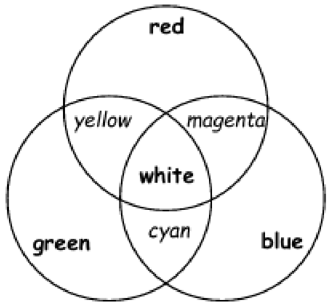
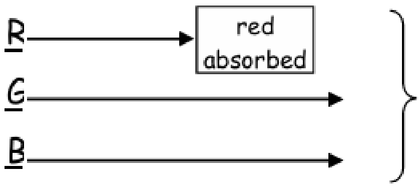
Colours and Complex Ions

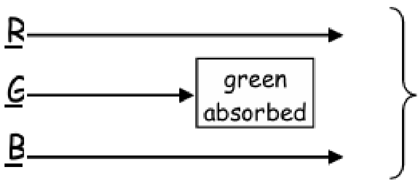
Transition metals ions (simple or complex) are often coloured

- ion absorbs light in certain parts of the visible spectrum
- remaining wavelengths are transmitted
- colour seen is complementary to colour absorbed

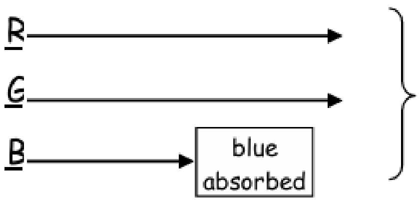




G + B transmitted
cyan (green/blue) observed



R + B transmitted
magenta (red/blue) observed



R + G transmitted
yellow (red/green) observed

In a free ion, all five 3d-orbitals are degenerate (of equal energy)

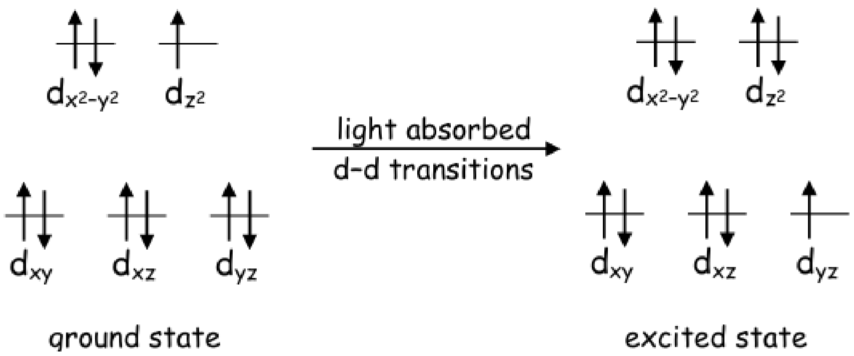
- 3d orbitals are labelled d_{xy}, d_{xz}, d_{yz}, $d_{x^2-y^2}$, d_{z^2}
- $d_{x^2-y^2}$ and d_{z^2} orbitals are raised to a higher energy level due to electrostatic repulsion from the ligands in the complex
- energy difference between the split in the d-orbitals depends on the ligand involved. Ligands are listed in the Spectrochemical Series

$$I^- < Br^- < Cl^- < F^- < H_2O < NH_3 < CN^-$$

Transition metals can absorb light because photons (at a particular energy and therefore particular wavelength) excite electrons in the lower d-orbitals (ground state) up to a higher energy d-orbital (excited state)

- this absorbed energy dissipates as heat energy and does not remerge as light energy

e.g. Cu^{2+} ion with electron arrangement [Ar] $3d^9$



- For Cu^{2+}, blue green is transmitted as red light is absorbed to excite a d-orbital electron.

<u>However</u>

- MnO_4^- ions have Mn in Oxidation State = 7
- Mn has electronic configuration of $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ in this state
- Mn has no electrons in 3d orbital in this state
- Purple colour is caused by different kind of electron transition

UV and Visible Absorption Spectroscopy

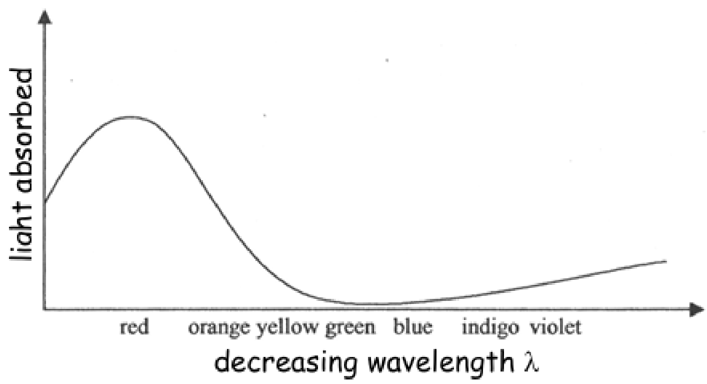
- Effect of d-d transitions can be studied using UV and visible spectroscopy

- UV and visible absorption spectroscopy involves the energy difference between and electron's ground and excited states being supplied by particular wavelengths in the UV and visible regions of the EM spectrum

    - UV λ = 200 – 400 nm
    - Visible λ = 400 – 700 nm

- The particular wavelengths used to promoted (excite) electrons are removed from the light passing through the sample and appear as dark lines in the transmitted light spectrum

- The spectrophotometer compares the reduced intensity of particular wavelengths from the sample against the original intensity of the light passing though the sample



Transition Metal Catalysis

- Transition metals often act as catalysts in a wide selection of chemical reactions

Process	Reaction	Catalyst Used
Haber	$N_2 + 3H_2 \rightarrow 2NH_3$	Fe granules
Contact	$SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$	V_2O_5
Ostwald	$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$	Pt gauze
Catalytic Converter in car exhaust	$4CO + 2NO_2 \rightarrow 4CO_2 + N_2$	Platinum Pt, Palladium Pd and Rhodium Rh
Preparation of Methanol	$CO + 2H_2 \rightarrow CH_3OH$	Copper
Preparation of Margarine	$C_{17}H_{33}COOH + H_2 \rightarrow C_{17}H_{35}COOH$	Nickel
Polymerisation of Alkenes	$n\ C_2H_4 \rightarrow (C_2H_4)_n$	Titanium compounds

- Transition metals can form a variable number of bonds due to the availability of unoccupied and half-filled d-orbitals

- This allows the easier formation of intermediate complexes

- This provides reaction pathways of lower energy to proceed

- The variability of oxidation state of transition metals is another important factor. The transition metal reverts to original oxidation state once the reaction is complete