Big Idea: Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.

Objectives:
The student will be able to...
  □ given a set of experimental observations regarding physical, chemical, biological, or environmental processes that are reversible, construct an explanation that connects the observations to the reversibility of the underlying chemical reactions or processes.
  □ given a manipulation of a chemical reaction or set of reactions (e.g., reversal of reaction or addition of two reactions), determine the effects of that manipulation on $Q$ or $K$.
  □ connect kinetics to equilibrium by using and reasoning about equilibrium, such as LeChâtelier’s principle, to infer the relative rates of the forward and reverse reactions.
  □ given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, $K$, use the tendency of $Q$ to approach $K$ to predict and justify the prediction as to whether the reaction will proceed toward products or reactants as equilibrium is approached.
  □ given data (tabular, graphical, etc.) from which the state of a system at equilibrium can be obtained, calculate the equilibrium constant, $K$.
  □ given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, $K$, use stoichiometric relationships and the law of mass action ($Q$ equals $K$ at equilibrium) to determine qualitatively and/or quantitatively the conditions at equilibrium for a system involving a single reversible reaction.
  □ for a reversible reaction that has a large or small $K$, to determine which chemical species will have very large versus very small concentrations at equilibrium.
  □ use LeChâtelier’s principle to predict the direction of the shift resulting from various possible stresses on a system at chemical equilibrium.
  □ use LeChâtelier’s principle to design a set of conditions that will optimize a desired outcome, such as product yield.
  □ connect LeChâtelier’s principle to the comparison of $Q$ to $K$ by explaining the effects of the stress on $Q$ and $K$.
  □ generate or use a particular representation of an acid (strong or weak or polyprotic) and a strong base to explain the species that will have large versus small concentrations at equilibrium.
  □ reason about the distinction between strong and weak acid solutions with similar values of pH, including the percent ionization of the acids, the concentrations needed to achieve the same pH, and the amount of base needed to reach the equivalence point in a titration.
  □ interpret titration data for monoportic or polyprotic acids involving titration of a weak or strong acid by a strong base (or a weak or strong base by a strong acid) to determine the concentration of the titrant and the $pK_a$ for a weak acid, or the $pK_b$ for a weak base.
  □ based on the dependence of $K_w$ on temperature, reason that neutrality requires $[H^+] = [OH^-]$ as opposed to requiring $pH = 7$, including especially the applications to biological systems.
☐ identify a given solution as containing a mixture of strong acids and/or bases and calculate or estimate the pH (and concentrations of all chemical species) in the resulting solution.

☐ identify a given solution as being the solution of a monoprotic weak acid or base (including salts in which one ion is a weak acid or base), calculate the pH and concentration of all species in the solution, and/or infer the relative strengths of the weak acids or bases from given equilibrium concentrations.

☐ given arbitrary mixture of weak and strong acids and bases (including polyprotic systems), determine which species will react strongly with one another (i.e., with $K > 1$) and what species will be present in large concentrations at equilibrium.

☐ design a buffer solution with a target pH and buffer capacity by selecting an appropriate conjugate acid-base pair and estimating the concentrations needed to achieve the desired capacity.

☐ relate the predominant form of a chemical species involving a labile proton (i.e., protonated/deprotonated form of a weak acid) to the pH of a solution and the $pK_a$ associated with the labile proton.

☐ identify a solution as being a buffer solution and explain the buffer mechanism in terms of the reactions that would occur on addition of acid or base.

☐ predict the solubility of a salt, or rank the solubility of salts, given the relevant $K_{sp}$ values.

☐ interpret data regarding solubility of salts to determine, or rank, the relevant $K_{sp}$ values.

☐ interpret data regarding the relative solubility of salts in terms of factors (common ions, pH) that influence the solubility.

☐ analyze the enthalpic and entropic changes associated with the dissolution of a salt, using particulate level interactions and representations.

☐ express the equilibrium constant in terms of $\Delta G^\circ$ and $RT$ and use this relationship to estimate the magnitude of $K$ and, consequently, the thermodynamic favorability of the process.