

Lesson 14: Coloured Transition Metal Complexes

- *Read through the lesson notes. You can write them out, print them or save them.
- *Once you have tried to understand the lesson answer the questions that follow at the end.
- *The answers to the question sheet(s) will be posted later and this will allow you to self-evaluate your learning.

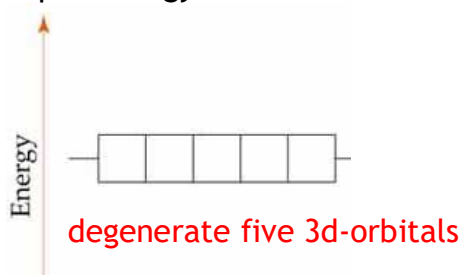
Learning Intentions

- Learn why many transition metal complexes are coloured.
- Learn about the use of spectroscopy to analyse coloured transition metal complexes.

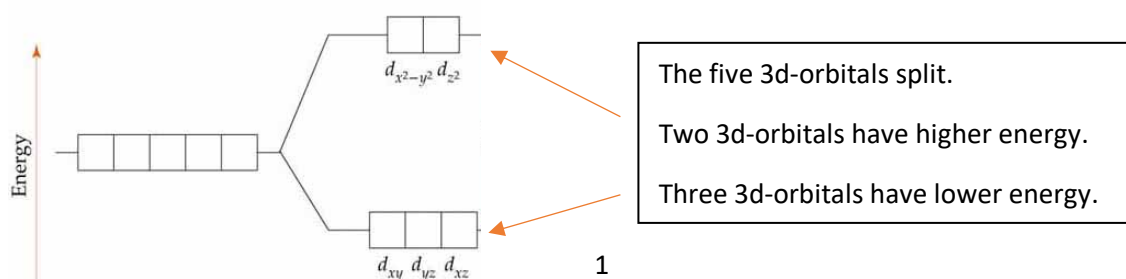
Background

We have previously touched on the fact that many transition metal complexes are coloured. In this lesson we look at why this is the case. Moreover, from the earlier part of Unit 1 we discussed emission spectroscopy and absorption spectroscopy. In this lesson we look specifically at how spectroscopy can be used to analyse many of the coloured transition metal complexes.

In a free transition metal atom or ion the five 3d-orbitals are degenerate, i.e. of equal energy.

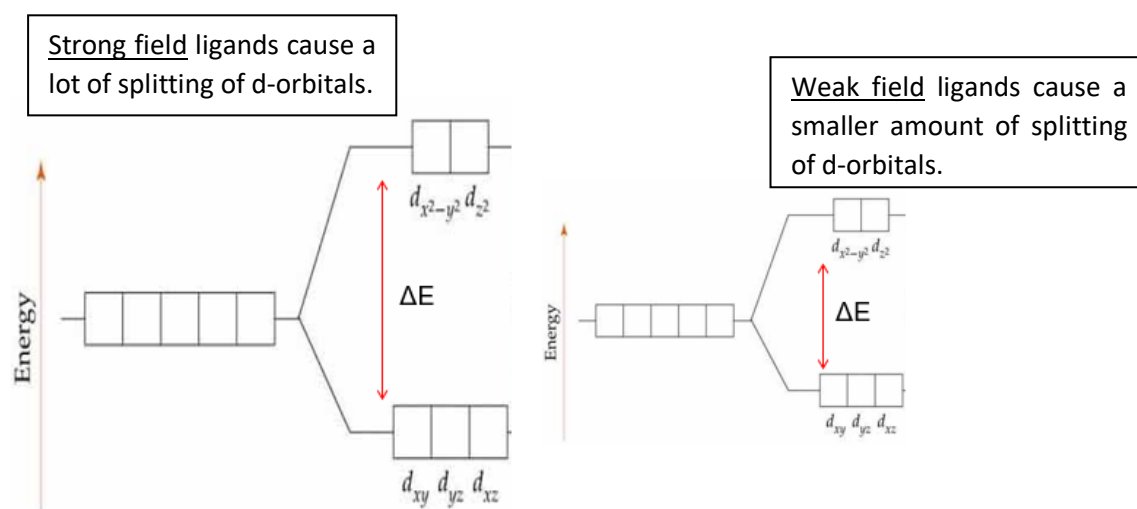
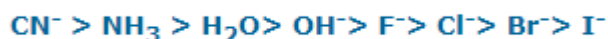


When a transition metal complex forms, the ligands break the degeneracy and cause the five 3d-orbitals to split. The ligands approach along the axes x, y and z. Two of the 3d-orbitals lie along these axes and are repelled by the approaching ligands. This causes them to have slightly more energy and the remaining three 3d-orbitals to have slightly less energy.

