
- * 400 nm violet light absorbed \rightarrow Green-yellow observed
- * 430 nm Blue light absorbed \rightarrow Orange observed.
- * 450 nm Blue light absorbed \rightarrow Yellow observed.
- * 490 nm - Blue-green light absorbed \rightarrow Red observed.
- * 570 nm - yellow-green light absorbed \rightarrow Violet observed.
- * 580 nm - yellow-light absorbed \rightarrow Dark blue observed
- * 600 nm - orange light absorbed \rightarrow Blue observed
- * 650 nm - Red light absorbed \rightarrow Green observed.

Arrange the following complexes in their increasing order of the wavelength of light absorbed and explain.



Since all the complexes containing Co^{3+} ion as the central metal ion, the wavelength of light absorbed depends on the magnitude of Δ_0 . The Δ_0 depends on the types of ligands attached to the metal ion.

In the given problem, the following is the ~~order~~ increasing order of strength of the ~~ligand~~ ligands.



$[\text{Co}(\text{CN})_6]^{3-} \rightarrow$ Complex consisting of strong ligand
 \rightarrow Splitting of d orbital is large i.e.
 \rightarrow Magnitude of Δ_0 is high.
 \rightarrow Absorbs photons in higher energy or lower wavelength.

$[\text{Co}(\text{H}_2\text{O})_6]^{2+} \rightarrow$ Complex consisting of weak ligand
 \rightarrow Splitting of d orbital is small i.e. magnitude of Δ_0 is low.
 \rightarrow Therefore absorbs photons in lower energy or higher wavelength.

$[\text{Co}(\text{NH}_3)_6]^{3+} \rightarrow$ Intermediate ligand.

\therefore The increasing order of the wavelength of light absorbed is

