Topic 3: Periodicity

6 hours

Essential idea: The arrangement of elements in the periodic table helps to predict their electron configuration.

3.1 Periodic table

Nature of science:

Obtain evidence for scientific theories by making and testing predictions based on them—scientists organize subjects based on structure and function; the periodic table is a key example of this. Early models of the periodic table from Mendeleev, and later Moseley, allowed for the prediction of properties of elements that had not yet been discovered. (1.9)

Understandings:

- The periodic table is arranged into four blocks associated with the four sub-levels—s, p, d, and f.
- The periodic table consists of groups (vertical columns) and periods (horizontal rows).
- The period number (*n*) is the outer energy level that is occupied by electrons.
- The number of the principal energy level and the number of the valence electrons in an atom can be deduced from its position on the periodic table.
- The periodic table shows the positions of metals, non-metals and metalloids.

Applications and skills:

- Deduction of the electron configuration of an atom from the element's position on the periodic table, and vice versa.

Guidance:

- The terms alkali metals, halogens, noble gases, transition metals, lanthanoids and actinoids should be known.
- The group numbering scheme from group 1 to group 18, as recommended by IUPAC, should be used.

International-mindedness:

- The development of the periodic table took many years and involved scientists from different countries building upon the foundations of each other's work and ideas.

Theory of knowledge:

- What role did inductive and deductive reasoning play in the development of the periodic table? What role does inductive and deductive reasoning have in science in general?

Utilization:

- Other scientific subjects also use the periodic table to understand the structure and reactivity of elements as it applies to their own disciplines.

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

Aims:

- **Aim 3**: Apply the organization of the periodic table to understand general trends in properties.
- **Aim 4**: Be able to analyse data to explain the organization of the elements.
- **Aim 6**: Be able to recognize physical samples or images of common elements.

Essential idea: Elements show trends in their physical and chemical properties across periods and down groups.

3.2 Periodic trends

Nature of science:

Looking for patterns—the position of an element in the periodic table allows scientists to make accurate predictions of its physical and chemical properties. This gives scientists the ability to synthesize new substances based on the expected reactivity of elements. (3.1)

Understandings:

- Vertical and horizontal trends in the periodic table exist for atomic radius, ionic radius, ionization energy, electron affinity and electronegativity.
- Trends in metallic and non-metallic behaviour are due to the trends above.
- Oxides change from basic through amphoteric to acidic across a period.

Applications and skills:

- Prediction and explanation of the metallic and non-metallic behaviour of an element based on its position in the periodic table.
- Discussion of the similarities and differences in the properties of elements in the same group, with reference to alkali metals (group 1) and halogens (group 17).
- Construction of equations to explain the pH changes for reactions of Na_2O, MgO, P_4O_{10}, and the oxides of nitrogen and sulfur with water.

Guidance:

- Only examples of general trends across periods and down groups are required. For ionization energy the discontinuities in the increase across a period should be covered.
- Group trends should include the treatment of the reactions of alkali metals with water, alkali metals with halogens and halogens with halide ions.

International-mindedness:

- Industrialization has led to the production of many products that cause global problems when released into the environment.

Theory of knowledge:

- The predictive power of Mendeleev’s Periodic Table illustrates the “risk-taking” nature of science. What is the demarcation between scientific and pseudoscientific claims?
- The Periodic Table is an excellent example of classification in science. How does classification and categorization help and hinder the pursuit of knowledge?

Utilization:

Syllabus and cross-curricular links:
Topic 2.2—anomalies in first ionization energy values can be connected to stability in electron configuration
Topic 8.5—production of acid rain

Aims:

- **Aims 1** and **8**: What is the global impact of acid deposition?
- **Aim 6**: Experiment with chemical trends directly in the laboratory or through the use of teacher demonstrations.
- **Aim 6**: The use of transition metal ions as catalysts could be investigated.
- **Aim 7**: Periodic trends can be studied with the use of computer databases.

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.	