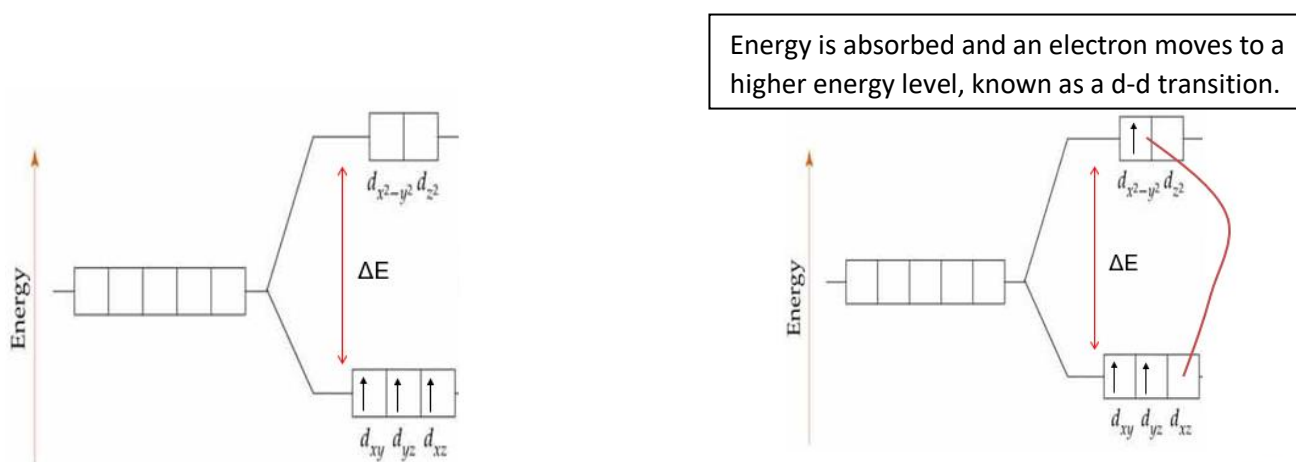


All ligands DO NOT split the d-orbitals to the same extent as some ligands cause a greater degree of splitting. The SPECTROCHEMICAL SERIES indicates the strength of ligands and therefore allows us to compare the extent of splitting that ligands may cause.

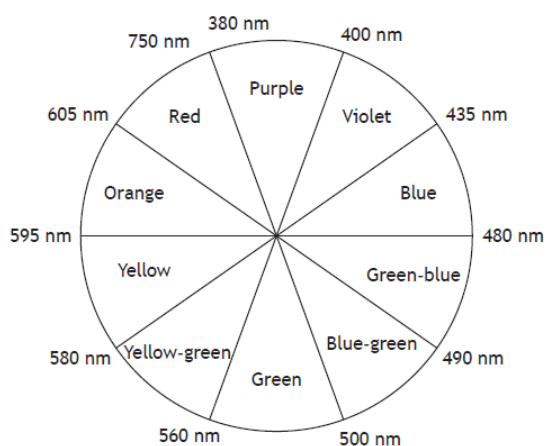
The list below is a shortened version of the spectrochemical series and shows that for example the cyanido ligand (CN^-) is stronger than the ammine ligand (NH_3). Therefore, the cyanido ligand will cause a greater degree of splitting than the ammine ligand. **You do not need to memorise the spectrochemical series.**



Transition metal complexes absorb light due to the split in the d-orbitals. Electrons in the lower d orbitals can absorb energy and move to the higher energy d orbitals. If the energy absorbed in this d-d transition is in the visible region of the electromagnetic spectrum the colour of the transition metal complex will be the **COMPLEMENTARY** colour (opposite colour) of the colour absorbed.



Page 20 of data booklet contains a colour wheel and will help you to work out the colour of complexes given data on the wavelength of energy absorbed by the electrons during d-d-transitions.



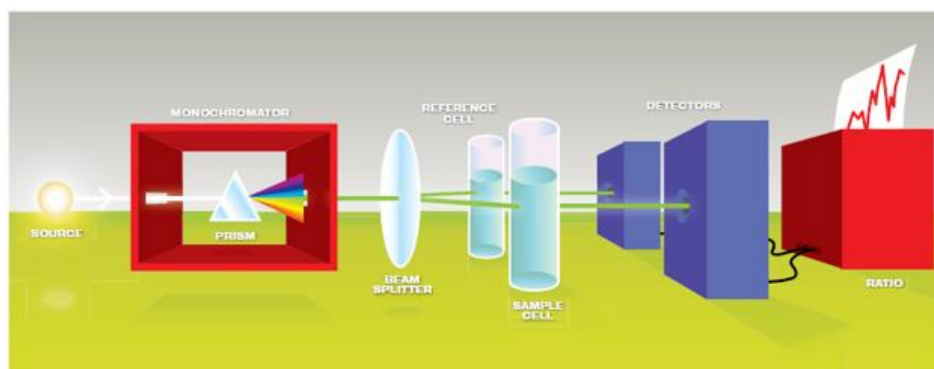
A copper complex may appear blue as it absorbs energy corresponding to the yellow region of the electromagnetic spectrum, i.e. a wavelength between 580nm and 595nm.

