

Topic 19: Redox processes

6 hours

Essential idea: Energy conversions between electrical and chemical energy lie at the core of electrochemical cells.

19.1 Electrochemical cells

Nature of science:

Employing quantitative reasoning—electrode potentials and the standard hydrogen electrode. (3.1)

Collaboration and ethical implications—scientists have collaborated to work on electrochemical cell technologies and have to consider the environmental and ethical implications of using fuel cells and microbial fuel cells. (4.5)

Understandings:

- A voltaic cell generates an electromotive force (EMF) resulting in the movement of electrons from the anode (negative electrode) to the cathode (positive electrode) via the external circuit. The EMF is termed the cell potential (E°).
- The standard hydrogen electrode (SHE) consists of an inert platinum electrode in contact with 1 mol dm^{-3} hydrogen ion and hydrogen gas at 100 kPa and 298 K. The standard electrode potential (E°) is the potential (voltage) of the reduction half-equation under standard conditions measured relative to the SHE. Solute concentration is 1 mol dm^{-3} or 100 kPa for gases. E° of the SHE is 0 V.
- When aqueous solutions are electrolysed, water can be oxidized to oxygen at the anode and reduced to hydrogen at the cathode.
- $\Delta G^\circ = -nFE^\circ$. When E° is positive, ΔG° is negative indicative of a spontaneous process. When E° is negative, ΔG° is positive indicative of a non-spontaneous process. When E° is 0, then ΔG° is 0.
- Current, duration of electrolysis and charge on the ion affect the amount of product formed at the electrodes during electrolysis.
- Electroplating involves the electrolytic coating of an object with a metallic thin layer.

International-mindedness:

- Many electrochemical cells can act as energy sources alleviating the world's energy problems but some cells such as super-efficient microbial fuel cells (MFCs) (also termed biological fuel cells) can contribute to clean-up of the environment. How do national governments and the international community decide on research priorities for funding purposes?

Theory of knowledge:

- The SHE is an example of an arbitrary reference. Would our scientific knowledge be the same if we chose different references?

Utilization:

- Electroplating.
- Electrochemical processes in dentistry.
- Rusting of metals.

Syllabus and cross-curricular links:

Topics 1.2 and 1.3—problems involving Avogadro's constant, amount of substance and the ideal gas equation
Topic 9.1—redox processes

19.1 Electrochemical cells

Applications and skills:

- Calculation of cell potentials using standard electrode potentials.
- Prediction of whether a reaction is spontaneous or not using E° values.
- Determination of standard free-energy changes (ΔG°) using standard electrode potentials.
- Explanation of the products formed during the electrolysis of aqueous solutions.
- Perform lab experiments that could include single replacement reactions in aqueous solutions.
- Determination of the relative amounts of products formed during electrolytic processes.
- Explanation of the process of electroplating.

Guidance:

- Electrolytic processes to be covered in theory should include the electrolysis of aqueous solutions (eg sodium chloride, copper(II) sulfate etc) and water using both inert platinum or graphite electrodes and copper electrodes. Explanations should refer to E° values, nature of the electrode and concentration of the electrolyte.
- $\Delta G^\circ = -nFE^\circ$ is given in the data booklet in section 1.
- Faraday's constant = $96\,500\text{ C mol}^{-1}$ is given in the data booklet in section 2.
- The term "cells in series" should be understood.

Topic 15.2—spontaneity of a reaction

Option C.6—Nernst equation

Biology option B.3—environmental protection; waste treatment and microbial fuel cells

Aims:

- **Aim 8:** Biological fuel cells can produce electrical energy to power electrical devices, houses, factories etc. They can assist in environmental clean-up. Microbial fuel cells (MFCs) powered by microbes in sewage can clean up sewage which may result in cost-free waste water treatment.