Additional higher level

Topic 13: The periodic table—the transition metals

4 hours

Essential idea: The transition elements have characteristic properties; these properties are related to their all having incomplete d sublevels.

13.1 First-row d-block elements

Nature of science:

Looking for trends and discrepancies—transition elements follow certain patterns of behaviour. The elements Zn, Cr and Cu do not follow these patterns and are therefore considered anomalous in the first-row d-block. (3.1)

Understandings:

- Transition elements have variable oxidation states, form complex ions with ligands, have coloured compounds, and display catalytic and magnetic properties.
- Zn is not considered to be a transition element as it does not form ions with incomplete d-orbitals.
- Transition elements show an oxidation state of +2 when the s-electrons are removed.

Applications and skills:

- Explanation of the ability of transition metals to form variable oxidation states from successive ionization energies.
- Explanation of the nature of the coordinate bond within a complex ion.
- Deduction of the total charge given the formula of the ion and ligands present.
- Explanation of the magnetic properties in transition metals in terms of unpaired electrons.

Guidance:

- Common oxidation numbers of the transition metal ions are listed in the data booklet in sections 9 and 14.

International-mindedness:

- The properties and uses of the transition metals make them important international commodities. Mining for precious metals is a major factor in the economies of some countries.

Theory of knowledge:

- The medical symbols for female and male originate from the alchemical symbols for copper and iron. What role has the pseudoscience of alchemy played in the development of modern science?

Utilization:

Syllabus and cross-curricular links:
Topic 9.1—redox reactions
Topic 10.2—oxidation of alcohols, hydrogenation of alkenes
Option A.3—homogeneous and heterogeneous catalysis

Aims:

- **Aim 6**: The oxidation states of vanadium and manganese, for example, could be investigated experimentally. Transition metals could be analysed using redox titrations.
- **Aim 8**: Economic impact of the corrosion of iron.

Essential idea: d-orbitals have the same energy in an isolated atom, but split into two sub-levels in a complex ion. The electric field of ligands may cause the d-orbitals in complex ions to split so that the energy of an electron transition between them corresponds to a photon of visible light.

13.2 Coloured complexes

Nature of science:

Models and theories—the colour of transition metal complexes can be explained through the use of models and theories based on how electrons are distributed in d-orbitals. (1.10)

Transdisciplinary—colour linked to symmetry can be explored in the sciences, architecture, and the arts. (4.1)

Understandings:

- The d sub-level splits into two sets of orbitals of different energy in a complex ion.
- Complexes of d-block elements are coloured, as light is absorbed when an electron is excited between the d-orbitals.
- The colour absorbed is complementary to the colour observed.

Applications and skills:

- Explanation of the effect of the identity of the metal ion, the oxidation number of the metal and the identity of the ligand on the colour of transition metal ion complexes.
- Explanation of the effect of different ligands on the splitting of the d-orbitals in transition metal complexes and colour observed using the spectrochemical series.

Guidance:

- The spectrochemical series is given in the data booklet in section 15. A list of polydentate ligands is given in the data booklet in section 16.
- Students are not expected to recall the colour of specific complex ions.

Utilization:

Syllabus and cross-curricular links:
Topic 2.2—electron configuration of atoms and ions

Aims:

- **Aim 6**: The colours of a range of complex ions, of elements such as Cr, Fe, Co, Ni and Cu could be investigated.
- **Aim 7**: Complex ions could be investigated using a spectrometer data logger.
- **Aim 8**: The concentration of toxic transition metal ions needs to be carefully monitored in environmental systems.

13.2 Coloured complexes	
• The relation between the colour observed and absorbed is illustrated by the colour wheel in the data booklet in section 17. • Students are not expected to know the different splitting patterns and their relation to the coordination number. Only the splitting of the 3-d orbitals in an octahedral crystal field is required.	