Topic 3: Using and Controlling Reactions

The use and control of chemical reactions are important tasks undertaken by chemists. This topic looks at the energy changes that accompany chemical reactions and their rates and extents. It also examines the ways in which chemical reactions are controlled and used to make materials and generate the energy needed by a modern industrial society.

The increased use of energy from chemical reactions has been a major factor in the development of the industrialised world. In this topic students consider the ways in which this energy is produced and begin quantitative consideration of the energy changes that accompany chemical reactions.

The production of chemicals is the main function of the chemical industry. These chemicals allow naturally occurring materials to be modified or replaced, and previously unknown materials to be developed. The industrialised world depends on the chemical industry for the manufacture of a diverse range of materials. In this topic students look at how chemicals are produced and how the production can be performed most efficiently.

Knowledge of chemistry can be applied to manipulate the reaction conditions of industrial processes in order to determine the quantity or quality of the product.

3.1 Measuring Energy Changes

Key Ideas	Intended Student Learning
Almost all chemical reactions occur with either an absorption or a release of heat or light energy. Other forms of energy, such as electrical energy, can also be released.	Identify combustion and respiration as reactions that release energy and photosynthesis as a reaction that absorbs energy.
Exothermic reactions release energy to the surroundings, whereas endothermic reactions absorb energy from the surroundings.	Deduce whether a reaction is exothermic or endothermic from information provided.
The measurement of the heat change in chemical reactions is called 'calorimetry'; the insulated apparatus used for the measurement is a calorimeter.	Calculate the heat released or absorbed for a reaction from experimental data, given the specific heat capacity of water (4.18 J g^{-1} K^{-1}).
The heat released or absorbed in a reaction at constant pressure is called the 'enthalpy change for the reaction'; it is represented by the symbol ΔH.	Determine enthalpy changes from experimental data for reactions, including: • the combustion of alcohols • the neutralisation of acids with bases • solution processes.
Exothermic reactions have negative ΔH values. Endothermic reactions have positive ΔH values.	Identify a reaction as exothermic or endothermic, given a thermochemical equation or the value of its enthalpy change.
Thermochemical equations express a quantitative relationship between the quantities of reactants and the enthalpy change.	Write thermochemical equations that correspond to given molar enthalpies of combustion, neutralisation, and solution.
The magnitude of the heat absorbed or evolved for a reaction is directly proportional to the quantities of reactants involved.	Calculate the theoretical temperature change of a specified mass of water or solution heated or cooled by a reaction, given molar enthalpies and quantities of reactants.

3.2 Fuels

Key Ideas	Intended Student Learning
Carbon-based fuels provide energy and are feedstock for the chemical industry.	Describe the advantages and disadvantages of the use of carbon-based fuels as sources of heat energy, compared with their use as feedstock.
Carbon dioxide and water are produced by the complete combustion of compounds containing carbon and hydrogen.	Write balanced equations for the complete combustion of fuels in which the only products are carbon dioxide and water.
The products of the incomplete combustion of carbon-based fuels include carbon (soot) and carbon monoxide. Soot and carbon monoxide are harmful to the environment.	Describe the undesirable consequences of incomplete combustion.
Fuels can be compared on the basis of the quantity of heat released.	Calculate the quantities of heat evolved per mole, per gram, and per litre (for liquids) for the complete combustion of fuels.

3.3 Electrochemistry

Key Ideas	Intended Student Learning
Electrochemical cells are conveniently divided into galvanic cells, which produce electrical energy from spontaneous redox reactions, and electrolytic cells, which use electrical energy from an external source to cause a non-spontaneous chemical reaction.	Identify a cell as galvanic or electrolytic, given sufficient information.
Redox reactions can be considered as two half-reactions, one involving oxidation and the other reduction.	Write half-equations for half-reactions, including those in acidic solution, given information about the reactants and the products.
Galvanic and electrolytic cells involve oxidation at the anode and reduction at the cathode, with electrons being transferred from one electrode to the other through an external circuit.	Identify the anode and cathode in a galvanic cell or an electrolytic cell, given information about the reactants and the products.
Galvanic cells are commonly used as portable sources of electric currents.	Identify the: • charge on the electrodes • direction of electron flow • movement of ions in the salt bridge or electrolyte given a sketch for a galvanic cell and information about electrode reactions.
Fuel cells are galvanic cells in which the electrode reactants are available in continuous supply.	State the advantages and disadvantages of fuel cells compared with other galvanic cells.
Some galvanic cells can be recharged by using an external electrical supply to reverse the electrode reactions.	Describe the complementary nature of the charging and discharging of rechargeable galvanic cells.

