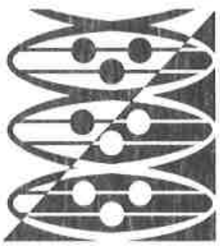

STUDENT ACHIEVEMENT

Chemistry 12

Key Elements: Reaction Kinetics

Estimated Time: 14–16 hours

By the end of this course, students will be able to explain the significance of reaction rates, demonstrate how rates can be measured and explain, with reference to Collision Theory and reaction mechanisms, how rates are altered.

Vocabulary

activated complex, activation energy, catalyst, collision theory, ΔH notation, endothermic, enthalpy, exothermic, KE distribution curve, kinetic energy (KE), potential energy (PE), product, rate-determining step, reactant, reaction intermediate, reaction mechanism, reaction rate, successful collision, thermochemical equation

Knowledge

- reaction rates
- collision theory (significance with respect to reaction rates)
- factors affecting reaction rates
- reaction mechanisms (including role and applications of catalysts)

Skills and Attitudes

- calculating reaction rates from experimental data (e.g., bleach decomposition, zinc in hydrochloric acid, iodine clock reaction)
- analysing reaction mechanisms
- graphically representing energy changes in reactions

REACTION KINETICS

Prescribed Learning Outcomes	Suggested Achievement Indicators
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
A1 demonstrate awareness that reactions occur at differing rates	☐ give examples of reactions proceeding at different rates ☐ recognize that rate is described in terms of some quantity (produced or consumed) per unit of time
A2 experimentally determine rate of a reaction	☐ identify properties that could be monitored in order to determine a reaction rate ☐ recognize some of the factors that control reaction rates ☐ compare and contrast factors affecting the rates of both homogeneous and heterogeneous reactions ☐ describe situations in which the rate of reaction must be controlled ☐ calculate the rate of a reaction using experimental data
A3 demonstrate knowledge of collision theory	☐ identify the following principles as aspects of collision theory: – reactions are the result of collisions between reactant particles – not all collisions are successful – sufficient kinetic energy (KE) and favourable geometry are required – to increase the rate of a reaction, one must increase the frequency of successful collisions – energy changes are involved in reactions as bonds are broken and formed – a KE distribution curve can explain how changing temperature or adding a catalyst changes the rate
A4 describe the energies associated with reactants becoming products *Organizer 'Reaction Kinetics' continued on page 46*	☐ describe the activated complex in terms of its potential energy (PE), stability, and structure ☐ define *activation energy* ☐ correctly describe the relationship between activation energy and rate of reaction ☐ describe the changes in KE and PE as reactant molecules approach each other. ☐ draw and label PE diagrams for both exothermic and endothermic reactions, including ΔH, activation energy, and the energy of the activated complex ☐ relate the sign of ΔH to whether the reaction is exothermic or endothermic ☐ write chemical equations that describe energy effects in two ways: – a chemical equation that includes the energy term (thermochemical equation) – a chemical equation using ΔH notation

Prescribed Learning Outcomes	Suggested Achievement Indicators
Organizer 'Reaction Kinetics' continued from page 45	
A5 apply collision theory to explain how reaction rates can be changed	☐ use collision theory to explain the effect of the following factors on reaction rate: – nature of reactants – concentration – temperature – surface area
A6 analyse the reaction mechanism for a reacting system	☐ explain why most reactions involve more than one step ☐ describe a reaction mechanism as the series of steps (collisions) that result in the overall reaction and describe the role of the rate-determining step ☐ explain the significance and role of a catalyst ☐ identify reactant, product, reaction intermediate, activated complex, and catalyst from a given reaction mechanism
A7 represent graphically the energy changes associated with catalyzed and uncatalyzed reactions	☐ compare the PE diagrams for a catalyzed and uncatalyzed reaction in terms of – reactants – products – activated complex – reaction intermediates – reaction mechanism – ΔH – activation energy
A8 describe the uses of specific catalysts in a variety of situations	☐ identify platinum in automobile catalytic converters as a catalyst ☐ describe the effect of a catalyst on a number of reactions, such as – decomposition of hydrogen peroxide (catalysts: manganese (IV) oxide, raw liver, raw potato) – the reaction of the oxalate ion with acidified potassium permanganate solution (catalyst: Mn^{2+}) – the decomposition of bleach (catalyst: cobalt (II) chloride)

Key Elements: Dynamic Equilibrium

Estimated Time: 14–16 hours

By the end of this course, students will be able to analyse reversible reacting systems, with reference to equilibrium systems, Le Châtelier's Principle, and the concept of a reaction constant, K_{eq}.

