Reading: Faure 10.5, 10.6

Goals:
- Use our chemical reactions toolbox to analyze the weathering of feldspar

1. The role of Aluminum
   a. We have looked at Al solubility. Very low in most settings. Exceptions are low pH and high pH environments.
   b. Thus.. Intense weathering tends to remove more soluble species (like Na\(^+\) and SiO\(_2\)), and the soil is left with Al(OH)\(_3\) and related compounds—example= bauxite
   c. In most cases, the Al combines with silicate (and maybe cations) to form clay minerals (see Faure chapter 13 for details on clay minerals)
      i. Montmorillonite/smectite clays: Rich in Mg, usually form where mafic rocks are weathered. Lots of exchangeable cations.
      ii. Illite clays: Similar to micas, usually form where granitic rocks weather.
      iii. Kaolinite: Stabilized by more intense weathering and acidic conditions.

2. Writing a reaction.
   a. We could write it in terms of complete (i.e., congruent) dissolution…
   b. But it is better to include the Al-bearing solids that stay behind
      i. Silicates are generally strong base cations plus weak acid anions
         1. so the reaction gives off OH\(^-\) ions (OR consumes H\(^+\))
            a. Note that these are equivalent.
      ii. Example:
         \[
         2 \text{K-Feldspar} + \text{acid} \rightarrow \text{Kaolinite} + \text{dissolved K and silica}
         \]
         \[
         2 \text{KAlSi}_3\text{O}_8 + 9 \text{H}_2\text{O} + 2 \text{H}^+ \rightarrow \text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4 + 2 \text{K}^+ + 4 \text{H}_4\text{SiO}_4
         \]
   c. H\(^+\) is consumed in the weathering reaction. So do you think weathering is promoted or decreased by low pH conditions?
   d. Also... we can rewrite the equation with carbonic acid on the left side instead of H\(^+\) ions, and bicarbonate on the right

3. Does the reaction go to completion, to equilibrium, or are they generally incomplete (because of slow kinetics)?
   a. Unstable phases (most igneous minerals) are continually consumed, rarely or never reach equilibrium.
   b. Equilibrium is approached with certain minerals; the solution becomes saturated with respect to them, probably supersaturated.
   c. Rapid flushing of water through soils (wet climates) means more dilute waters, fewer minerals in equilibrium with them.
   d. If a soil solution has a long residence time, that leads to greater dissolution of unstable minerals, greater concentrations.
4. **If equilibrium is approached**
   a. The Mass action equations provide relationships between activities. For the example in 2) above, explore these relationships between the activities of silica, potassium ion, and hydrogen ion.
   b. Consider changes/perturbations using LeChatelier’s principle.
      i. e.g., does increased pH tend to stabilize K-feldspar or destabilize it, relative to kaolinite?
      ii. e.g., how about increased dissolved K$^+$ or silica?
      iii. Can you guess which side of the equation is stabilized by increased T?
   c. Diagrams plotting **ratios of activities** are very useful:
      i. See Faure, 10.6
      ii. Consider a soil or aquifer environment where concentrations have built up to high concentrations and:
      iii. solution is saturated with respect to Kaolinite (common)
      iv. solution is saturated with respect to K-feldspar (uncommon)
      v. Aqueous [SiO$_2$], [K$^+$], and [H$^+$] are variable
      vi. So we can plot the possible values of these at equilibrium; this gives a line in 2-D (see Faure fig. 10.5) or a surface in 3-D
      vii. If the solution composition plots on that line, then the solution is in equilibrium with both Kaolinite and K-feldspar (assuming equilibrium is closely approached for both solid phases)
      viii. If it plots to the upper right- K-feldspar stable, Kaolinite not stable
      ix. If it plots to the lower left- K-feldspar unstable, Kaolinite stable