**KEY Student Activity 1: Comparing Strong and Weak Acids and Bases**

1. ALL of the substances are 0.1M.
   a. Calculate the pH of a 0.1M H+ solution? Show equations and work here.
      \[ \text{pH} = -\log[H^+] = -\log[0.1] = 1 \]
   b. Calculate the pH of a 0.1M OH- solution? Show equations and work here.
      \[ \text{pOH} = -\log[OH^-] = -\log[0.1] = 1 \]
      \[ \text{pH} = 14 - \text{pOH} = 14 - 1 = 13 \]

Use the beaker diagrams to answer the questions below. ALL of the substances are 0.1M.

2. Is substance #1 an acid or a base? How can you tell?
   Acid because it dissociates to create protons. It also has a pH less than 7.
   Also has -COOH in chemical formula

3. Is substance #2 an acid or a base? How can you tell?
   Acid because it dissociates to create protons. It also has a pH less than 7.
   Also starts with H-

4. Compare the beaker diagrams for beaker #1 and #2. How are they the same? How are they different?
   Both are acids because they produce H+.
   In beaker #1, the acid did not completely dissociate like beaker #2.

5. Even though both substance #1 and #2 are 0.1M, how do their pH values compare? Be specific here.
   They both have pH values below 7; however, beaker #2 has a pH that matches the calculations in problem 1 above. The pH is not as acidic for beaker #1.

6. Why might substance #2 be the pH value that we expected from your response to 1a; however, substance #1 is NOT the expected pH? (Use the beaker diagram to form your response)
   Since not all of the acid dissociated, this acid created less H+ which is the species that has an impact on the pH. Less H+, less acidic. In beaker #1, the acid dissociates completely which maximizes acidity value for pH.

7. Is substance #3 an acid or a base. How can you tell?
   Base because it generates OH- in water. It has a pH greater than 7.
   It is salt which contains -OH

8. Is substance #4 an acid or a base. How can you tell?
   Base because it generates OH- in water. It has a pH greater than 7.
   NH3 is a base.

9. Compare the beaker diagrams for beaker #3 and #4. How are they the same? How are they different?
   These are similar because they both produce OH-. They are different because beaker #3 dissociates into OH- completely. In beaker #4, most of the molecules are not dissociating.

10. Even though both substance #3 and #4 are 0.1M, how do their pH values compare? Be specific here.
    #3 = 13
    #4 = 11.3
    Both values are greater than 7 making them both bases. Beaker #3 is less basic than
beaker #4. Beaker #3 matches the calculations in problem 2 above.

11. Why might substance #3 be the pH value that we expected from your response to 1a; however, substance #4 is NOT the expected pH? (Use the beaker diagram to form your response).
   Since #3 dissociates completely, the pH value is 13 which matches out calculations above in #2. However, in #4, since the molecule do not completely dissociate, the pH is not as basic since it is not producing as many OH- ions.

12. Substances with high levels of dissociation like salt are good electrical conductors. Why?
   Ions dissolved into water are charged and mobile and can therefore carry an electrical charge.

13. Which of the substances in this activity would be GOOD electrical conductors?
   Beaker #2 and #3 because both dissociate completely creating lots of ions to carry a charge.

14. By definition, STRONG acids and bases dissociate COMPLETELY (100%). WEAK acids and bases DO NOT dissociate much – only a small amount. Based on this, list substances #1-6 in each of the following categories:
   a. Strong Acid: #2
   b. Weak Acid: #1 and #5
   c. Strong Base: #3
   d. Weak Base: #4 and #6

15. Because STRONG acids/bases dissociate completed, they are considered to be NON-reversible reactions. The reaction arrow only goes one way. Write the dissociation reaction for one strong acid and one strong base.
   Salt example:
   - NaCl \rightarrow Na^+ + Cl^- (All of the salt breaks into ions)
   - HNO_3 \rightarrow H^+ + NO_3^-
   - NaOH \rightarrow Na^+ + OH^-

16. Because WEAK acids/bases do not completely dissociate, they are at equilibrium/reversible therefore the reaction arrow goes both ways. Write the dissociation reaction for one weak acid and one weak base.
   Salt example (insoluble salt):
   - AgCl \rightleftharpoons Ag^+ + Cl^- (most of the salt stays AgCl)
   - HF \rightleftharpoons H^+ + F^-
   - NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-
**KEY Student Notes: Comparing Weak and Strong Acids and Bases**