Vocabulary

chemical equilibrium, closed system, dynamic equilibrium, enthalpy, entropy, equilibrium concentration, equilibrium constant expression, equilibrium shift, Haber process, heterogeneous reaction, homogeneous reaction, K_{eq}, Le Châtelier's principle, macroscopic properties, open system, PE diagram

Knowledge

- characteristics of chemical equilibrium
- requirements for chemical equilibrium
- Le Châtelier's principle (dynamic equilibrium and equilibrium shifts – significance and application)

Skills and Attitudes

- predicting effect on equilibrium when changes are made (e.g., chromate-dichromate, iron (III) thiocyanide equilibria)
- performing calculations involving K_{eq}, initial concentrations, and equilibrium concentration

DYNAMIC EQUILIBRIUM

Prescribed Learning Outcomes	Suggested Achievement Indicators
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
B1 explain the concept of chemical equilibrium with reference to reacting systems	☐ describe the reversible nature of most chemical reactions and how it can be represented on a PE diagram ☐ describe the dynamic nature of chemical equilibrium ☐ relate the changes in rates of the forward and reverse reactions to the changing concentrations of the reactants and products as equilibrium is established ☐ describe chemical equilibrium as a closed system at constant temperature: – whose macroscopic properties are constant – where the forward and reverse reaction rates are equal – that can be achieved from either direction – where the concentrations of reactants and products are constant ☐ infer that a system not at equilibrium will tend to move toward a position of equilibrium
B2 predict, with reference to entropy and enthalpy, whether reacting systems will reach equilibrium	☐ explain the significance of enthalpy and entropy ☐ determine entropy and enthalpy changes from a chemical equation (qualitatively) ☐ predict the result when enthalpy and entropy factors – both favour the products – both favour the reactants – oppose one another
B3 apply Le Châtelier's principle to the shifting of equilibrium	☐ explain the term shift as it applies to equilibria ☐ describe shifts resulting from the following: – temperature change – concentration change – volume change of gaseous systems ☐ explain equilibrium shifts using the concepts of reaction kinetics ☐ identify the effect of a catalyst on dynamic equilibrium
B4 apply the concept of equilibrium to a commercial or industrial process *Organizer 'Dynamic Equilibrium' continued on page 49*	☐ describe the Haber process for the production of ammonia (NH_3)

Prescribed Learning Outcomes	Suggested Achievement Indicators
Organizer 'Dynamic Equilibrium' continued from page 48	
B5 draw conclusions from the equilibrium constant expression	☐ gather and interpret data on the concentration of reactants and products of a system at equilibrium ☐ write the expression for the equilibrium constant when given the equation for either a homogeneous or heterogeneous equilibrium system ☐ explain why certain terms (i.e., pure solids and liquids) are not included in the equilibrium constant expression ☐ relate the equilibrium position to the value of K_{eq} and vice versa ☐ predict the effect (or lack of effect) on the value of K_{eq} of changes in the following factors: temperature, pressure, concentration, surface area, and catalyst
B6 perform calculations to evaluate the changes in the value of K_{eq} and in concentrations of substances within an equilibrium system	☐ perform calculations involving the value of K_{eq} and the equilibrium concentration of all species ☐ perform calculations involving the value of K_{eq}, the initial concentrations of all species, and one equilibrium concentration ☐ perform calculations involving the equilibrium concentrations of all species, the value of K_{eq}, and the initial concentrations ☐ determine whether a system is at equilibrium, and if not, in which direction it will shift to reach equilibrium when given a set of concentrations for reactants and products

Key Elements: Solubility Equilibria

Estimated Time: 14–16 hours

By the end of this course, students will be able to demonstrate and explain solute-solvent interactions in solubility equilibria and describe the significance of K_{sp} with respect to saturated systems.

