EXPERIMENT 20: Determination of pH of Common Substances

Materials:

pH paper and color chart (pH range 3 to 12) or pH meter

- distilled water
- white vinegar
- household ammonia (or baking soda)

- spot plate test or 3 small test tubes
- stirring rod

- solutions / fruits juice (lemon, lime, orange, or melon)
- beverages (cola, carbonated non-cola, milk)

chlorox

INTRODUCTION

For most of the science experiments below, you will need a pH indicator, such as wide-range litmus, pH paper, or pH meter. These pH indicators contain a chemical that changes color when it comes in contact with acids or bases. For example, litmus and pH paper turn red in strong acids and blue in strong bases. Because only a few pH indicators measure pH over a wide range of pH values, you will need to find out the pH range of the indicator you use. Typically, the color chart provided with each pH indicator kit will show the pH range of that indicator. Color pH indicators provide only an approximate measure of the pH, or the strength of the acid or base. They are not as accurate as the expensive instruments scientists use to measure pH, but they are adequate for the experiments below.

Indicators, in chemistry, are natural or synthetic substances that change color in response to the nature of chemical environment. Litmus, for example, is a natural dye that turns red in most acidic solutions and blue in most basic solutions. Compounds that undergo color changes when there is a pH change in the solutions in which they are contained are called indicators (Table 1).

Indicators are used to provide information about the degree of acidity of a substance or the state of some chemical reactions within a solution being tested or analyzed.

How to Measure With pH Paper

When measuring pH with pH paper, dip the end of a strip of pH paper into each mixture you want to test. After about two seconds, remove the paper, and immediately compare the color at the wet end of the paper with the color chart provided with that pH indicator. When measuring pH with pH meter, dip the end of electrode of pH meter into each mixture you want to test. Write down the pH value and color. Always use a clean, unused strip of pH paper for each mixture that you test.
### Table 1 – Indicators and pH ranges

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Acid(color change)</th>
<th>Base(color change)</th>
<th>pH range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl orange</td>
<td>Red</td>
<td>Yellow</td>
<td>3.1-4.4</td>
</tr>
<tr>
<td>Methyl Red</td>
<td>Red</td>
<td>Yellow</td>
<td>4.2-6.3</td>
</tr>
<tr>
<td>Bromothymol Blue</td>
<td>Yellow</td>
<td>Blue</td>
<td>6.0-7.8</td>
</tr>
<tr>
<td>Phenol Red</td>
<td>Yellow</td>
<td>Red</td>
<td>6.4-8.0</td>
</tr>
<tr>
<td>Phenolphthalein</td>
<td>Colorless</td>
<td>Pink</td>
<td>8.0-9.8</td>
</tr>
<tr>
<td>Thymol Blue</td>
<td>Red</td>
<td>Yellow</td>
<td>1.2-2.8</td>
</tr>
<tr>
<td>Alizarin Yellow</td>
<td>Yellow</td>
<td>Red</td>
<td>10.1-12.0</td>
</tr>
</tbody>
</table>

Example 1 - Vinegar is an acid, and in this experiment it will display a pH of about 4. Vinegar at pH 4 turns pH paper yellow and most other pH indicators red.

Example 2 - Ammonia is a base and in this experiment it will display a pH of about 12. Bases turn most pH indicators blue.

Example 3 - Pure distilled water would have tested neutral, but pure distilled water is not easily obtained because carbon dioxide in the air around us mixes, or dissolves, in the water, making it somewhat acidic. The pH of distilled water is between 5.6 and 7.

Traditionally, solutions were labeled as being acidic or basic based on their taste and texture. Those that tasted sour were said to be acidic and solutions that tasted bitter and were slippery to touch were said to be basic. Thus, substances such as lemon juice and vinegar were identified as acids, and solutions of lye and caustic soda as bases. Several definitions have been proposed for acids and bases. Depending upon the situation, one or more definition is applicable.

In this case, the hydronium ion, $\text{H}_3\text{O}^+$, forms when a proton, $\text{H}^+$, is transferred from one $\text{H}_2\text{O}$ molecule to another. The other species that result from this process is the hydroxide ion, $\text{OH}^-$. Thus while one water molecule, the proton acceptor, functions as the base, the other plays the role of the acid. The ability of one water molecule to accept a proton from another water molecule or any acid is due to the two lone pairs of electrons on the oxygen atom of water.
The autoionization results in equal molar amounts of H$_3$O$^+$ ions and OH$^-$ ions and hence the solution is neutral. In a sample of pure H$_2$O, the concentrations of H$_3$O$^+$ and OH$^-$ ions at 25 $^o$C are 1.0 x 10$^{-7}$ M.

$$[\text{H}_3\text{O}^+] = [\text{OH}^-] = 1.0 \times 10^{-7} \text{ M}$$

The concentration of hydronium ion, [H$_3$O$^+$], of a solution is commonly expressed in terms of the pH of the solution, which is defined as the negative logarithm of [H$_3$O$^+$] or negative logarithm of [H$^+$] in the solution;

$$\text{pH} = - \log [\text{H}_3\text{O}^+] \quad \text{or} \quad \text{pH} = - \log [\text{H}^+]$$

