Objectives
Introduce or review elements of chemistry to prepare for applied lessons in agricultural chemistry.

Suggested grade levels
9-12

Alaska Content Standards
Science, D1, D3

Terms to Define
ion
valence
chemical reaction
equilibrium
cations
anions
pH
alkaline
acid

Introduction
This lesson lays the groundwork for four lessons that apply the principles of chemistry to agriculture in real applications. It may be used for review.

Basic Chemistry Principles

A. Valence
The valence of an element can be thought of as the number of hydrogen ions it will take to replace or combine with the element in a chemical reaction. For example, two H+ ions will combine with one O-2 ion to form H2O. Thus, the valence of the oxygen element is -2.

B. Ions
A single atom (or a group of elements) with an electrical charge is called an ion. Ions which are positively charged are called cations while those with negative charges are called anions.

Cations: H+, NH4+, Ca+2, Fe+3
Anions: OH-, NO3-, SO4-2, Cl-

C. Chemical Reactions

A + B        C + D

Le Chatelier’s Principle:
A system has to be in chemical equilibrium. When a system at equilibrium is disturbed, the equilibrium position will shift in the direction which tends to minimize, or counteract, the effect of the disturbance.

Examples:
If the concentration of a reactant is increased, the equilibrium position shifts to use up the added reactants by producing more products.

If the pressure on an equilibrium system is increased, then the equilibrium position shifts to reduce the pressure.

If the volume of a gaseous equilibrium system is reduced (equivalent to an increase in pressure) then the equilibrium position shifts to increase the volume (equivalent to a decrease in pressure)

If the temperature of an endothermic equilibrium system is increased, the equilibrium position shifts to use up the heat by producing more products.

D. What is pH?

pH is a measure of the hydrogen ion concentration, H+
pH can be calculated using the following formula:

\[ pH = -\log_{10} [H^+] \]

Hydrogen ion concentration \([H^+]\) can be calculated using the following formula:

\[ [H^+] = 10^{-pH} \]

**Acid Solutions**

Solutions where the H+ concentration is greater than 10-7 or the pH is less than 7 are considered acidic.

**Alkaline Solutions**

Solutions where the H+ concentration is less than 10-7 or the pH is greater than 7 are considered alkaline or basic.

**Neutral Solutions**

Solutions where the H+ concentration equals 10-7 or the pH equals 7 are considered neutral.

**E. Oxidation-reduction reactions (Redox reactions)**

Oxidation is the process that results in the loss of one or more electrons.

\[ \text{Fe}^{+2} - e^- \rightarrow \text{Fe}^{+3} \]

Reduction is the process that results in the gain of one or more electrons.

\[ \text{Fe}^{+3} + e^- \rightarrow \text{Fe}^{+2} \]

**Redox reactions**

Oxidant: gains electrons (oxidant is reduced) and causes the other compound or element to be oxidized.

Reducant: loses electrons (reductant is oxidized) and causes the other compound or element to be reduced.

The reductant (oxidized element or compound) provides electrons to the oxidant (reduced element or compound).

**Example:**

\[ \text{Na} \quad \text{Na}^+ + e^- \]

\[ \text{F} + e^- \rightarrow \text{F}^- \]

\[ \text{F} + \text{Na} \rightarrow \text{F}^- + \text{Na}^+ \]

F is the oxidant and was reduced.

Na is the reductant and was oxidized.
Table showing oxidized and reduced forms of several important elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Oxidized form found in well-aerated soils</th>
<th>Reduced form found in waterlogged soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>$\text{NO}_3^-$</td>
<td>$\text{N}_2, \text{NH}_4^+$</td>
</tr>
<tr>
<td>Sulfur</td>
<td>$\text{SO}_4^{2-}$</td>
<td>$\text{H}_2\text{S}, \text{S}^{2-}$</td>
</tr>
<tr>
<td>Iron</td>
<td>$\text{Fe}^{3+}$</td>
<td>$\text{Fe}^{2+}$</td>
</tr>
<tr>
<td>Carbon</td>
<td>$\text{CO}_2, \text{C}_6\text{H}_12\text{O}_6$</td>
<td>$\text{CH}_4, \text{C}_2\text{H}_4$</td>
</tr>
</tbody>
</table>

F. Units of Measure

Mole = Avogadro’s number of molecules = $6.023 \times 10^{23}$

Molecular and formula weights:

Molecular weight = grams/mole

Formula weight = all elemental molecular weights added together

Example: What is the formula weight of ammonium nitrate $\text{NH}_4\text{NO}_3$ (a common fertilizer)?

