Topic 1: Elemental and Environmental Chemistry

This topic deals with some of the underlying principles of chemistry ('elemental chemistry') and then considers the chemistry of the environment. The elemental chemistry component of the topic focuses on the periodic table and the concept of electronegativity; together these underlie most of the other topics in this subject outline. The environmental chemistry component focuses on a small number of inorganic molecular substances and their impacts on the environment.

When the chemical elements are arranged in a periodic table, similarities and trends in properties become apparent. This topic examines the properties of compounds and elements; these properties can be explained in terms of the electronegativities of the elements and their positions in the periodic table.

In the last hundred years, concern about the effects of humans on the environment has extended from the local to the global scale. Students are often exposed to environmental issues, sometimes in emotive ways. In this topic students are exposed to factual information and consider the causes of and solutions to environmental problems.

1.1 The Periodic Table

Key Ideas	Intended Student Learning
The arrangement of electrons in any atom can be described in terms of shells and subshells.	Write, using subshell notation, the electron configuration of an atom or monatomic ion of any of the first thirty-eight elements in the periodic table.
The position of an element in the periodic table reflects its electron configuration.	Identify the *s*, *p*, *d*, and *f* block elements in the periodic table.
The periodic table is the unifying framework for the study of the chemical elements and their compounds. Elements within each group of the periodic table have similar chemical properties that can be explained in terms of their similar outer-shell electron configurations.	Predict the following properties of the *s* and *p* block elements of any of the first thirty-eight elements in the periodic table: • metal, metalloid, or non-metal nature of the element • charge of the monatomic ions • likely oxidation number(s) of the element in its compounds (including octet expansion for phosphorus, sulfur, and chlorine).
The electronegativities of non-metallic atoms are higher than those of metals; non-metallic atoms tend to gain electrons in chemical reactions.	Find regions in the periodic table with elements of high, intermediate, and low electronegativity.
The trend from metallic to non-metallic behaviour across a period is related to the increase in electronegativity. These trends are reflected in changes in the acidic/basic character of the oxides.	Predict the acidic/basic character of the oxides of an element from the position of the element in the periodic table.
The oxides of non-metals are acidic. Their acidic character can be displayed by reaction with hydroxide ions to produce an oxyanion and, in most cases, by reaction with water to produce an oxyacid.	Write equations for the reactions of oxides of non-metals such as SiO_2, CO_2, SO_2, SO_3, and P_4O_{10} with hydroxide ions and with water, where a reaction occurs.

Key Ideas	Intended Student Learning
The oxides of metals are basic. Their basic character can be displayed by reaction with an acid to produce a cation and, in some cases, by reaction with water to produce OH^- in solution.	Write equations for the reactions of oxides of metals such as MgO, Na_2O, CuO, and Fe_2O_3 with acids and with water, where a reaction occurs.
Metalloids form amphoteric oxides. Amphoteric oxides can display basic character by reaction with hydrogen ions and acidic character by reaction with hydroxide ions.	Write equations for the reactions of amphoteric oxides such as Al_2O_3 and ZnO with hydrogen ions or hydroxide ions.
Small molecules are formed from elements in a small section of the periodic table. Small molecules are those either of non-metallic elements or of compounds of non-metallic elements.	Predict whether or not a compound or element is likely to be molecular, given its properties, name, elemental composition, or formula.
Atoms in a molecule are bound strongly to each other by covalent bonds. Molecules interact weakly with each other.	Compare the strengths of covalent bonds with the strengths of secondary interactions.
The strengths of secondary interactions between non-polar molecules depend on their molar mass.	Explain the higher melting points and boiling points of substances of large molar mass.
The shape of molecules can be explained and predicted by repulsion between pairs of bonding and non-bonding electrons.	Draw diagrams showing covalent bonds, non-bonding pairs, and shapes for three-element molecules and two-element ions containing no more than five atoms. Examples that involve valence shell octet expansion are limited to PO_4^{3-} tetrahedra, SO_2 , and SO_3.
The polarity of a molecule results from the polar character of the bonds and their spatial arrangement.	Predict whether or not a molecule is polar, given its spatial arrangement.
The strengths of secondary interactions between molecules of similar molar mass depend on the polarity of the molecules.	Explain the higher melting points and boiling points of polar substances compared with those of non-polar substances of similar molar mass.
Molecules containing N–H or O–H groups can form hydrogen bonds to N or O atoms in other molecules.	Describe, with the aid of diagrams, hydrogen bonding between molecules.