Thus the hydrogen ion concentration can be obtained from the pH of the solution as follows;

$$[\text{H}_3\text{O}^+] = 10^{-\text{pH}}$$

Similarly the concentration of hydroxide ion, [OH$^-$], of a solution is commonly expressed in terms of the pOH of the solution, which is defined as the negative logarithm of [OH$^-$]

$$\text{pOH} = - \log [\text{OH}^-]$$

The hydroxide ion concentration can be obtained from the pOH of the solution using the equation

$$[\text{OH}^-] = 10^{-\text{pOH}}$$

Additonal, the pH and the pOH of any aqueous solution are related as are the hydrogen and the hydroxide ion concentrations. The relevant equations are;

$$[\text{H}^+] \ [\text{OH}^-] = 1.0 \times 10^{-14} \quad \text{pH} + \text{pOH} = 14$$

**Example (1)**

What is the pH and pOH of a solution that contains 3.50 x 10$^{-5}$ M hydronium ions?

$$\text{pH} = - \log [\text{H}_3\text{O}^+] = - \log (3.50 \times 10^{-5}) = 4.46$$

$$\text{pOH} = 14 - \text{pH} = 14 - 4.46 = 9.54$$
**Example (2)**

Calculate the hydronium ion and hydroxide ion concentrations of a solution that has a pOH of 4.40.

\[
\text{pH} = 14 - \text{pOH} = 14 - 4.40 = 9.60
\]

\[
[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-9.60} = 2.51 \times 10^{-10} \text{ M}
\]

\[
[\text{OH}^-] = 10^{-\text{pOH}} = 10^{-4.40} = 3.98 \times 10^{-5} \text{ M}
\]

In water, \([\text{H}_3\text{O}^+]\) is equal to \(1.0 \times 10^{-7} \text{ M}\), so the pH is 7.0. Because \([\text{H}_3\text{O}^+] = [\text{OH}^-]\) in water, which is neither acid nor base.

\[
\text{pH} = 7.0 \text{ (neutral)} \quad \text{pH < 7.0 (acidic)} \quad \text{pH > 7.0 (basic)}
\]

The pH scale has a range of 0.0 to 14.0. A practical way to evaluate the relative acidity or basicity of solutions is to compare their effect on indicators.

In this experiment, you will observe the properties of acids and bases with suitable indicators. By the end of this experiment, you will be able to determine the pH of various solutions such as some fruits, common beverages, and borax. Clorox and Borax are cleaning agent that some people add to their laundry detergent. Acids usually taste sour, and bases bitter. Household cleaners are poisons so you should never taste them. You will observe the color of several indicators in these solutions and also using pH paper and pH meter.

**PROCEDURE**

1. Dip an unused strip of pH paper into solution. Leave until wet (about 2 seconds). Immediately compare with the color chart. Write down the approximate pH value of the solution. If you’re using pH meter write down the approximate pH value of the solution.
2. Repeat the same process for the other solutions and record your observation in the table.
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REPORT FORM

Name __________________________________________

Instructor ______________________________________

Date __________________________________________ Partner’s Name: _______________________

Results and Observations

<table>
<thead>
<tr>
<th>Acid, Base, and Household Product</th>
<th>pH</th>
<th>[H₃O⁺]</th>
<th>pOH</th>
<th>[OH⁻]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 0.10M HCl (aq)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. 0.10M Na₃PO₄ (aq)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3. 0.10M Na₂CO₃ (aq)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. 0.10M NaOH (aq)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Shampoo (aq)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>6. ¹Alconox (aq)</td>
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</tr>
<tr>
<td>7. ²Formula 409</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>8. ³Cascade (aq)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Milk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Coca-Cola</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Orange Juice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Vinegar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Tea</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Coffee</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. ⁴Mylanta</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

¹Alconox is a surfactant widely used for cleaning lab glassware.
²Formula 409 is a household cleaning solution especially formulated for greasy deposits on hard surfaces.
³Cascade is a solid cleaner for use in dishwashers. It is more powerful than the liquid surfactant used for washing dishes in the sink.
⁴Mylanta is formulated as an over-the-counter remedy for stomach distress.
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Name: ________________________

Pre-laboratory Questions and Exercises
Due before lab begins. Answer in space provided.

1. Define hydrolysis

2. Give two examples of balanced chemical equations for hydrolysis reaction. (other than NaCl and H₂O)

3. Provide definitions for the following terms;
   a) Arrhenius acid and base
   b) Lewis acid and base

4. Identify the following as acidic, basic, or neutral salts.
   NaNO₃  K₂CO₃  ZnSO₄  KF

5. Calculate the [OH⁻], hydronium ion concentration, of the followings;
   a) pOH = 10.9  b) pH = 9.98  d) [H⁺] = 5.18 x 10⁻¹¹ M
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Post-laboratory Questions and Exercises
Due after completing lab. Answer in space provided.

1. Write the balanced chemical equation between $\text{NaC}_2\text{H}_3\text{O}_2$ and $\text{HCl}$.

2. Determine the pH of the following solutions as ( > 7.0 ) (<7.0 ), or ( =7.0 ).

<table>
<thead>
<tr>
<th>KCl</th>
<th>NaNO$_2$</th>
<th>NH$_4$Cl</th>
<th>LiF</th>
</tr>
</thead>
</table>

3. What are the pH of the following substances?

<table>
<thead>
<tr>
<th>Human Blood</th>
<th>Tomatoes</th>
<th>Wine and Beer</th>
<th>Baking Soda</th>
</tr>
</thead>
<tbody>
<tr>
<td>____________</td>
<td>________</td>
<td>_____________</td>
<td>___________</td>
</tr>
</tbody>
</table>

4. The pH of a solution is measured to be 12.4. Calculate the following;

   a) $[\text{H}_3\text{O}^+]$
   b) pOH
   c) $[\text{OH}^-]$