Introductory Chemistry Lab: Acids, Bases, and pH

Outcomes

As a result of today's laboratory, you will have:

- Observed the properties of some acids and bases.
- Measured the conductivity of a number of substances.
- Classified Substances as strong electrolytes, weak electrolytes, or nonelectrolytes.
- Classified a number of acids or bases as strong or weak.
- Measured the pH of a number of substances and correlated the value to acidity or basicity of the solution.

Prelab

Prepare a Title (can use the lab handout for this), Purpose (a concise statement) and a Procedure (short "to do" list … see "Writing a Procedure" in the lab handouts folder).

Purpose

To observe the properties of acids and bases.

Background Information

Acids and bases are important substances used throughout the world in industry, in foods and beverages, and in living systems. One way to classify acids and bases is by their taste. Acids are sour (lemons and vinegar) and bases (chocolate and medicines) are bitter. Since it is not safe to taste every substance, chemists need other means of classifying something as an acid or as a base.

The current model of acids and bases focuses on the ability of substances to transfer hydrogen ions, H^+, or protons. Since an atom of the most common isotope of hydrogen contains one proton and one electron, a hydrogen ion, which forms when the hydrogen atom loses an electron, is the same thing as a proton. A substance that is a proton donor is an acid. A base is a proton acceptor. Both an acid and a base must be present in a system since for one substance to donate a proton there must be something present to accept the proton. When an acid is put into water, it will donate a proton to water to form H_3O^+, hydronium ion. In water, most acids form ions; the process is called dissociation.

$$HA_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + A^-_{(aq)}$$

In this ionization reaction of an acid, the water acts as a base since it accepts a proton from the acid.

Similarly there are molecular substances that react with water to accept a proton from water to form hydroxide ions. The general reaction for this ionization process is:

$$B_{(aq)} + H_2O_{(l)} \rightarrow BH^+_{(aq)} + OH^-_{(aq)}$$

In this case water acts an acid, donating a proton to the base.

The ability of an acid to donate a proton or of a base to accept a proton depends on a number of factors but can generally be measured by determining the number of ions that form when the acid or base dissolves in water. Acids that are very good proton donors easily transfer a proton to water. These acids are called strong acids. Similarly bases that are very good acceptor of protons and form many ions in solution are called strong bases. Poor donors and poor acceptors are said to be weak acids and weak bases. Only a few of the weak acid or weak base molecules react with water to form ions. Solutions of weak acids or bases will contain only a few ions, and are mostly unionized molecules.

The ability to form ions in solution is measured using the electrical conductivity. When many ions are formed in solution, the amount of current that can flow between two electrodes placed in the solution is high. If a smaller number of ions are formed, the amount of current that can flow is low and if no ions are present, then no electricity will be able to flow. When working with a mutimeter configured as a conductivity tester the amount of current that is measured is directly displayed as milliamperes.

Water soluble ionic compounds will form many ions in solution because the action of the water separates the already existing ions. This process is called dissociation and can be represented by the following reaction.

$$MX_{(s)} \rightarrow M^{+}_{(aq)} + X^{-}_{(aq)}$$

Solutions with high conductivity are called strong electrolytes. Soluble ionic compounds, strong acids, and strong bases are strong electrolytes. Substances with poor conductivity are called weak electrolytes. Weak acids and weak bases are weak electrolytes. Any substance that does not form ions in solution, and consequently does not conduct electricity, is called a non-electrolyte.

The acidity of a solution is determined by the concentration of H_3O^+, hydronium ions, present in the solution. The amount of acidity depends on both the concentration of the acid and the strength of the acid. Higher acid concentration (more the H_3O^+ present), results in higher acidity. For different acids with the same concentration, the stronger acid will form more hydronium ions. The acidity of a solution is given by a number called the pH. The pH of a solution ranges between 0 and 14 and is related to the hydronium ion concentration. The H_3O^+ concentration in moles per Liter is equal to 10^{-pH}.

$$[H_3O^+] = 10^{-pH}$$

As acidity of the solution increases, pH decreases, while H_3O^+ concentration increases. As acidity of the solution decreases, the pH increases, while the H_3O^+ concentration decreases. Since this is a log function, a pH change of 1 unit corresponds to a H_3O^+ concentration change of a factor of 10. Solutions with a pH less than 7 are acidic, while those with pH greater than 7 are basic. Solutions with a pH of exactly 7 are neutral.

pH	**$[H_3O^+]$**	**Solution Type**
1	10^{-1}	Very acidic
4	10^{-4}	Acidic
7	10^{-7}	Neutral
10	10^{-10}	Basic
14	10^{-14}	Very basic

The pH of a solution is typically measured by using either an indicator or an electronic sensor. Indicators are organic molecules that have different colors depending on the pH of their environment. The indicators can be used in a solution color or can be impregnated onto paper strips. A pH meter uses a pH electrode to measure a current flow with a display calibrated in pH.