Molecular weight of $\text{N} = 14 \text{ g/mole} \times 2 = 28 \text{ g/mole}$
Molecular weight of $\text{H} = 1 \text{ g/mole} \times 4 = 4 \text{ g/mole}$
Molecular weight of $\text{O} = 16 \text{ g/mole} \times 3 = 48 \text{ g/mole}$

Formula weight of $\text{NH}_4\text{NO}_3^- = 80 \text{ g/mole}$

Concentrations:

Molarity is a measure of the concentration of a solution

Molarity refers to the number of moles of an element or compound per liter of solution

Molarity can be expressed as moles/liter, mol/L, mol L$^{-1}$, or M
1. Cations: Cu\(^{+2}\), NH\(_4\)^+, Mn\(^{+2}\), Ca\(^{+2}\)
   Anions: NO\(_3\)^-, H\(_2\)PO\(_4\)^-, SO\(_4\)^-, Cl^-

2. Write the balanced equation for the dissociation of the acid
   \[ \text{HCl} \rightarrow \text{H}^+ \text{(aq)} + \text{Cl}^- \text{(aq)} \]
   Use the equation to find the [H\(^+\)]:
   0.2 mol L\(^{-1}\) HCl produces 0.2 mol L\(^{-1}\) H\(^+\) since HCl is a strong acid that fully dissociates
   Calculate pH: \[ \text{pH} = -\log_{10}[\text{H}^+] \]
   \[ \text{pH} = -\log_{10}[0.2] = 0.7 \]

3. Write the balanced equation for the dissociation of the acid
   \[ \text{H}_2\text{SO}_4 \rightarrow 2\text{H}^+ \text{(aq)} + \text{SO}_4^{2-} \text{(aq)} \]
   Use the equation to find the [H\(^+\)]:
   0.2 mol L\(^{-1}\) H\(_2\)SO\(_4\) produces 2 x 0.2 = 0.4 mol L\(^{-1}\) H\(^+\) since H\(_2\)SO\(_4\) is a strong acid that fully dissociates
   Calculate pH: \[ \text{pH} = -\log_{10}[\text{H}^+] \]
   \[ \text{pH} = -\log_{10}[0.4] = 0.4 \]

4. pH = 3.0
   \[ [\text{H}^+] = 10^{-3.0} \]
   \[ [\text{H}^+] = 10^{-3.0} = 0.001 \text{mol L}^{-1} \]

5. oxidation
   
   reduction
   Cu\(^{+2}\) = oxidant & Zn = reductant

6. Determine Formula Weight of ammonium nitrate= 80 g/mole
   Determine % of N in ammonium nitrate = 28 g/mole divided by 80 g/mole = 35% N
   Need 2.0 g of N, so 2.0 g N / x g ammonium nitrate = 0.35 N / 1.0 ammonium nitrate
   \[ 0.35x = 2.0 \text{ g N} \]
   \[ x = 5.71 \text{ grams of ammonium nitrate} \]
Basic Chemistry & Agriculture Problems

1. Which of the following elements and compounds are cations and which are anions?
   NO₃⁻, H₂PO₄⁻, Cu²⁺, SO₄²⁻, NH₄⁺, Mn²⁺, Cl⁻, Ca²⁺

   Cations:
   Anions:

2. Find the pH of a 0.2 mol/L (0.2M) solution of HCl.

3. Find the pH of a 0.2 mol/L (0.2M) solution of H₂SO₄.

4. Find the concentration of H⁺ in a nitric acid solution with a pH of 3.0.

5. Consider the following chemical reaction: Zn → Zn²⁺ + 2e⁻
   Is this an oxidation or reduction reaction?

   Consider the following chemical reaction: Cu²⁺ + 2e⁻ → Cu
   Is this an oxidation or reduction reaction?

   Consider the following chemical reaction: Cu²⁺ + Zn → Cu + Zn²⁺
   Which element is the oxidant and which element is the reductant?

6. How much ammonium nitrate (NH₄NO₃⁻) is needed to apply 2.0 g of N to a pot of soil?