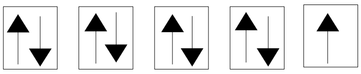
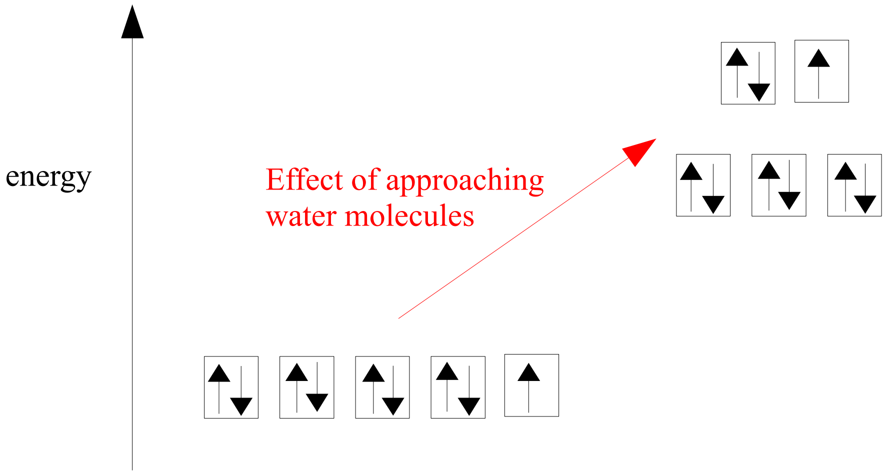
Chemguide – answers

COMPLEX IONS – ORIGIN OF COLOUR

1. a) red

   b) yellow

2. a) 

   b) 

c) The water molecules increase the energy of all the d orbitals, but there is now an energy gap within the d orbitals, with two of the orbitals having a higher energy than the other three. If light of the right frequency (and therefore energy) falls on the ion, an electron from the lower energy orbitals can be promoted into the space in the higher energy orbital.

If energy is used to promote the electron, then that energy is no longer contained in the light beam – it has been absorbed.

d) Different ligands cause different amounts of splitting in the d orbitals. Ammonia causes more splitting than water. That means that the energy needed to promote an electron from the lower to the higher set of orbitals is greater, and needs light of a higher energy, and therefore a higher frequency. Yellow light has a higher frequency (lower wavelength) than red light, and so this is absorbed instead of red in this case.

e) Mg^{2+}: $1s^2 2s^2 2p^6$

Sc^{3+}: $1s^2 2s^2 2p^6 3s^2 3p^6$

Zn^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

None of these has a partly filled d level. Mg^{2+} and Sc^{3+} have no d electrons at all. Zn^{2+} does have d electrons, and so there will be splitting as with copper, but there is no space in the higher energy orbitals to promote an electron in to.

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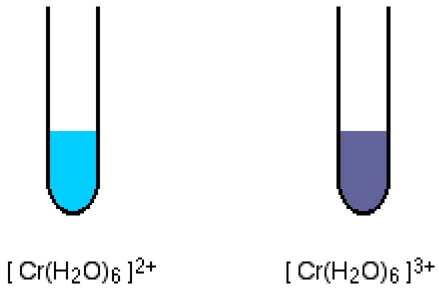
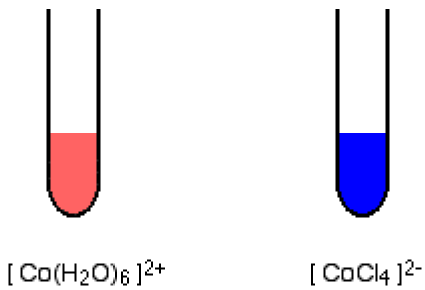
3. a) The obvious one to use is from the Chemguide page:



The change in oxidation state is from +2 to +3, and the colour change from pale blue to violet-blue-grey.

(Actually, if you have done this in the lab you will probably have got a green solution for the chromium(III) complex. This is caused by a rearrangement in the complex involving other negative ions which may be present such as sulphate ions. You will find a mention of this in the Chemguide page about chromium from the Transition Metals Menu. Technically, the green colour doesn't answer the question, because it involves both oxidation state change and ligand change.)

b) The simplest example comes from cobalt chemistry:



The colour changes from pink to blue as you change both the ligand and the coordination.

There is an exactly equivalent case in copper(II) chemistry as well (replace Co by Cu in the formulae for the ions), with the colour change from pale blue to green (or other green/yellow/brown colours depending on the concentration). The cobalt case is much easier to describe!