Procedure

Part I. Preparation of pH Indicator **(one batch per class … made by the instructor)**

Caution!

Handle acids and bases with care. Avoid contact. Be sure you are wearing your safety goggles during the entire lab. If you get any acid or base on yourself, wash the area immediately with lots of cold water. Immediately notify your instructor of any spills or personal contact.

Part II. Properties of Acid and Bases **Work in a group of 4. Divide into 2 pairs (Pair A and Pair B).**

Each pair will test one acid and one base and exchange data with the other pair in your group.

Tests 1 – 6: Pair A: test HCl and NH_4OH

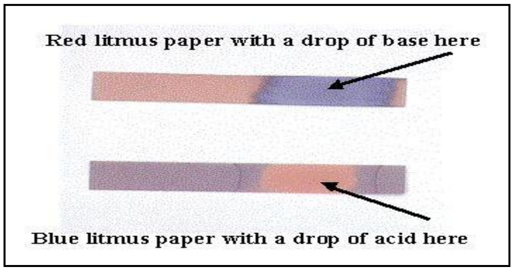
Pair B: test CH_3COOH and NaOH.

Test 1: Effect on red litmus

1. Put ~1 mL of the acid and ~ 1 mL of the base into separate clean test tubes. Put two pieces of red litmus paper onto a clean watch glass. Use a stirring rod to transfer one drop of the acid or the base to each paper. *Never dip litmus paper into the test solution as dye from the paper can contaminate your sample.* Observe and record any color changes in Table 4.

Test 2: Effect on blue litmus

2. Repeat the process above with blue litmus paper. Observe and record any changes in color in Table 4.



Record a distinct color change
Mere darkening, cause of wetness, is a “No Reaction”

Test 3: Effect on phenolphthalein

3. Add one drop of phenolphthalein to each test tube (From 1 above). Record the color observed in Table 4.

Test 4: Effect on active metals

Test Zn metal

Test Mg metal

4. Put ~ 1 mL of the acid and ~ 1 mL of the base into separate clean test tubes, add a small piece of Zn metal to each, and record any signs of a chemical reaction in Table 4. Repeat the same process with a piece of Mg metal. Discard any leftover metal into the labeled waste beaker and clean the test tubes.

Test 5: Effect on metal ions

$Fe(NO_3)_3$ (testing Fe^{3+} ion)

$CaCl_2$ (testing Ca^{2+} ion)

5. Put ~ 1 mL of the acid and ~ 1 mL of the base into separate clean test tubes, add **~** ½ mL of $Fe(NO_3)_3$ solution to each test tube, and record any signs of a chemical reaction in Table 4. Dispose of the solutions in the waste beaker and clean the test tubes. Repeat the process in clean test tubes using the $CaCl_2$ solution.

Test 6: Effect on carbonates

Test Na_2CO_3

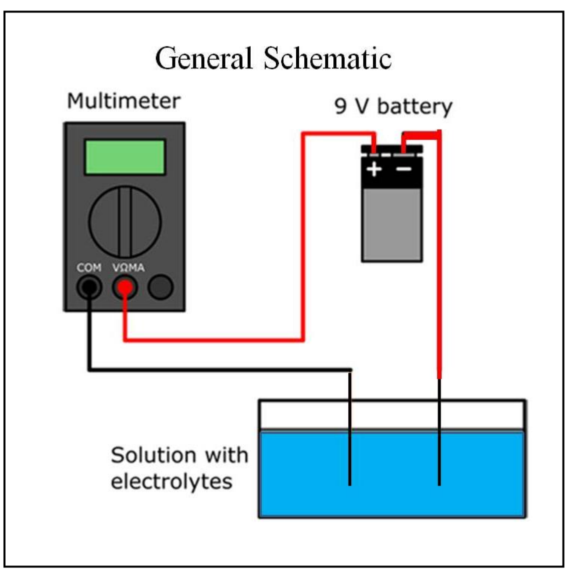
Test K_2CO_3

6. Put a small spatula full of solid Na_2CO_3 into two small clean test tubes, add ~1 mL of the acid or base to each test tube, and record any signs of chemical reaction in Table 4. Repeat the test using K_2CO_3.

7. Exchange data with the other pair in your group to complete Table 4.

Part III. Acid and Bases Strength

There will be 10 solutions to be tested: Deionized water, tap water, sucrose, NaCl, Na_2CO_3, Ethyl alcohol, HCl, Acetic acid, NH_4OH, and NaOH. Each has its own testing device.