Ultraviolet-Visible Spectroscopy

The effects of d-d transitions can be studied using spectroscopy. If the absorbed energy is in the visible part of the electromagnetic spectrum (400nm-700nm), giving a coloured compound, visible spectroscopy is used. If the absorbed energy is in the ultraviolet part of the electromagnetic spectrum (200nm-400nm), the compound will be colourless and ultraviolet spectroscopy is used.

During the Researching Chemistry Unit of the Advanced Higher course we look in greater detail at two instruments called a COLORIMETER and SPECTROPHOTOMETER. These instruments allow chemists to measure the absorbance of ultraviolet or visible light of a sample, i.e. in many cases transition metal complexes.

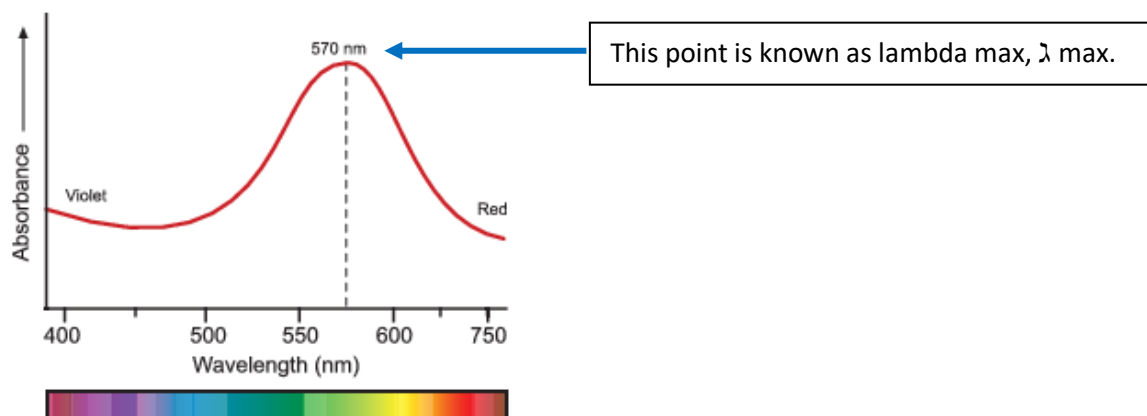
The exact manner in which the instruments work is not required at this stage, however a brief summary has been included for your own information.



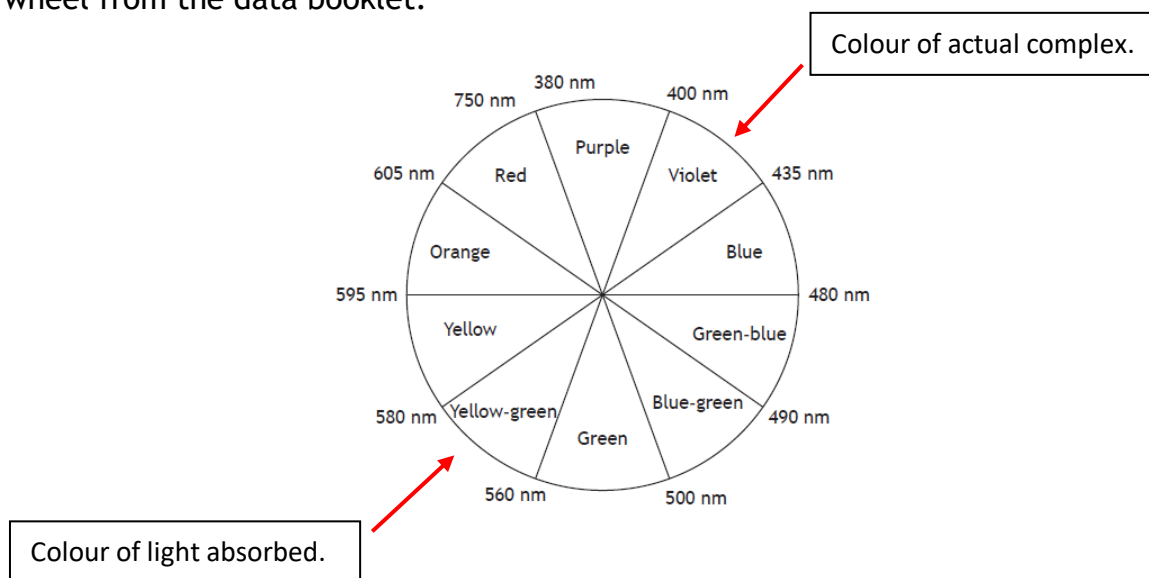
Incident radiation (radiation hitting the sample) is passed through a sample cell and a reference cell. The spectrophotometer measures the intensity of radiation transmitted through the sample and compares this with the intensity of the incident radiation through the reference sample (normally distilled water). The outcome is

