

Grade 12

A: Reaction Kinetics

(Introduction)

It is expected that students will:

- A1. recognize that reactions proceed at different rates
- A2. describe or calculate rate in terms of some quantity (produced or consumed) per unit of time
- A3. determine rate of a reaction from experimental data, and describe how rate changes over time as the reaction proceeds
- A4. identify properties that could be monitored in order to determine a reaction rate
- A5. recognize some of the factors that control reaction rates
- A6. compare and contrast factors affecting the rates of both homogeneous and heterogeneous reactions
- A7. discuss situations in which the rate of reaction must be controlled

B: Reaction Kinetics

(Collision Theory)

It is expected that students will:

- B1. demonstrate an awareness of the following:
 - 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
 - a KE distribution curve can explain how changing temperature or adding a catalyst changes the rate
 - energy changes are involved in reactions as bonds are broken and formed
- B2. describe the activated complex in terms of its potential energy (PE), stability, and structure
- B3. define activation energy

- B4. describe the relationship between activation energy and rate of reaction
- B5. describe the changes in KE and PE as reactant molecules approach each other
- B6. draw and label PE diagrams for both exothermic and endothermic reactions, including:
- the relative PE of reactants, products, and activated complex
 - activation energy
 - ΔH
- B7. relate the sign of ΔH to whether the reaction is exothermic or endothermic
- B8. write chemical equations that describe energy effects in 2 ways:
- a chemical equation that includes the energy term (thermochemical equation)
 - a chemical equation using ΔH notation
- B9. use collision theory to explain the effect of the following factors on reaction rate
- nature of reactants
 - concentration
 - temperature
 - surface area

C: Reaction Kinetics

(Reaction Mechanisms and Catalysts)

It is expected that students will:

- C1. explain why most reactions involve more than one step
- C2. 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
- C3. define catalyst
- C4. compare and contrast the PE diagrams for a catalyzed and uncatalyzed reaction in terms of:
- reaction mechanism
 - ΔH
 - activation energy
- C5. identify reactant, product, reaction intermediate, activated complex, and catalyst from a given reaction mechanism
- C6. describe the uses of specific catalysts in a variety of situations including Pt in catalytic converters in automobiles

D: Dynamic Equilibrium

(Introduction)

It is expected that students will:

- D1. describe the reversible nature of most chemical reactions
- D2. identify the reversible pathways of a chemical reaction on the PE diagram
- D3. relate the changes in rates of the forward and reverse reactions to the changing concentrations of the reactants and products as equilibrium is established
- D4. 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
- D5. describe the dynamic nature of chemical equilibrium
- D6. state that a system not at equilibrium will tend to move toward a position of equilibrium
- D7. determine entropy and enthalpy changes from a chemical equation (qualitatively)
- D8. state that systems tend toward a position of minimum enthalpy and maximum entropy (randomness)
- D9. predict the result when enthalpy and entropy factors:
 - both favour the products
 - both favour the reactants
 - oppose one another

E: Dynamic Equilibrium

(Le Châtelier's Principle)

It is expected that students will:

- E1. describe the term shift as it applies to equilibria
- E2. apply Le Châtelier's principle to the shifting of equilibrium involving the following:

- temperature change
- concentration change
- volume change of gaseous systems
- adding an inert gas to a gaseous system

E3. explain the above shifts using the concepts of reaction kinetics

E4. identify the effect of a catalyst on dynamic equilibrium

E5. apply the concept of equilibrium to a commercial or industrial process

F: Dynamic Equilibrium

(The Equilibrium Constant)

It is expected that students will:

- F1. gather and interpret data on the concentration of reactants and products of a system at equilibrium
- F2. Write the expression for the equilibrium constant when given the equation for either a homogeneous or heterogeneous equilibrium system. Explain why certain terms are not included in the expression.
- F3. relate the equilibrium position to the value of K_{eq} and vice versa
- F4. 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
- F5. perform calculations involving the value of K_{eq} and the equilibrium concentration of all species
- F6. perform calculations involving the value of K_{eq} , the initial concentrations of all species and one equilibrium concentration
- F7. calculate the equilibrium concentrations or amounts of all species given the value of K_{eq} and the initial concentrations
- F8. 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

G: Solubility Equilibria

(Concept of Solubility)

It is expected that students will:

- G1. classify a solution as ionic or molecular given its conductivity or the formula of its solute
- G2. describe the conditions necessary to form a saturated solution
- G3. describe solubility as the concentration of a substance in a saturated solution
- G4. use appropriate units to represent the solubility of substances in solutions
- G5. determine the solubility of a compound in solution
- G6. describe the equilibrium that exists in a saturated solution
- G7. write a net ionic equation that describes the equilibrium in a saturated solution
- G8. calculate the concentration of the positive and negative ions given the concentration of a solute dissolved in a solution

H: Solubility Equilibria

(Solubility and Precipitation)

It is expected that students will:

- H1. describe a compound as having high or low solubility relative to 0.1 M by using a solubility chart
- H2. use a solubility chart to predict if a precipitate will form when two solutions are mixed, and identify the precipitate
- H3. write a formula equation, complete ionic equation, and net ionic equation that represent a precipitation reaction
- H4. use a solubility chart to predict if ions can be individually separated from solution through precipitation reactions, and outline an experimental procedure which includes
 - compound added
 - precipitate formed
 - method of separation

- H5. predict qualitative changes in the solubility equilibrium upon the addition of a common ion, or the removal of an ion
- H6. identify an unknown ion through experimentation involving a qualitative analysis scheme
- H7. devise a procedure by which the calcium and or magnesium ions can be removed from hard water

I: Solubility Equilibria

(Quantitative Aspects)

It is expected that students will:

- I1. describe the K_{sp} expression as a specialized K_{eq} expression
- I2. write a K_{sp} expression for a solubility equilibrium
- I3. calculate the K_{sp} for a compound when given its solubility.
For example: $AgCl$, Ag_2S , $PbCl_2$
- I4. calculate the solubility of a compound from its K_{sp}
- I5. predict the formation of a precipitate by comparing the trial K_{sp} to the accepted K_{sp} value using specific data
- I6. calculate the maximum allowable concentration of one ion given the K_{sp} and the concentration of the other ion just before precipitation occurs
- I7. demonstrate and describe a method for determining the concentration of a specific ion

J: Acids, Bases, and Salts

(Properties and Definitions)

It is expected that students will:

- J1. identify acids and bases through experimentation
- J2. list general properties of acids and bases
- J3. write balanced equations representing the neutralization of acids by bases in solution

- J4. define Arrhenius acids and bases
- J5. write names and formulae of some common household acids and bases
- J6. define Brønsted-Lowry acids and bases
- J7. identify and label Brønsted-Lowry acids and bases in an equation
- J8. write balanced equations representing the reaction of acids or bases with water
- J9. identify an H_3O^+ ion as a protonated H_2O molecule that can be represented in shortened form as $\text{H}^+(\text{aq})$
- J10. define conjugate acid-base pair
- J11. identify the conjugate of a given acid or base
- J12. show that in any Brønsted-Lowry acid-base equation there are two conjugate pairs present

K: Acids, Bases, and Salts

(Strong and Weak Acids and Bases)

It is expected that students will:

- K1. relate electrical conductivity in a solution to the total concentration of ions in the solution
- K2. classify an acid or base in solution as either weak or strong by comparing conductivity
- K3. define a strong acid and a strong base
- K4. define a weak acid and a weak base
- K5. write equations to show what happens when strong and weak acids and bases are dissolved in water
- K6. compare the relative strengths of acids or bases by using a table of relative acid strengths

- K7. identify and explain why the strongest acid in aqueous solutions is H_3O^+ and the strongest base in aqueous solutions is OH^-
- K8. predict whether products or reactants are favoured in an acid-base equilibrium by comparing the strength of the two acids (or two bases)
- K9. 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
- K10. define amphiprotic
- K11. identify chemical species that are amphiprotic
- K12. describe situations in which H_2O would act as an acid or base

L: Acids, Bases, and Salts

(K_w , pH, pOH)

It is expected that students will:

- L1. write equations representing the ionization of water using either H_3O^+ and OH^- or H^+ and OH^-
- L2. write the equilibrium expression for the ion product constant of water, (water ionization constant), K_w
- L3. predict the effect of the addition of an acid or base to the equilibrium system:

$$2\text{H}_2\text{O}(\ell) \leftrightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq})$$
- L4. state the relative concentrations of H_3O^+ and OH^- in acid, base, and neutral solutions
- L5. state the value of K_w at 25°C
- L6. describe and explain the variation of the value of K_w with temperature
- L7. calculate the concentration of $[\text{H}_3\text{O}^+]$ (or $[\text{OH}^-]$) given the other, using K_w
- L8. describe the pH scale with reference to everyday solutions
- L9. define pH and pOH
- L10. define $\text{p}K_w$, give its value at 25°C , and its relation to pH and pOH
- L11. calculate pH, and pOH from $[\text{H}_3\text{O}^+]$ or $[\text{OH}^-]$
- L12. calculate $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ from pH or pOH

M: Acids, Bases, and Salts

(K_a and K_b Problem Solving)

It is expected that students will:

- M1. write K_a and K_b equilibrium expressions for weak acids or bases
- M2. 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
- M3. given the K_a, K_b, and initial concentration, calculate any of the following:
- [H₃O⁺]
 - [OH⁻]
 - pH
 - pOH
- M4. calculate the value of K_b for a base given the value of K_a for its conjugate acid (or vice versa)
- M5. calculate the value of K_a or K_b given the pH and initial concentration
- M6. calculate the initial concentration of an acid or base given the appropriate K_a, K_b, pH or pOH values

N: Acids, Bases, and Salts

(Hydrolysis of Salts)

It is expected that students will:

- N1. write a dissociation equation for a salt in water
- N2. write net ionic equations representing the hydrolysis of salts
- N3. predict whether a salt solution would be acidic, basic, or neutral (compare K_a and K_b values where necessary)
- N4. determine whether an amphiprotic ion will act as a base or an acid in solution (compare K_a and K_b values where necessary)
- N5. Calculate the pH of a salt solution from relevant data, assuming that the predominant hydrolysis reaction is the only reaction determining the pH

O: Acids, Bases, and Salts

(Indicators)

It is expected that students will:

- O1. describe an indicator as a mixture of a weak acid and its conjugate base, each with distinguishing colours
- O2. describe the term transition point of an indicator, including the conditions that exist in the equilibrium system
- O3. describe the shift in equilibrium and resulting colour changes as an acid or a base is added to an indicator
- O4. predict the approximate pH at the transition point using the K_a value of an indicator
- O5. predict the approximate K_a value for an indicator given the approximate pH range of the colour change
- O6. match an indicator colour in a solution with an approximate pH, using a table of indicators

P: Acids, Bases, and Salts

(Neutralizations of Acids and Bases)

It is expected that students will:

- P1. demonstrate an ability to design and perform a titration experiment involving the following:
 - primary standards
 - standardized solutions
 - titration curves
 - indicators selected so the transition point of the indicator coincides with the equivalence point of the titration reaction
- P2. calculate the concentration of an acid or base using titration data or similar data such as grams or moles
- P3. calculate the volume of an acid or base of known molarity needed to completely react with a given amount of base or acid
- P4. write formula, complete ionic, 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

P5. calculate the pH of a solution formed when a strong acid is mixed with a strong base

P6. 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

Q: Acids, Bases, and Salts

(Buffer Solutions)

It is expected that students will:

Q1. describe the function of a buffer solution to resist changes in pH. It must be able to buffer the addition of small amounts of strong acid and it must also buffer the addition of small amounts of strong base

Q2. describe the composition of an acidic buffer and a basic buffer

Q3. outline a procedure to prepare a buffer solution

Q4. identify the limitations in buffering action (as being the amount of either the weak acid (or base) or its conjugate base (or acid))

Q5. 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^-)

Q6. describe common buffer systems present in industrial, environmental, or biological systems including the common blood buffer

R: Acids, Bases, and Salts

(Acid Rain)

It is expected that students will:

- R1. predict whether a metal or nonmetal oxide will produce acidic or basic solutions; write equations representing the formation of the acidic or basic solutions
- R2. describe the pH conditions (5.0 and lower) required for rain to be called acid rain
- R3. relate the pH (about 5.6) of normal rain to the presence of dissolved CO_2
- R4. describe common sources of NO_x (automobile engines) and SO_x (smelters of sulphide ores and fuels containing sulphur)
- R5. discuss general environmental problems associated with acid rain

S: Oxidation-Reduction

(Introduction)

It is expected that students will:

- S1. define and identify the following:
 - oxidation
 - reduction
 - oxidizing agent
 - reducing agent
 - half-reaction
 - redox reaction
- S2. 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
- S3. relate change in oxidation number to gain or loss of electrons
- S4. from data for a series of redox reactions, create a table of reduction half-reactions
- S5. identify the relative strengths of oxidizing and reducing agents from their positions on a half-reaction table
- S6. use a table of reduction half-reactions to predict whether a spontaneous redox reaction will occur between any two species

T: Oxidation-Reduction

(Balancing Redox Equations)

It is expected that students will:

- T1. balance a half-reaction in solution (acid, base, neutral)
- T2. balance a net ionic redox equation in acid and base solution
- T3. write the equations for reduction and oxidation half-reactions given a redox reaction
- T4. identify reactants and products for several redox reactions performed in a laboratory and write balanced equations
- T5. select a suitable reagent to be used in a redox titration in order to determine the concentration of a species, and be familiar with a few common reagents used in redox titrations, including acidified permanganate and dichromate
- T6. determine the concentration or amount of a species from redox titration data, or similar data such as grams or moles

U: Oxidation-Reduction

(Electrochemical Cells)

It is expected that students will:

- U1. define, construct, and label the parts of an electrochemical cell
- U2. determine the half-reactions that take place at each electrode of an electrochemical cell, and use these reactions to predict typical observations as well as the overall reaction
- U3. predict the direction of movement of each type of ion in the cell
- U4. predict the direction of flow of electrons in an external circuit
- U5. predict what happens to the mass of each electrode as the cell operates
- U6. predict the voltage (potential) of the cell when equilibrium is reached

- U7. determine voltages of half-reactions by analyzing the voltages of several cells.
Recognize that reduction half cell voltages are relative to the standard hydrogen half cell (voltage = 0V)
- U8. recognize that E° of an electrochemical cell represents the cell potential at standard conditions
- U9. predict the voltage (E°) of an electrochemical cell using the table of standard reduction half-cells
- U10. predict the spontaneity of the forward or reverse reaction from the E° of a redox reaction
- U11. demonstrate a general understanding of applications of electrochemical cells, including lead-acid storage batteries, alkali cells and hydrogen-oxygen fuel cells

V: Oxidation-Reduction

(Corrosion)

It is expected that students will:

- V1. describe the conditions necessary for corrosion of metals (spontaneous oxidation) to occur
- V2. describe the process of metal corrosion in electrochemical terms
- V3. suggest several methods of preventing or inhibiting corrosion of a metal, and explain why these methods work.
- V4. describe and explain the principle of cathodic protection

W: Oxidation-Reduction

(Electrolytic Cells)

It is expected that students will:

- W1. define electrolysis and electrolytic cell
- W2. design and label the parts of an electrolytic cell used for the electrolysis of a molten binary salt such as NaCl liquid
- W3. 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)

- W4. predict the direction of flow of all ions in the cell and electrons in the external circuit
- W5. write the half-reactions occurring at each electrode and predict observations based on these half reactions
- W6. write the overall cell reaction and predict the minimum voltage required for it to operate under standard conditions
- W7. demonstrate an understanding of the principles involved in simple electroplating
- W8. construct an electrolytic cell capable of electroplating an object
- W9. demonstrate a general understanding of applications of electrolytic cells in metal refining processes including refining of Zn and Al