Vocabulary

aqueous solution, common ion, complete ionic equation, dissociation equation, electrical conductivity, formula equation, hard water, ionic solution, K_{sp}, molecular solution, net ionic equation, precipitate, relative solubility, saturated solution, solubility equilibrium

Knowledge

- ionic vs. molecular solutions
- relative solubility of solutes
- solubility rules
- equilibrium in saturated solutions

Skills and Attitudes

- distinguishing between ionic and molecular solutions (e.g., electrical conductivity)
- determining the composition of solutions and the concentration of an ion in a given solution
- performing calculations involving solubility equilibrium concepts

SOLUBILITY EQUILIBRIA

Prescribed Learning Outcomes	Suggested Achievement Indicators
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
C1 determine the solubility of a compound in aqueous solution	☐ classify a solution as ionic or molecular, given its conductivity or the formula of the solute ☐ describe the conditions necessary to form a saturated solution ☐ describe solubility as the concentration of a substance in a saturated solution ☐ use appropriate units to represent the solubility of substances in aqueous solutions
C2 describe a saturated solution as an equilibrium system	☐ describe the equilibrium that exists in a saturated aqueous solution ☐ describe a saturated solution using a net ionic equation
C3 determine the concentration of ions in a solution	☐ write dissociation equations ☐ calculate the concentration of the positive and negative ions given the concentration of a solute in an aqueous solution
C4 determine the relative solubility of a substance, given solubility tables *Organizer 'Solubility Equilibria' continued on page 52*	☐ describe a compound as having high or low solubility relative to 0.1 M by using a solubility chart ☐ use a solubility chart to predict if a precipitate will form when two solutions are mixed, and identify the precipitate ☐ write a formula equation, complete ionic equation, and net ionic equation that represent a precipitation reaction

Prescribed Learning Outcomes	Suggested Achievement Indicators
Organizer 'Solubility Equilibria' continued from page 51	
C5 apply solubility rules to analyse the composition of solutions	☐ use a solubility chart to predict if ions can be separated from solution through precipitation, and outline an experimental procedure that includes – compound added – precipitate formed – method of separation ☐ predict qualitative changes in the solubility equilibrium upon the addition of a common ion or the removal of an ion ☐ identify an unknown ion through experimentation involving a qualitative analysis scheme ☐ devise a procedure by which the calcium and/or magnesium ions can be removed from hard water
C6 formulate equilibrium constant expressions for various saturated solutions	☐ describe the K_{sp} expression as a specialized K_{eq} expression ☐ write a K_{sp} expression for a solubility equilibrium
C7 perform calculations involving solubility equilibrium concepts	☐ calculate the K_{sp} for a compound when given its solubility (e.g., AgCl, Ag_2S, $PbCl_2$) ☐ calculate the solubility of a compound from its K_{sp} ☐ predict the formation of a precipitate by comparing the trial ion product to the K_{sp} value using specific data ☐ calculate the maximum allowable concentration of one ion given the K_{sp} and the concentration of the other ion just before precipitation occurs
C8 devise a method for determining the concentration of a specific ion	☐ determine the concentration of chloride ion (by titration or gravimetric methods) using a precipitation reaction with silver ion

Key Elements: Nature of Acids and Bases

Estimated Time: 7–10 hours

By the end of this course, students will be able to describe the specific characteristics of acids and bases and distinguish the varying strengths of acids or bases for equilibria using a Brönsted-Lowry model.

Vocabulary

acid, amphiprotic, Arrhenius, base, Brönsted-Lowry, conjugate acid-base pair, electrical conductivity, strong acid, strong base, weak acid, weak base

Knowledge

- names, properties, and formulae of acids and bases
- models for representing acids and bases
- weak and strong acids and bases

Skills and Attitudes

- identifying acids or bases experimentally (e.g., common household acids and bases with litmus paper)
- writing balanced equations involving acids or bases
- analysing weak-acid and weak-base equilibria

NATURE OF ACIDS AND BASES

Prescribed Learning Outcomes	Suggested Achievement Indicators
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
D1 identify acids and bases through experimentation	☐ list general properties of acids and bases ☐ write names and formulae of some common household acids and bases ☐ write balanced equations representing the neutralization of acids by bases in solution ☐ outline some of the uses and commercial names of common household acids and bases
D2 identify various models for representing acids and bases	☐ define *Arrhenius acids* and *bases* ☐ define *Brönsted-Lowry acids* and *bases*
D3 analyse balanced equations representing the reaction of acids or bases with water	☐ identify Brönsted-Lowry acids and bases in an equation ☐ define *conjugate acid-base pair* ☐ identify the conjugate of a given acid or base ☐ show that in any Brönsted-Lowry acid-base equation there are two conjugate pairs present ☐ identify an H_3O^+ ion as a protonated H_2O molecule that can be represented in shortened form as H^+
D4 classify an acid or base in solution as either weak or strong, with reference to its electrical conductivity	☐ relate electrical conductivity in a solution to the total concentration of ions in the solution ☐ define and give several examples for the following terms: – strong acid – strong base – weak acid – weak base ☐ write equations to show what happens when strong and weak acids and bases are dissolved in water
D5 analyse the equilibria that exist in weak acid or weak base systems	☐ compare the relative strengths of acids or bases by using a table of relative acid strengths ☐ predict whether products or reactants are favoured in an acid-base equilibrium by comparing the strength of the two acids (or two bases) ☐ compare the relative concentrations of H_3O^+ (or OH^-) between two acids (or between two bases) using their relative positions on an acid strength table
D6 identify chemical species that are amphiprotic	☐ define *amphiprotic* ☐ describe situations in which H_2O would act as an acid or base