referred to as a spectrum for the sample and is a plot of light intensity or absorbance against wavelength.

The spectrum for a complex is shown below.



As the complex is mainly absorbing yellow-green light (around 570nm) the colour of the actual complex is violet as this is the complementary colour using the colour wheel from the data booklet.



The absorbance of a sample is proportional to its concentration, i.e. the more concentrated a sample is, the more light it will absorb. As a result ultraviolet-visible spectroscopy can be used to determine the rate of a reaction by determining the concentration of a substance in a reaction. Moreover, it can be used to analyse enzyme activity as well as environmental applications such as metal content in water samples.

Additional Resources

-Watch the clips from Youtube.

<https://www.youtube.com/watch?v=d2CQPYo0WAA>

<https://www.youtube.com/watch?v=au21TCG8ZnQ>

-Read Scholar Section 3.4 and 3.5

-Read BrightRed text book pages 23 and 24

-Answer the questions from Sheet 1.18 and check the answers when you have completed them.

-If there are any questions regarding this lesson or the questions from sheet 1.18, then please leave a post on Microsoft Teams.



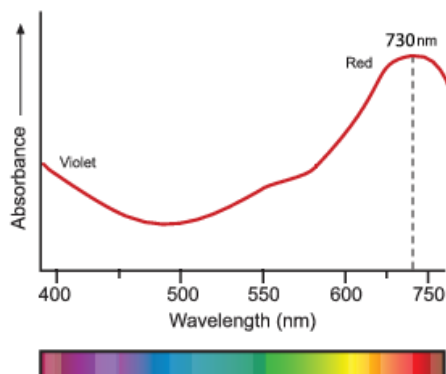
1.18 Coloured Transition Metal Complexes

1. The complex ion $[\text{Ni}(\text{OH}_2)_6]^{2+}$ is present in an aqueous solution of nickel sulfate. When concentrated hydrochloric acid is added to the solution the green colour changes to blue.

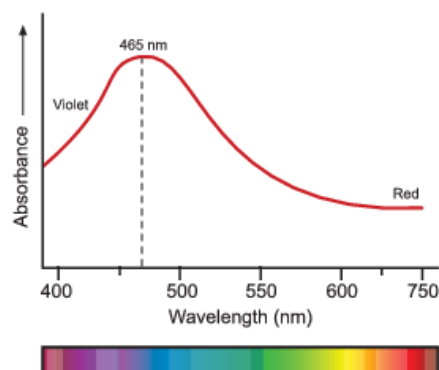
- Explain, with reference to the d-electrons, why the nickel ion is green coloured in this complex.
- Explain why addition of concentrated hydrochloric acid changes the colour of the complex.
- What does this indicate about the relative strength of the aqua ligands and chlorido ligands? Explain your answer.

2. A student analysed two chromium complexes using visible spectroscopy. The spectra are shown below.

Hexachloridochromate(III)



Hexaamminechromium(III)



- Write the formulae of the two complexes above.
 - What colour is Hexachloridochromate(III)?
 - What colour is Hexaamminechromium(III)?
 - The student repeated the analysis for the hexaamminechromium(III) complex using a sample that was diluted by 50%. Sketch the original spectrum and add a sketch to show the spectrum for the diluted sample.
 - Part of the spectrochemical series is: $\text{CN}^- > \text{NH}_3 > \text{Cl}^-$
Explain what the student would observe from the spectrum when analysing hexacyanidochromate(III).
3. In aqueous solution, the complex ion $[\text{Ti}(\text{OH}_2)_6]^{3+}$ has an available unoccupied energy level 239 kJ mol^{-1} above the highest occupied level.
- Name the titanium complex above.
 - What wavelength, in nm, of light will bring about the transition from the lower to the upper level?
 - Use page 20 of the data booklet to deduce the observed colour of the titanium complex.