Topic 9: Redox processes

8 hours

Essential idea: Redox (reduction–oxidation) reactions play a key role in many chemical and biochemical processes.

9.1 Oxidation and reduction

Nature of science:

How evidence is used—changes in the definition of oxidation and reduction from one involving specific elements (oxygen and hydrogen), to one involving electron transfer, to one invoking oxidation numbers is a good example of the way that scientists broaden similarities to general principles. (1.9)

Understandings:

- Oxidation and reduction can be considered in terms of oxygen gain/hydrogen loss, electron transfer or change in oxidation number.
- An oxidizing agent is reduced and a reducing agent is oxidized.
- Variable oxidation numbers exist for transition metals and for most main-group non-metals.
- The activity series ranks metals according to the ease with which they undergo oxidation.
- The Winkler Method can be used to measure biochemical oxygen demand (BOD), used as a measure of the degree of pollution in a water sample.

Applications and skills:

- Deduction of the oxidation states of an atom in an ion or a compound.
- Deduction of the name of a transition metal compound from a given formula, applying oxidation numbers represented by Roman numerals.
- Identification of the species oxidized and reduced and the oxidizing and reducing agents, in redox reactions.
- Deduction of redox reactions using half-equations in acidic or neutral solutions.
- Deduction of the feasibility of a redox reaction from the activity series or reaction data.

International-mindedness:

- Access to a supply of clean drinking water has been recognized by the United Nations as a fundamental human right, yet it is estimated that over one billion people lack this provision. Disinfection of water supplies commonly uses oxidizing agents such as chlorine or ozone to kill microbial pathogens.

Theory of knowledge:

- Chemistry has developed a systematic language that has resulted in older names becoming obsolete. What has been lost and gained in this process?
- Oxidation states are useful when explaining redox reactions. Are artificial conversions a useful or valid way of clarifying knowledge?

Utilization:

- Aerobic respiration, batteries, solar cells, fuel cells, bleaching by hydrogen peroxide of melanin in hair, household bleach, the browning of food exposed to air, etc.
- Driving under the influence of alcohol is a global problem which results in serious road accidents. A redox reaction is the basis of the breathalyser test.
- Natural and synthetic antioxidants in food chemistry.
- Photochromic lenses.
- Corrosion and galvanization.

9.1 Oxidation and reduction	
• Solution of a range of redox titration problems. • Application of the Winkler Method to calculate BOD. **Guidance:** • Oxidation number and oxidation state are often used interchangeably, though IUPAC does formally distinguish between the two terms. Oxidation numbers are represented by Roman numerals according to IUPAC. • Oxidation states should be represented with the sign given before the number, eg +2 not 2+. • The oxidation state of hydrogen in metal hydrides (-1) and oxygen in peroxides (-1) should be covered. • A simple activity series is given in the data booklet in section 25.	Syllabus and cross-curricular links: Topic 1.3—experimental determination of amounts, masses, volumes and concentrations of solutions Topic 3.2—halogen reactivity Topics 4.1 and 4.2—difference between ionic and covalent bonding Topic 10.2—oxidation of alcohols Biology topics 8.2 and 8.3—redox reactions in physiology **Aims:** • **Aim 6**: Experiments could include demonstrating the activity series, redox titrations and using the Winkler Method to measure BOD. • **Aim 8**: Oxidizing agents such as chlorine can be used as disinfectants. Use of chlorine as a disinfectant is of concern due to its ability to oxidize other species forming harmful by-products (eg trichloromethane).

Essential idea: Voltaic cells convert chemical energy to electrical energy and electrolytic cells convert electrical energy to chemical energy.

9.2 Electrochemical cells

Nature of science:

Ethical implications of research—the desire to produce energy can be driven by social needs or profit. (4.5)

Understandings:

Voltaic (*Galvanic*) cells:

- Voltaic cells convert energy from spontaneous, exothermic chemical processes to electrical energy.
- Oxidation occurs at the anode (negative electrode) and reduction occurs at the cathode (positive electrode) in a voltaic cell.

Electrolytic cells:

- Electrolytic cells convert electrical energy to chemical energy, by bringing about non-spontaneous processes.
- Oxidation occurs at the anode (positive electrode) and reduction occurs at the cathode (negative electrode) in an electrolytic cell.

Applications and skills:

- Construction and annotation of both types of electrochemical cells.
- Explanation of how a redox reaction is used to produce electricity in a voltaic cell and how current is conducted in an electrolytic cell.
- Distinction between electron and ion flow in both electrochemical cells.
- Performance of laboratory experiments involving a typical voltaic cell using two metal/metal-ion half-cells.
- Deduction of the products of the electrolysis of a molten salt.

International-mindedness:

- Research in space exploration often centres on energy factors. The basic hydrogen–oxygen fuel cell can be used as an energy source in spacecraft, such as those first engineered by NASA in the USA. The International Space Station is a good example of a multinational project involving the international scientific community.

Theory of knowledge:

- Is energy just an abstract concept used to justify why certain types of changes are always associated with each other? Are concepts such as energy **real**?

Utilization:

- Fuel cells.
- Heart pacemakers.

Syllabus and cross-curricular links:
Option C.6—fuel cells
Physics topic 5.3—electrochemical cells

Aims:

- **Aim 6**: Construction of a typical voltaic cell using two metal/metal-ion half-cells.
- **Aim 6**: Electrolysis experiments could include that of a molten salt. A video could also be used to show some of these electrolytic processes.

9.2 Electrochemical cells	
Guidance: • For voltaic cells, a cell diagram convention should be covered.	• **Aim 8**: Although the hydrogen fuel cell is considered an environmentally friendly, efficient alternative to the internal combustion engine, storage of hydrogen fuel is a major problem. The use of liquid methanol, which can be produced from plants as a carbon neutral fuel (one which does not contribute to the greenhouse effect), in fuel cells has enormous potential. What are the current barriers to the development of fuel cells?