Key Elements: Acids and Bases: Quantitative Problem Solving

Estimated Time: 8–12 hours

By the end of this course, students will be able to describe the special role played by water in aqueous systems and use the acid-base equilibrium constants (K_a and K_b) and the ionization constant of water (K_w) to calculate pH and pOH values for different acid-base equilibria.

Vocabulary

acid ionization constant (K_a), base ionization constant (K_b), ion product constant, pH, pK_w, pOH, water ionization constant (K_w)

Knowledge

- the pH/pOH scale
- acid and base ionization constants
- water ionization constant
- the K_a table

Skills and Attitudes

- analysing weak-acid and weak-base equilibria using the K_a table
- performing calculations
  - involving K_a and K_b
  - relating pH, pOH, $[H_3O^+]$, and $[OH^-]$

ACIDS AND BASES: QUANTITATIVE PROBLEM SOLVING

Prescribed Learning Outcomes	Suggested Achievement Indicators
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
E1 analyse the equilibrium that exists in water	☐ write equations representing the ionization of water using either H_3O^+ and OH^- or H^+ and OH^- ☐ predict the effect of the addition of an acid or base to the equilibrium system: $2H_2O \leftrightarrows H_3O^+ + OH^-$ ☐ state the relative concentrations of H_3O^+ and OH^- in acid, base, and neutral solutions ☐ write the equilibrium expression for the ion product constant of water (water ionization constant: K_w) ☐ state the value of K_w at 25°C ☐ describe and explain the variation in the value of K_w with temperature ☐ calculate the concentration of H_3O^+ (or OH^-) given the other, using K_w
E2 perform calculations relating pH, pOH, $[H_3O^+]$, and $[OH^-]$	☐ define pH and pOH ☐ define pK_w, give its value at 25°C, and its relation to pH and pOH ☐ calculate $[H_3O^+]$ or $[OH^-]$ from pH and pOH ☐ describe the pH scale with reference to everyday solutions
E3 explain the significance of the K_a and K_b equilibrium expressions	☐ write K_a and K_b equilibrium expressions for weak acids or weak bases ☐ relate the magnitude of K_a (the acid ionization constant) or K_b (the base ionization constant) to the strength of the acid or base
E4 perform calculations involving K_a and K_b	☐ given the K_a, K_b, and initial concentration, calculate any of the following: – $[H_3O^+]$ – $[OH^-]$ – pH – pOH ☐ calculate the value of K_b for a base given the value of K_a for its conjugate acid (or vice versa) ☐ calculate the value of K_a or K_b given the pH and initial concentration ☐ calculate the initial concentration of an acid or base, given the appropriate K_a, K_b, pH, or pOH values

Key Elements: Applications of Acid-Base Reactions

Estimated Time: 11–14 hours

By the end of this course, students will be able to identify practical applications of acid-base systems, demonstrate the use of titrations to determine quantities of materials, explain the significance of hydrolysis, and relate buffer systems and acid rain to the concept of acid-base equilibrium.

Vocabulary

acid rain, buffers, dissociation equation, equivalence point (stoichiometric point), hydrolysis, hydrolysis reaction, indicator, primary standards, salt, titration, titration curve, transition point

Knowledge

- significance and use of indicators
- hydrolysis of ions in salt solutions
- buffer systems (characteristics, significance, applications)
- acid rain (nature, causes, significance)

Skills and Attitudes

- performing calculations
  - involving K_a and K_b
  - relating pH, pOH, $[H_3O^+]$, and $[OH^-]$
  - involving the pH in a solution and K_a for an indicator
- designing, performing, and analysing a titration experiment (e.g., acid-base titration)