**Ions to know:**
- $\text{H}^+$ = Proton
- $\text{H}_3\text{O}^+$ = hydronium
- $\text{OH}^-$ = hydroxide

**Acid-Base Definition Review:**
- **Arrhenius Acid** = Bronstead-Lowry Acid = H+ (proton) donor/ $\text{H}_3\text{O}^+$ (hydronium) producer
  - EX: $\text{HCl} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^-$
- **Arrhenius Base** = OH- (hydroxide) donor
  - That means it has to have an OH- in its chemical formula
  - EX: NaOH, KOH, Ca(OH)$_2$
  - EX: NaOH $\rightarrow$ Na$^+$ + OH$^-$
- **Bronstead-Lowry Base** = H$^+$ acceptor
  - Includes OH$^-$ because it accepts a proton to make water!
  - Most common examples are NH$_3$ and amines (ex: CH$_3$NH$_2$)
  - EX: CH$_3$NH$_2$ + H$_2$O $\rightleftharpoons$ CH$_3$NH$_3^+$ + OH$^-$

*It helps if students highlight or circle the species in the product that impacts the pH.*

**Acid-Base Strength**

**CONCENTRATION IS NOT THE SAME AS STRENGTH!!!!!!!!!!!!!!**
- Concentrate/Dilute is defined by molarity (6M is more concentrated than 1M)
  - This is relative for each specific chemical. There is not specific cut off for concentrated or dilute.
- Strength is determined by how much of the acid or base dissociates in water
  - DISSOCIATES IS DIFFERENT THAN DISSOLVING
  - DISSOCIATES means that it breaks into IONS!!!! In order for something to dissociate it must FIRST dissolve

**BEAKER DIAGRAM:**

<table>
<thead>
<tr>
<th>Strong Acid</th>
<th>Weak Acid</th>
<th>Strong Base</th>
<th>Weak Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{HCl} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^-$</td>
<td>$\text{HCN} + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{O}^+ + \text{CN}^-$</td>
<td>$\text{KOH} \rightarrow \text{K}^+$ and $\text{OH}^-$</td>
<td>$\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$</td>
</tr>
<tr>
<td>$\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$</td>
<td>$\text{HCN} \rightleftharpoons \text{H}^+ + \text{CN}^-$</td>
<td>$\text{Conj. Base}$</td>
<td>$\text{Conj. Acid}$</td>
</tr>
</tbody>
</table>

When writing dissociation reactions, the college board usually uses $\text{H}_3\text{O}^+$ but it is beneficial for the students to see it both ways because some resources/professors use $\text{H}^+$. 
Mention to the students that particulate drawings are not always quantitative. For example, the example above only has a few extra HCN molecules. Bases on calculations, there would have to be hundreds of those for each one CN\(^-\) and H\(_3\)O\(^+\). These just show that there are MORE HCN – not the actual proportion of them.

For weak acids/bases, using the \(\rightleftharpoons\) is important. This dissociation is at equilibrium with a value that is less than one. The reactants are favored. Since the reverse reaction is also occurring, the conjugate base is accepting an H\(^+\) and forming HCN (and vice versa for the base).

Sometimes you will see strong acids written with a double arrow \(\rightleftharpoons\). However, the Ka value is so large (sooooo product favored) that these reactions are considered to go to completely. The Cl\(^-\) is technically a conjugate base because it is an ineffective base because it will not accept a H\(^+\) to become HCl. You may want to save this part of the discussion until after the students have a solid foundation on this concept.

**Strong Acids DISSOCIATE COMPLETELY**
- You must memorize the 6 strong acids (there are more, but these are the most important!)
  - HCl = hydrochloric acid
  - HBr = hydrobromic acid
  - HI = hydroiodic acid
  - HNO\(_3\) = nitric acid
  - HClO\(_4\) = perchloric acid
  - H\(_2\)SO\(_4\) = sulfuric acid*

*Strong Bases DISSOCIATE COMPLETELY (sample list):*
- LiOH
- NaOH
- KOH
- CsOH
- Mg(OH)\(_2\)*
- Ca(OH)\(_2\)*
- Sr(OH)\(_2\)*

*These dissociate completely when dissolved, but do not dissolve well. There are additional Ksp considerations with these bases.

Instructions: For the following table, check acid or base, check strong or weak, and record the molarity.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Acid</th>
<th>Base</th>
<th>Strong</th>
<th>Weak</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>10M LiOH</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>10M</td>
</tr>
<tr>
<td>17M CH(_3)COOH</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>17M</td>
</tr>
<tr>
<td>0.01M H(_2)SO(_4)</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>0.01M</td>
</tr>
<tr>
<td>5M NH(_3)</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td>5M</td>
</tr>
<tr>
<td>0.5M KOH</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>0.5M</td>
</tr>
<tr>
<td>1M Citric Acid</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td>1M</td>
</tr>
<tr>
<td>12M HNO(_3)</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td>12M</td>
</tr>
</tbody>
</table>