Topic 5: Materials

In this topic students consider the chemical and physical properties of a range of materials and develop an understanding of the chemistry behind these properties. Polymers are important in nature and synthetic polymers represent one of the benefits of scientific advances.

Silicates and aluminosilicates are the most common materials in the Earth's crust. They form the basis of rocks and most minerals and are the major components of soils. The silicates of which they are composed determine the soils' chemical properties. Healthy soils are essential for sustainable food production.

Cleaning agents are familiar household chemicals that help in the maintenance of a healthy lifestyle. They function in a variety of ways that include dissolving, suspension, and oxidation.

5.1 Polymers

Key Ideas	Intended Student Learning
The production of synthetic polymers allows the manufacture of materials with a diverse range of properties.	Discuss the advantages and disadvantages of synthetic polymers.
Polymers or macromolecules are very large molecules composed of small repeating structural units.	Identify the repeating unit of a polymer, given the structural formula of a section of a chain.
Polymers are produced from small molecules (monomers) by one of two main polymerisation reactions: addition or condensation.	Identify a polymer as being the product of an addition polymerisation or a condensation polymerisation, given its structural formula.
Addition polymerisation occurs when monomer molecules link without the loss of atoms. The monomer usually has at least one carbon–carbon double bond per molecule.	Draw the structural formula of an addition polymer that could be produced from monomers containing one carbon–carbon double bond, given the structural formula(e) of the monomer(s), or vice versa.
Polyesters and polyamides are large molecules in which monomer units are linked by ester and amide groups respectively.	Identify the ester group in a polyester and the amide group in a polyamide.
Condensation polymerisation occurs when one or more compounds (such as water) are produced as the monomer molecules link.	Draw the structural formula(e) of the polyester or polyamide polymers that could be produced from monomers, given the structural formula(e) of the monomer(s), or vice versa.
Organic polymers can have different properties, such as rigidity, depending on the monomers and the degree of cross-linking between chains.	Describe the effect on rigidity of increasing the number of primary and secondary interactions between polymer chains.
Heat affects thermoplastic and thermoset polymers differently.	Describe the effects of heating on thermoplastic and thermoset polymers, and the consequent difference in the ease of recycling.

5.2 Silicates

Key Ideas	Intended Student Learning
Silicon dioxide, silicates, and aluminosilicates are important components of rocks and soils.	Write the formula of the anion in a silicate or aluminosilicate, given its formula.
The structure of silicates is based on SiO_4 tetrahedra.	Identify the SiO_4 structural unit in diagrams of silicate anions.
In silicates, oxygen atoms can be shared between two SiO_4 tetrahedra.	Draw the repeating unit and write the formula of an extended silicate anion, given its structural formula.
In silicates the oxidation state of silicon is +4 whereas that of oxygen is −2.	State the charge on a silicate anion, given the Si:O ratio.
The charge balance in silicate minerals is achieved by the presence of cations, most commonly Ca^{2+}, Mg^{2+}, K^+, Na^+, Fe^{2+}, and Fe^{3+}.	Write the formula of a silicate mineral, given the structural formula of the silicate anion and the metal ions present.
In minerals known as 'aluminosilicates', aluminium atoms replace some of the silicon atoms.	State the charge of an aluminosilicate ion, given its formula.
Cations held on the surface of soil silicates are in equilibrium with the cations in soil water, which are available as sources of plant nutrients.	Explain how cations held on the surface of soil silicates are made available to plants.
Soil silicates are able to adsorb H^+ in the soil water and release cations.	Describe the effect of acid rain in releasing cations from soil silicates.
The surface of fine silicate particles in clays is negatively charged and can be flocculated into larger particles by the addition of salts containing highly charged cations such as aluminium ions.	Explain the use of aluminium ions in flocculating clay particles suspended in water.
Silicates such as zeolites are able to soften water by the exchange of cations.	Explain the use of silicates in water softeners.

5.3 Cleaning Agents

Key Ideas	Intended Student Learning
Many stains can be removed by the use of an appropriate solvent.	Describe the use of non-polar solvents to dissolve non-polar materials and the use of polar solvents to dissolve polar materials.
Soaps and synthetic sulfonate detergents consist of a non-polar hydrocarbon chain, which is hydrophobic, and an ionic region, which is hydrophilic.	Describe and explain how soaps and synthetic sulfonate detergents remove grease.
Fats and oils can be hydrolysed by boiling with sodium hydroxide solution. The carboxylate salts formed are soaps.	Write equations for the alkaline hydrolysis of triglycerides.

Key Ideas	Intended Student Learning
Soaps form an insoluble material when used in hard water.	Write an equation for the formation of magnesium or calcium precipitate from soap, given the structural formula of the soap anion.
The effectiveness of soaps is significantly reduced when they are used in hard water, whereas the effectiveness of synthetic detergents is not greatly changed when they are used in hard water.	Describe how the reaction of soap with hard water differs from that of synthetic detergents.
The structure of phosphates is based on PO_4 tetrahedra.	Draw the structural formula of the PO_4^{3-} ion.
In tripolyphosphates, oxygen atoms can be shared between PO_4 tetrahedra.	Draw the structural formulae of linear and cyclic tripolyphosphate ions.
Tripolyphosphates are added to many detergent formulations.	Explain how tripolyphosphate ions keep: calcium and magnesium ions in solution; clay particles in suspension; and pH mildly alkaline.
Tripolyphosphates improve the effectiveness of detergent formulations.	Explain the importance of the actions of tripolyphosphate ions.
Phosphates can cause eutrophication in water bodies.	Describe the advantages and disadvantages of the use of phosphate fertilisers and polyphosphates in detergent formulations.
Chlorine bleaches are most stable at a pH above 7.	Explain the effect of lowering pH on the decomposition of hypochlorites to chlorine.
Enzymes are added to some detergent formulations.	Describe the use of enzymes in detergents and explain why they are sensitive to changes in pH and temperature.
Solid oxygen bleaches release hydrogen peroxide as an oxidising agent. Hydrogen peroxide decomposes to release oxygen.	Use the change in oxidation number of oxygen to show hydrogen peroxide and oxygen acting as oxidising agents.
Solid oxygen bleaches are added to some detergent formulations because they release hydrogen peroxide and hence oxygen in solution.	Describe how solid oxygen bleaches release oxidising agents when dissolved in water.
	Explain why the effectiveness of solid oxygen bleaches is affected by changes in temperature.