APPLICATIONS OF ACID-BASE REACTIONS

Prescribed Learning Outcomes	Suggested Achievement Indicators
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
F1 demonstrate an ability to design, perform, and analyse a titration experiment involving the following: – primary standards – standardized solutions – titration curves – appropriate indicators	☐ write formulae, complete ionic equations, and net ionic equations for – a strong acid reacting with a strong base (neutralization) – a weak acid reacting with a strong base – a strong acid reacting with a weak base ☐ demonstrate proper titration technique when performing a titration experiment ☐ explain the difference between the equivalence point (stoichiometric point) of a strong acid-strong base titration and the equivalence point of a titration involving a weak acid-strong base or strong acid-weak base ☐ interpret titration curves plotted from experimental data ☐ select indicators whose transition point coincides with the equivalence point of the titration reaction ☐ calculate the concentration of an acid or base using titration data or similar data (e.g., grams or moles) ☐ calculate the volume of an acid or base of known molarity needed to completely react with a given amount of base or acid ☐ calculate the pH of a solution formed when a strong acid is mixed with a strong base
F2 describe an indicator as an equilibrium system	☐ describe an indicator as a mixture of a weak acid and its conjugate base, each with distinguishing colours ☐ describe the term transition point of an indicator, including the conditions that exist in the equilibrium system ☐ describe the shift in equilibrium and resulting colour changes as an acid or a base is added to an indicator
F3 perform and interpret calculations involving the pH in a solution and K_a for an indicator *Organizer 'Applications of Acid-Base Reactions' continued on page 59*	☐ predict the approximate pH at the transition point using the K_a value of an indicator ☐ predict the approximate K_a value for an indicator given the approximate pH range of the colour change ☐ match an indicator's colour in a solution with an approximate pH, using a table of indicators

Prescribed Learning Outcomes	Suggested Achievement Indicators
Organizer 'Applications of Acid-Base Reactions' continued from page 58	
F4 describe the hydrolysis of ions in salt solutions	☐ write a dissociation equation for a salt in water ☐ write net ionic equations representing the hydrolysis of ions in solution
F5 analyse the extent of hydrolysis in salt solutions	☐ predict whether a salt solution would be acidic, basic, or neutral (compare K_a and K_b values, where necessary) ☐ determine whether an amphiprotic ion will act as a base or an acid in solution (compare K_a and K_b values, where necessary) ☐ calculate the pH of a salt solution from relevant data, assuming that the predominant hydrolysis reaction is the only reaction determining the pH
F6 describe buffers as equilibrium systems	☐ describe the tendency of buffer solutions to resist changes in pH (i.e., able to buffer the addition of small amounts of strong acid or the addition of small amounts of strong base) ☐ describe the composition of an acidic buffer and a basic buffer ☐ describe qualitatively how the buffer equilibrium shifts as small quantities of acid or base are added to the buffer; the stress being the change in the concentration of the stronger acid (H_3O^+) or base (OH^-) ☐ describe in detail a common buffer system (e.g., the blood buffer system)
F7 describe the preparation of buffer systems	☐ outline a procedure to prepare a buffer solution ☐ identify the limitations in buffering action
F8 predict what will happen when oxides dissolve in rain water	☐ write equations representing the formation of acidic solutions or basic solutions from non-metal and metal oxides ☐ describe the pH conditions required for rain to be called acid rain (pH 5.0 and lower) ☐ relate the pH of normal rain water to the presence of dissolved CO_2 (approximately pH 5.6) ☐ describe sources of NO_x (automobile engines) and SO_x (fuels containing sulfur and smelters of sulfide ores) ☐ discuss general environmental problems associated with acid rain

Key Elements: Oxidation-Reduction

Estimated Time: 12–13 hours

By the end of this course, students will be able to describe the essential components of reacting systems that involve electron transfer, determine the stoichiometry of redox reactions by balancing redox reactions, and apply their findings to perform redox titrations.

Vocabulary

half-reaction, oxidation, oxidation number, oxidizing agent, redox reaction, redox titration, reducing agent, reduction

Knowledge

- vocabulary of redox reactions
- characteristics of redox reactions
- "Standard Reduction Potentials of Half-Cells" table

Skills and Attitudes

- recognizing redox reactions
- assigning oxidation numbers
- creating a simple table of reduction half-reactions
- predicting the spontaneity of reactions
- analysing the relative strengths of reducing and oxidizing agents
- balancing redox equations
- perform a redox titration (e.g., the iron (II) ion with the permanganate ion)