1. The Multimeter measures the ion current flow (conductivity)
   Black lead in COM (lowest port on right side)
   Red lead   VΩmA port (immediately above COM)
2. Turn meter on … move selector to 200 m
3. The 9 Volt battery serves as the current source.
   Move battery switch to on
   Allow ~ 10 seconds to stabilize
4. Read meter
5. Record displayed value on your hand-in sheet (Table 5)
6. Move battery switch to off
7. Turn off multimeter

Using electrodes:
Submerge only the metal part
Do NOT touch the glass container

Part IV. pH (Acidity Level) of Solutions

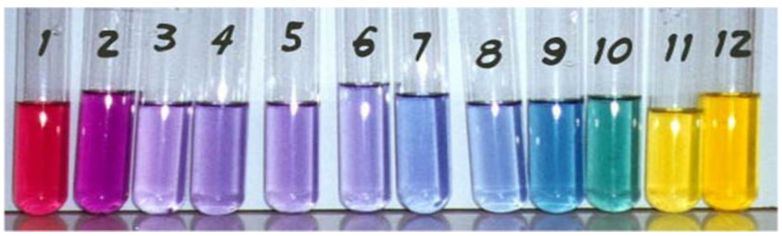
Test the acidity level of the acids and bases used in Part I as well as deionized water.

Pair A: Test HCl and NH_4OH and deionized water
Pair B: Test CH_3COOH (acetic acid) and NaOH

1. Add ~ 2 mL of the substance to be tested into a clean small test tube.
2. Add 3 drops of the cabbage indicator and swirl. Record the observed color and pH in Table 6.
3. Exchange data with the other pair in your group.

Table 3: Cabbage Indicator pH Colors

Color	Red	Pink	Purple	Blue	Green	Yellow
pH	1	2–3	3-7	7-9	9-10	11-13



These colors are easier to see if examined against a white background

Part V. Effect of Concentration on pH

(Each student pair will do either the acid or the base; share data)

Test the effect concentration on pH. Two solutions will be made for the acid and base by diluting the original solution and then using the indicator to measure pH.

Pair A: Test HCl   ***Pair B: Test NaOH***

Initial Solution

1. Label the test tubes 1 and 2.
2. Add 20 drops of 6 M acid or base into test tube 1. Add 3 drops of the cabbage indicator. Thoroughly Mix (use a stirring rod). Record the color and pH in Table 7.

Dilution for either acid or base

3. Using a graduated cylinder, measure 100.0 mL of distilled water
4. Pour the water into the clean 150 mL beaker.
5. Add one drop of the initial acid or base from step 2 above to the beaker. Thoroughly mix.
6. Pour about 1 mL of the diluted acid or base into test tube 2. Add 3 drops of cabbage indicator. Thoroughly mix. Record the color and pH in Table 7.

Part VI. pH of 2 Household Substances

1. Put ~ 2 mL of the substance to be tested into a small test tube. Add 3 drops of the cabbage indicator. Mix and record the indicator color, pH and inferred acid/base/neutral assignment in Table 8.

   a. For substances that are thin (watery) liquids: put ~2 mL of the substance to be tested into a small test tube. Add 3 drops of the cabbage indicator. Mix and record the indicator color, the pH and inferred acid/base/neutral assignment in Table 8.

   b. For substances that are thick (gel) liquids:, put ~ ½ mL of the substance to be tested into a small test tube and add 20 mL of deionized water. Add 3 drops of cabbage indicator. Mix and record the indicator color, the pH, and inferred acid/base/neutral assignment in Table 8.

   c. For substances that are solids or powders: put a small spatula full into a small clean test tube and add ~2 mL deionized water. Add 3 drops of cabbage indicator. Mix and record the indicator color, the pH, and inferred acid/base/neutral assignment in Table 8.

VII. Data / Observations

Complete the Data Tables in the Lab Hand-In and Staple to your lab report.

Conclusion

Summarize the characteristic properties of acids and bases. Describe the relationship between the pH value and the level of acidity in a solution.

Questions

1. Acid has a pH _______ (less than, equal to, greater than) 7.0.
   Neutral has a pH ______(less than, equal to, greater than) 7.0.
   Base has a pH _______ (less than, equal to, greater than) 7.0
   Strong acid has a _______ (lower, higher) pH than weak acid.
   Strong base has a _______(lower, higher) pH than weak base.
   Dilution makes an acid or base _______(stronger, weaker, the same).
2. Strong acids have ______ (more, the same, fewer) ions than weak acids.
3. Which acid is the better proton donor, a strong acid or a weak one?
4. When the amount of **acid** in a solution increases, does the pH increase, decrease or remain the same?
5. A 0.01 M solution of acid #1 is found to have a pH of 5 while a 0.01 M solution of acid #2 has a pH of 2. Which of these two acids is stronger?
6. **Based on your conductivity measurements** does deionized water undergo “self-protolysis” (below):

$$H_2O_{(l)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + OH^-_{(aq)}$$

   Explain your answer!