Solutions

Each answer shows the steps, then the **result**.

2.1

- d orbitals that have the same energy

2.2

- into a lower set of three and a higher set of two orbitals

2.3

- Zn^{2+} has a full $3d^{10}$ sub-shell; there is no vacancy to promote an electron into, so no d–d transition occurs and no visible light is absorbed

2.4

- $\Delta E = h\nu$, so a larger gap corresponds to a higher frequency absorbed

2.5

- The identity of the ligand; the oxidation state of the metal ion; the coordination number or the shape of the complex

3.1 B

- An electron is promoted between two non-degenerate d orbitals

3.2 B

- We see the complementary colour of the light absorbed

3.3

- the ligands split the d orbitals into two sets separated by ΔE; the complex absorbs light of energy equal to ΔE, promoting a d electron to the higher set; the colour seen is the complementary colour of the light absorbed

3.4

- a different ligand gives a different splitting energy ΔE; so a different frequency of light is absorbed, and a different complementary colour is seen

3.5

(a)

- The ligands split the five degenerate 3d orbitals into two levels separated by ΔE; Co^{2+} has a partially filled d sub-shell, so an electron can be promoted; it absorbs a photon whose energy equals ΔE, a d–d transition; the light not absorbed is transmitted, and the complementary colour is what is seen

(b)

- The colour seen is the complement of the colour absorbed

(c)

- Chloride ligands replace the water by ligand exchange; chloride is lower in the spectrochemical series than water, so ΔE decreases; the coordination number also falls from 6 to 4 and the shape changes from octahedral to tetrahedral, which splits the orbitals differently; a different frequency is therefore absorbed and the complementary colour seen changes from pink to blue

(d)

- Sc^{3+} has an empty $3d^0$ sub-shell; with no d electrons there can be no d–d transition, so no visible light is absorbed

(e)

- A higher frequency; cyanide is higher in the spectrochemical series than water, so it produces a larger ΔE, and $\Delta E = h\nu$