Hydrolysis of Salts

Background

Many chemical reactions are carried out in water solution. Water, a solvent, provides a medium in which the reacting substances may come together. In acidic and basic solutions, we have considered the H\(^+\) and OH\(^-\) ions formed directly from acids and bases by the process called ionization. We will now consider the formation of H\(^+\) and OH\(^-\) ions by the reaction of an ion with water. This reaction is called hydrolysis.

Normal salts are produced by acid-base neutralization. If this were entirely true, a dissolved salt would always produce a neutral solution in water. However, the solutions of some salts are not neutral. Pure water ionizes:

\[
2\text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq})
\]

But the H\(_3\)O\(^+\) and OH\(^-\) concentrations are very low; approximately 1 x 10\(^{-7}\) ions per mole.

Water molecules can act either as proton (H\(^+\)) donors or proton acceptors. A salt that is formed from a weak acid and a strong base will generally form water solutions that are basic. The basic anion accepts a proton from a water molecule forming a weak acid and leaving OH\(^-\) ions from the water molecules in solution. The solution will be basic due to the increase of OH\(^-\) ion concentration.

Salts that are formed from a strong acid and a weak base generally form water solutions that are acidic. The acidic cation donates a proton to the water molecule, forming a weak base and creating H\(_3\)O\(^+\) ions in solution. In addition, water molecules may accept protons from the hydrated metallic cations; imagine the water molecules surrounding the metal ions being replaced by hydroxide ions.

For metal(II) ions: 
\[
\text{M(H}_2\text{O)}_{\text{6}}^{2+} + \text{H}_2\text{O} \rightleftharpoons \text{M(H}_2\text{O)}_{\text{5}}^{+}\text{(OH)}^{+} + \text{H}_3\text{O}^{+}
\]

For metal (III) ions: 
\[
\text{M(H}_2\text{O)}_{\text{6}}^{3+} + \text{H}_2\text{O} \rightleftharpoons \text{M(H}_2\text{O)}_{\text{5}}^{+}\text{(OH)}^{+2} + \text{H}_3\text{O}^{+}
\]

The purpose of this experiment is to observe hydrolysis and to discover which salt solutions are neutral, acidic, or basic. Your job is to predict whether each salt will be acidic, basic or neutral in solution, test your predictions, then report back to the class.

Materials

- Small beakers
- Spatulas
- Glass stir rods
- pH Hydrion paper
- distilled water
- salts (see chart)
- labeling tape and markers
**Pre-lab**
You are part of a research team. Each team has been assigned three salts to investigate. For each of your salts,
  a) Predict whether the salt will be acidic, basic or neutral in water.
  b) Write your predictions for each salt, as well as your reasons for your predictions, in complete sentences on a separate sheet of paper. Leave a few lines below each prediction to use during the post-lab.

**Procedure**
*Safety:* All salts can be irritants to skin and eyes. Be sure to wear goggles and aprons when handling them. Potassium chlorate is a strong oxidizing agent; do not heat or poke with the spatula. Sodium oxalate is a poison. Be sure to wash your hands and wipe down the counters well after the lab.
1. Label a beaker clearly for each salt.
2. Mix a small amount (pea-sized scoop) of each salt in about 30-50 mL of deionized water in a small beaker and stir. Do not stir with the metal spatula.
3. Add 3-4 drops of universal indicator. Note the color. Add more UI as needed to see a definite color.
4. Determine the approximate pH by using a glass stir rod to place a drop of the solution on pH hydron paper.
5. Record your data in the chart provided.
6. Keep your beakers to use as exhibits in your reports. Cover with Parafilm.
7. Rinse off your stir rods and spatulas. Throw away used pH paper.

**Post-lab Part I: Report and Record**
1. Do these neatly below your predictions in part (a).
   a) For each salt, compare your predictions with your results. Write a sentence or two about how your predictions are similar or different from your results for each reaction. If they are different, also explain why you think the pH’s turned out as they did.
   b) Write both the complete and the net ionic equations for each salt in water. Add just one proton to basic anions. Make sure your equations agree with your results (hydronium ions produced if it was acidic, hydroxide ions produced if it was basic, no net ionic equation if it was neutral).
2. Report your findings to the rest of the class. Decide in advance who will report on what; each person should report on some section of your research. Use your beakers and the large paper provided to aid in your presentation. Be sure to include in your report:
   a) Your predictions and explanations
   b) Your observations
   c) Your revisions to your predictions, with explanations
   d) Your equations (written large on poster paper)
3. Record the findings of the other groups as they report in your data table. Ask questions of the reporting groups. Make them explain their predictions and final equations.
**Clean-Up:** Once everyone has reported, put on your goggles, then pour your solutions down the sink and rinse well with water. Wash your hands and wipe down the counters.

**Post-lab Part II: Analyze**

a) Fill out the table for all the salts.

b) Write the complete equations and net ionic equations for each salt in water. If there is no NIE, write “no NIE”.

c) Write a paragraph about what you learned from this lab. Use your results as well as results from other groups as examples. How could this lab be improved? This may be typed or hand-written neatly.

d) Turn in your predictions + revisions, table, equations and paragraph.

<table>
<thead>
<tr>
<th>Normal salt solution</th>
<th>Color with U.I.</th>
<th>Approximate pH (hydron)</th>
<th>Parent acid</th>
<th>Parent Acid: strong or weak?</th>
<th>Parent base</th>
<th>Parent Base: strong or weak?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 NaCl</td>
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<td>2 NaC(_2)H(_3)O(_2)</td>
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<td>4 AlCl(_3)</td>
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<td>5 Na(_2)CO(_3)</td>
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<td>6 NaHCO(_3)</td>
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<td>7 NH(_4)Cl</td>
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<td>11 Na(_3)PO(_4)</td>
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<tr>
<td>12 KClO(_3)</td>
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</table>

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