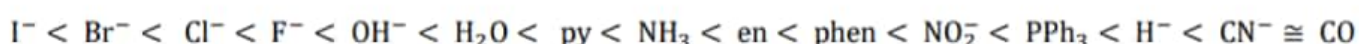


## The Spectrochemical Series

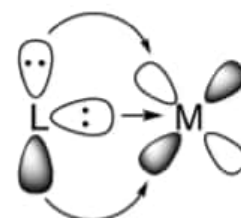
**Introduction.** Inorganic chemists use specific terms to indicate the various properties of ligands. These include things like “strong field”, “weak field”, “hard”, “soft”, “monodentate”, “chelating”, or “pi-donor”. These ligand properties influence the stability and electronic structure of the complexes that are formed when they are combined with a metal atom or ion. One useful way to estimate the electronic effects that a ligand has on a metal is to find the ligand’s position in the spectrochemical series, shown below. The spectrochemical series places ligands in order of increasing  $\Delta$ ; that is, the magnitude of the energy difference between the d-orbitals that an electron jumps between when light is absorbed.



Ligands on the left are commonly referred to as weak-field ligands, and ligands on the right side are called strong-field ligands. It’s important to remember that this series does not necessarily correspond to the binding strength of a ligand; this is just about  $\Delta$ . Ligands are broken up into three major categories:

**$\sigma$ -donor ligands:** **All ligands are  $\sigma$ -donors.** The ligand lone pair that forms a bond with the  $L \rightarrow M$  metal will maximize its overlap with the metal’s orbital by pointing directly at it. The more readily a ligand can share its lone pair, the higher its position on the spectrochemical series. This is why hydride is so high in the series; it can’t hold on to its lone pair well at all.<sup>1</sup>

**$\pi$ -donor ligands:** Some ligands have extra lone pairs on their binding atom beyond the one that forms the  $\sigma$ -donor interaction. These additional lone pair electrons can also interact with the metal’s d-orbital in a side-on fashion, creating an additional bond. Despite this, we don’t generally draw bonds to  $\pi$ -donor ligands as double bonds because the interaction is usually very weak. Strangely,  $\pi$ -donor interactions actually **cause  $\Delta$  to shrink** compared to a  $\sigma$ -donor of equal strength. Halide ions are the most common examples of this type of ligand. Don’t confuse the small  $\Delta$  value of halides for weak metal-ligand binding; halides can form extremely strong bonds with metals.



**$\pi$ -acceptor ligands:** Sometimes a ligand can donate electrons with its lone pair to form one bond, but also accept electrons from the metal with one of its empty orbitals. This phenomenon is sometimes called back-donation or back-bonding. The interaction is very strong, and results in **very large  $\Delta$  values**. If a ligand can kill you, chances are good that it’s a  $\pi$ -acceptor. In addition to creating large  $\Delta$  values,  $\pi$ -acceptors tend to bind very tightly to metals, sometimes irreversibly.



# What is spectrochemical series? Explain the difference between a weak field ligand and a strong field ligand

## Answer:

Crystal field theory describes the net change in crystal energy resulting from the orientation of d orbitals of a transition metal cation inside a coordinating group of ions also called ligands.

Crystal field splitting depends on the field produced by the ligand and the charge on the metal ion. An experimentally determined series based on the absorption of light by coordination compound with different ligands known as spectrochemical series.

Weak field ligands induce less splitting of the crystal fields. They form complexes with high spins.

Examples: chloride ions, fluoride ions etc.

Strong field ligands result in greater splitting of the crystal field. They form complexes with low spins.

Examples: Co and cyanide ion.

Spectrochemical series arranges ligands in order of their field strength as:

