Chemistry 12 Standards **Updated April, 2016**

This is a plan for how the curriculum of Chemistry 12 will be broken down. It is possible that some standards will be combined or broken up, any such changes will occur before the unit they appear in begins.

Reaction Kinetics

Rate of Reaction and Collision Theory: (A1, A2,A3,A5) Demonstrate awareness that reactions occur at differing rates and experimentally determine rate of a reaction. Demonstrate knowledge of collision theory and apply collision theory to explain how reaction rates can be changed.

- 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
- 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
- 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
- use collision theory to explain the effect of the following factors on reaction rate:
  - nature of reactants
  - concentration
  - temperature
  - surface area

Energy in Reactions: (A4): describe the energies associated with reactants becoming products

- Explain energy changes are involved in reactions as bonds are broken and formed
- use a KE distribution curve to explain how changing temperature changes the rate
- 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

Reaction Mechanisms and Catalysts:(A5,A6,A7) Analyse the reaction mechanism for a reacting system, represent graphically the energy changes associated with catalyzed and uncatalyzed reactions and describe the uses of specific catalysts in a variety of situations

- 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
- 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
- describe the effect of a catalyst on a number of reactions

Equilibrium

Nature of Equilibrium: (B1, B2) Explain the concept of chemical equilibrium with reference to reacting systems and predict, with reference to entropy and enthalpy, whether reacting systems will reach equilibrium

- 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
- 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

Le Chatelier's Principle and K_{eq}:(B3,B4,B5) Apply Le Châtelier's principle to the shifting of equilibrium, apply the concept of equilibrium to a commercial or industrial process and draw conclusions from the equilibrium constant expression

- 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
- describe the Haber process for the production of ammonia (NH3)
- 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 Keq and vice versa
- predict the effect (or lack of effect) on the value of Keq of changes in the following factors: temperature, pressure, concentration, surface area, and catalyst

Equilibrium Calculations (B6): perform calculations to evaluate the changes in the value of Keq and in concentrations of substances within an equilibrium system perform calculations involving the value of Keq and the equilibrium concentration of all species

- perform calculations involving the value of Keq, the initial concentrations of all species, and one equilibrium concentration
- perform calculations involving the equilibrium concentrations of all species, the value of Keq, 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

Solubility Equilibrium

Solubility equilibriums (C1,C2,C3): determine the solubility of a compound in aqueous solution, describe a saturated solution as an equilibrium system and determine the concentration of ions in a 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
- describe a saturated solution as an equilibrium system
- describe the equilibrium that exists in a saturated aqueous solution
- determine the concentrations 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

Precipitation reactions (C4,C5): determine the relative solubility of a substance, given solubility tables. Apply solubility rules to analyse the composition of solutions, apply solubility rules to analyse the composition of solutions

- 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
- 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
- devise a procedure by which the calcium and/or magnesium ions can be removed from hard water
- identify an unknown ion through experimentation involving a qualitative analysis scheme

Solubility product (C6,C7,C8): Formulate equilibrium constant expressions for various saturated solutions, perform calculations involving solubility equilibrium concepts

- describe the Ksp expression as a specialized Keq expression
- write a Ksp expression for a solubility equilibrium
- calculate the Ksp for a compound when given its solubility (e.g., AgCl, Ag2S, PbCl2)
- calculate the solubility of a compound from its Ksp
- predict the formation of a precipitate by comparing the trial ion product to the Ksp value using specific data
- calculate the maximum allowable concentration of one ion given the Ksp and the concentration of the other ion just before precipitation occurs
- determine the concentration of chloride ion using a precipitation reaction with silver ions

Acids, Bases and Salts

Theories of Acids and Bases (D1, D2,D3, D6): Identify acids and bases through experimentation, identify various models for representing acids and bases, and identify chemical species that are amphiprotic

- 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
- define Arrhenius acids and bases
- identify an H_3O^+ ion as a protonated H_2O molecule that can be represented in shortened form as H^+
- define Brönsted-Lowry acids and bases
- identify Brönsted-Lowry acids and bases in an equation
- define amphiprotic
- describe situations in which H_2O would act as an acid or base
- 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

Strong and Weak Acids and Bases (D4, D5): Classify an acid or base in solution as either weak or strong, with reference to its electrical conductivity, analyse the equilibria that exist in weak acid or weak base systems.

- 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
- 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

Ionization and Hydrolysis (E1,E3 F4, F5): analyse the equilibrium that exists in water, perform calculations relating pH, pOH, $[H_3O^+]$, and $[OH^-]$, explain the significance of the K_a and K_b equilibrium expressions, perform calculations involving Ka and Kb, describe the hydrolysis of ions in salt solutions, analyse the extent of hydrolysis in salt solutions

- 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: $2H_2O \rightleftharpoons H_3O^+ + OH^-$
- 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 Kw with temperature
- calculate the concentration of H3O$^+$ (or OH^-) given the other using K_w
- write K_a and K_b equilibrium expressions for weak acids or weak bases
- calculate the value of Kb for a base given the value of Ka for its conjugate acid (or vice versa)
- 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
- write a dissociation equation for a salt in water
- write net ionic equations representing the hydrolysis of ions in solution
- 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)

pH and pOH calculations(E2, E4): perform calculations relating pH, pOH, $[H_3O^+]$, and $[OH^-]$, explain the significance of the K_a and K_b equilibrium expressions, perform calculations involving Ka and Kb,

- define pH and pOH
- define pKw, give its value at 25°C, and its relation to pH and pOH
- calculate [H3O+] or [OH-] from pH and pOH
- describe the pH scale with reference to everyday solutions
- given the Ka, Kb, and initial concentration, calculate any of the following:
  - $[H_3O^+]$
  - $[OH^-]$
  - pH
  - pOH
- calculate the value of Ka or Kb 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
- calculate the pH of a salt solution from relevant data, assuming that the predominant hydrolysis reaction is the only reaction determining the pH

Titrations (F1,F2, F3): demonstrate an ability to design, perform, and analyse a titration experiment involving primary standards, standardized solutions, titration curves, and appropriate indicators, describe an indicator as an equilibrium system, perform and interpret calculations involving the pH in a solution and K_a for an indicator

- 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
- calculate the pH of a solution formed when a strong acid is mixed with a strong 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
- 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
- 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

Buffers and Acid Rain (F6,F7,F8) Note 23-24: describe buffers as equilibrium systems, describe the preparation of buffer systems, predict what will happen when oxides dissolve in rain water

- 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)
- outline a procedure to prepare a buffer solution
- identify the limitations in buffering action
- 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

Electrochemistry

Electrochemistry basics (G1, G2): describe oxidation and reduction processes, analyse the relative strengths of reducing and oxidizing agents

- 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 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

Redox Equations (G3, G4): Balance equations for redox reactions determine the concentration of a species by performing a redox titration

- 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
- 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)

Electrochemical Cells(H1, H2, H3): Analyse an electrochemical cell in terms of its components and their functions, describe how electrochemical concepts can be used in various practical applications, analyse the process of metal corrosion in electrochemical terms

- 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 E0 values
- predict the voltage (E0) of an electrochemical cell using the “Standard Reduction Potentials of Half-Cells” table
- predict the spontaneity of the forward or reverse reaction from the E0 of a redox reaction
- give examples of applications of electrochemical cells, including lead-acid storage batteries, alkali cells, and hydrogen-oxygen fuel cells, and explain how each functions
- 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

Electrolysis (H4, H5): Analyse an electrolytic cell in terms of its components and their functions, describe how electrolytic
concepts can be used in various practical applications

- 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
- 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