Key Ideas	Intended Student Learning
Electrolytic cells are used in the production of active metals.	Describe, with the aid of equations, the electrolytic production of active metals.

3.4 Rate of Reaction

Key Ideas	Intended Student Learning
The time taken for a reaction to reach a specified point is an indication of the rate of the reaction.	Determine the effect of varying conditions on the rate of a given reaction, using experimental data.
The rates of a reaction at different times can be compared by considering the slope of a graph of quantity (or molar concentration) of reactant or product against time.	Draw and interpret graphs representing changes in quantities or concentration of reactants or products against time.
The rates of a reaction are affected by changes in the: • concentration of reactants • temperature of the reaction mixture • pressure of the reaction mixture (for systems involving gases) • state of subdivision of reactants • presence of catalysts (including enzymes) • intensity of light (for photochemical reactions).	Predict and explain the effect that changes in condition have on the rates of reactions in terms of the: • frequency of collisions between reactant particles • orientation of colliding particles • energy of colliding particles • activation energy.
The energy changes in a reaction can be represented by an energy profile diagram.	Draw and interpret energy profile diagrams that show the relative enthalpies of reactants and products, the activation energy, and the enthalpy change for the reaction.

3.5 Chemical Equilibrium

Key Ideas	Intended Student Learning
All chemical reactions carried out in a closed system at a fixed temperature eventually reach a state of dynamic equilibrium in which the concentrations of all the reactants and products cease to change with time. The total mass of reactants and products in a closed system remains constant.	Describe the dynamic nature of a chemical system at equilibrium.
The position of equilibrium in a chemical system at a given temperature can be indicated by a constant, K_C, related to the concentrations of reactants and products.	Write K_C expressions that correspond to given reaction equations, and perform calculations involving K_C and equilibrium concentrations in which all reacting species are included in the expression.

Key Ideas	Intended Student Learning
The changes in concentrations of reactants and products as a system reaches equilibrium can be represented graphically.	Draw and interpret graphs representing changes in concentration of reactants and products against time.
The final equilibrium concentrations for a given reaction depend on the: • initial concentrations of the reactants and products • temperature • value of K_c • pressure (for systems involving gases).	Calculate the initial and/or equilibrium concentrations or quantities of reactants and products, given sufficient information about a particular system initially and/or at equilibrium.
If a change is made to a system at equilibrium so that it is no longer at equilibrium, a net reaction will occur (if possible) in the direction that counteracts the change. This is a statement of Le Châtelier's principle.	Predict, using Le Châtelier's principle, the effect on the equilibrium position of a system of a change in the: • concentration of a reactant or product • overall pressure of a gaseous mixture • temperature of an equilibrium mixture for which the ΔH value for the forward or back reaction is specified.

3.6 Chemical Industry

Key Ideas	Intended Student Learning
In any industrial chemical process it is necessary to select conditions that will give maximum yield in a short time. This will often involve compromises between conditions that produce the maximum rate, conditions that produce the maximum yield, and costs.	Explain the reaction conditions that will maximise yield.
The steps in industrial chemical processes can be conveniently displayed in flow charts.	Interpret flow charts and use them for such purposes as identifying: raw materials; chemicals present at different steps in the process; waste products; and by-products.

3.7 Metal Production

Key Ideas	Intended Student Learning
The likelihood that an uncombined metal will occur naturally increases with lack of reactivity.	Predict whether a metal is likely to occur in nature uncombined or combined with other elements, given the relative position of the metal in a table of metal reactivities.
The stages in the production of metals from their ores include concentration of the mineral; conversion of the mineral into a compound suitable for reduction; reduction; and refinement of the metal.	Identify the stages in the production of a metal from its ore and explain why not all stages are necessary in the production of some metals.

Key Ideas	Intended Student Learning
The stages in the electrolytic production of zinc from its ore are concentration of the zinc mineral; conversion of the zinc mineral into a form suitable for reduction; and electrolytic reduction.	Describe, with the aid of equations, the production of zinc from its ore.
Electrolysis of molten electrolyte is used in the reduction stage for the production of more reactive metals.	Explain why the production of aluminium requires a molten non-aqueous electrolyte.
Reduction of the oxide using carbon can be used for the production of less active metals.	Explain why zinc and iron can be obtained by reduction using carbon whereas this is not possible for aluminium.
The method used in the reduction stage in the production of a metal is related to the reactivity of the metal.	Predict the likely method of reduction of a metal compound to the metal, given the position of the metal in the activity series of metals.
Energy cost is a factor taken into account in the production of all metals.	Explain why reduction using electrolysis of an aqueous solution is preferable to electrolysis of a melt.