OXIDATION-REDUCTION

Prescribed Learning Outcomes	Suggested Achievement Indicators
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
G1 describe oxidation and reduction processes	☐ define and identify – oxidation – reduction – oxidizing agent – reducing agent – half-reaction – redox reaction ☐ determine the following: – the oxidation number of an atom in a chemical species – the change in oxidation number an atom undergoes when it is oxidized or reduced – whether an atom has been oxidized or reduced by its change in oxidation number ☐ relate change in oxidation number to gain or loss of electrons
G2 analyse the relative strengths of reducing and oxidizing agents	☐ from data for a series of simple redox reactions, create a simple table of reduction half-reactions ☐ identify the relative strengths of oxidizing and reducing agents from their positions on a half-reaction table ☐ use the "Standard Reduction Potentials of Half-Cells" table to predict whether a spontaneous redox reaction will occur between any two species
G3 balance equations for redox reactions	☐ balance the equation for – a half-reaction in solutions that are acidic, basic, or neutral – a net ionic redox reaction in acidic or basic solution ☐ write the equations for reduction and oxidation half-reactions, given a redox reaction ☐ identify reactants and products for various redox reactions performed in a laboratory, and write balanced equations
G4 determine the concentration of a species by performing a redox titration	☐ demonstrate familiarity with at least two common reagents used in redox titrations (e.g., permanganate, dichromate, hydrogen peroxide) ☐ select a suitable reagent to be used in a redox titration, in order to determine the concentration of a species ☐ calculate the concentration of a species in a redox titration from data (e.g., grams, moles, molarity)

Key Elements: Applications of Redox Reactions

Estimated Time: 10–13 hours

By the end of this course, students will be able to use the concept of spontaneous and non-spontaneous reactions to explain practical applications of redox such as batteries, electroplating, electrorefining, and corrosion.

Vocabulary

cathodic protection, corrosion, electrochemical cell, electrode, electrolysis, electrolytic cell, electroplating, electrorefining, half-cell

Knowledge

- electrochemical cells: parts, voltages (E^0), half-reactions involved, practical applications
- common electrochemical cells (e.g., lead-acid battery, fuel cell, alkaline cell)
- electrolytic cells: parts, voltages required, half-reactions involved, practical applications
- metal corrosion as a chemical process (causes, prevention)

Skills and Attitudes

- designing and building electrochemical and electrolytic cells
- predicting ion flow and calculating voltages in electrochemical and electrolytic cells

APPLICATIONS OF REDOX REACTIONS

Prescribed Learning Outcomes	Suggested Achievement Indicators
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
H1 analyse an electrochemical cell in terms of its components and their functions	☐ construct an electrochemical cell ☐ define and label the parts of an electrochemical cell ☐ determine the half-reactions that take place at each electrode of an electrochemical cell, and use these to make predictions about the overall reaction and about – the direction of movement of each type of ion in the cell – the direction of flow of electrons in an external circuit – what will happen to the mass of each electrode as the cell operates ☐ predict the cell potential when equilibrium is reached ☐ determine voltages of half-reactions by analysing the voltages of several cells, with reference to the standard hydrogen half-cell ☐ identify the standard conditions for E^0 values ☐ predict the voltage (E^0) of an electrochemical cell using the "Standard Reduction Potentials of Half-Cells" table ☐ predict the spontaneity of the forward or reverse reaction from the E^0 of a redox reaction
H2 describe how electrochemical concepts can be used in various practical applications	☐ give examples of applications of electrochemical cells, including lead-acid storage batteries, alkali cells, and hydrogen-oxygen fuel cells, and explain how each functions
H3 analyse the process of metal corrosion in electrochemical terms	☐ describe the conditions necessary for corrosion of metals to occur ☐ suggest several methods of preventing or inhibiting corrosion of a metal, including cathodic protection, and account for the efficacy of each method
H4 analyse an electrolytic cell in terms of its components and their functions	☐ define *electrolysis* and *electrolytic cell* ☐ design and label the parts of an electrolytic cell used for the electrolysis of a molten binary salt such as NaCl liquid ☐ design and label the parts of an electrolytic cell capable of electrolyzing an aqueous salt such as KI aqueous (use of overpotential effect not required) ☐ predict the direction of flow of all ions in the cell and electrons in the external circuit ☐ write the half-reaction occurring at each electrode and predict observations based on this information ☐ write the overall cell reaction and predict the minimum voltage required for it to operate under standard conditions
H5 describe how electrolytic concepts can be used in various practical applications	☐ explain the principles involved in simple electroplating ☐ design and label an electrolytic cell capable of electroplating an object ☐ demonstrate familiarity with electrolytic cells in metal refining processes, including refining of zinc and aluminum