1.2 Cycles in Nature

Key Ideas	Intended Student Learning
The presence (aerobic conditions) or absence (anaerobic conditions) of oxygen affects the products of the decomposition of the organic compounds derived from living organisms.	State, for aerobic and anaerobic conditions, the products of the decomposition of organic matter containing carbon, nitrogen, phosphorus, or sulfur.
Photosynthesis and respiration are important processes in the cycles of carbon and oxygen.	Describe and write equations for the processes of photosynthesis and aerobic respiration involving glucose.

Key Ideas	Intended Student Learning
Nitrogen may be converted into compounds by biological processes such as fixation or by reaction with oxygen during lightning discharges and at high temperatures such as those which occur in engines and furnaces.	Describe and write equations for the formation of oxides of nitrogen by the reaction of nitrogen and oxygen at high temperatures.
Nitrogen compounds are important in the chemistry of life processes.	Describe how the nitrogen cycle operates by natural processes (e.g. lightning, nitrogen-fixing bacteria, and decay) and industrial processes (e.g. fertiliser manufacture and combustion engines).
Plants require substantial amounts of nitrogen and phosphorus, which they obtain from the soil.	Explain why fertilisers need to contain nutrients in soluble form.

1.3 The Greenhouse Effect

Key Ideas	Intended Student Learning
Some gases in the atmosphere, called 'greenhouse gases', serve as insulation to maintain the temperature of the Earth's atmosphere. This is known as the 'natural greenhouse effect'.	Describe the action of the common greenhouse gases, carbon dioxide and methane, that serve to maintain a steady temperature in the Earth's atmosphere.
Human activity that affects the concentration of greenhouse gases has the potential to disrupt the thermal balance of the atmosphere. This is known as the 'enhanced greenhouse effect'.	Explain the enhanced greenhouse effect and its potential consequences for the environment.

1.4 Acid Rain

Key Ideas	Intended Student Learning
pH is a measure of the concentration of hydrogen ions: i.e. $pH = -\log [H^+]$.	Calculate the concentration of H^+ and OH^- of solutions, given their pH, and vice versa.
Rain containing dissolved carbon dioxide is acidic.	Write equations to show how carbon dioxide produces acidic rain.
Rainfall with a pH of less than 5.6, known as 'acid rain', is formed when oxides of nitrogen and sulfur dissolve in water in the atmosphere.	Describe and write equations for the formation of acid rain.
Acid rain has harmful environmental effects.	Describe the environmental effects of acid rain, including its action on metals and carbonates (with equations) and on the mobilisation of toxic cations such as aluminium.
The low pH of acid rain is due to the presence of sulfuric and nitric acids.	Calculate the pH of solutions of strong bases and strong monoprotic acids.

1.5 Photochemical Smog

Key Ideas	Intended Student Learning
Nitrogen oxides are formed in high-temperature engines and furnaces.	Write equations for the formation of nitrogen oxides NO and NO_2.
Nitrogen oxides lead to the formation of ozone in the troposphere.	Describe and write equations showing the role of nitrogen oxides in the formation of ozone in the troposphere.
Nitrogen oxides and ozone in the troposphere are pollutants.	Explain the terms 'primary pollutants' and 'secondary pollutants' with reference to the harmful effects of nitrogen oxides and ozone in the troposphere.
It is possible to reduce the quantities of nitrogen oxides generated by cars.	Describe how catalytic converters reduce the quantities of nitrogen oxides generated by cars.

1.6 Water Treatment

Key Ideas	Intended Student Learning
Suspended matter is removed from water by flocculation followed by sedimentation or filtration.	Describe the use of aluminium ions in the removal of suspended matter from water.
Hypochlorous acid, chlorine, and hypochlorites are used for water purification.	State that hypochlorous acid, chlorine, and hypochlorites kill bacteria by their oxidising action.
Chlorine is used for water purification.	Explain the effect of pH on the equilibrium between chlorine, water, and hydrochloric acid and hypochlorous acid.