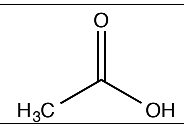
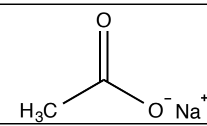
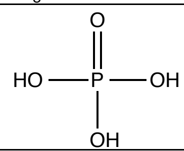
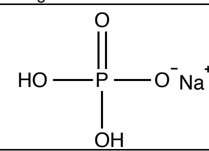
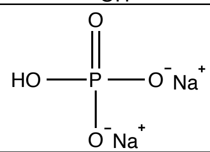
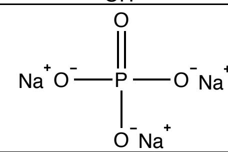
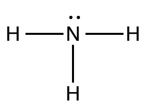
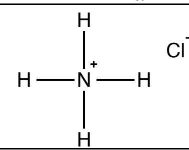
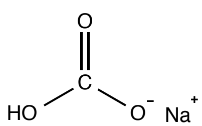
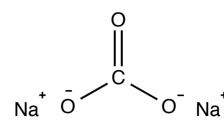
Identifying Acids and Bases

Solutions A, C, and D are the acids HCl, HNO_3, and H_2SO_4, and solutions B, E, and F are the bases NaOH, $Ba(OH)_2$, and KOH. In the space below draw Lewis structures for the three acids and, in a few sentences, describe the type of bonding (covalent, ionic, metallic) that is present in each of the six acids or bases.

In the space below, and considering the reactivities of these acids and bases with bromothymol blue, phenolphthalein, Mg, and $Mg(NO_3)_2$, propose some simple rules that you can use to determine if a compound is an acid or a base based on its chemical formula and its structure.

Examine the formulas and structures for the compounds in the table on the reverse side of this page, and predict whether each is an acid (A) or a base (B). If you have insufficient information on which to base a prediction then indicate this. ***It is okay if you are unsure of your predictions***. When your predictions are complete, use the available 1 M solutions of each compound and the reagents bromothymol blue, phenolphthalein, Mg, and $Mg(NO_3)_2$ to determine if each is an acid or a base, adding this result to the your table. Based on the results of your tests, list below any changes you need to make to your rules for predicting if a compound is an acid or a base.

formula	structure	prediction	result	formula	structure	prediction	result
$HC_2H_3O_2$				$NaC_2H_3O_2$			
H_3PO_4				NaH_2PO_4			
Na_2HPO_4				Na_3PO_4			
NH_3				NH_4Cl			
$NaHCO_3$				Na_2CO_3			

Acid–Base Strength

For a generic acid with the formula HA, the reaction responsible for its acidity is

$$HA(aq) + H_2O(l) \leftrightarrows H_3O^+(aq) + A^-(aq)$$

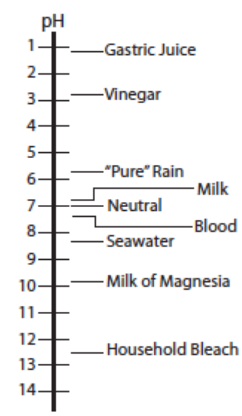
and for a generic base with the formula B, the reaction responsible for its basicity is

$$B(aq) + H_2O(l) \leftrightarrows OH^-(aq) + HB^+(aq)$$

The strength of an acid or base is the extent to which these reactions proceed to the right. For acids of equal concentration, the one that produces more H_3O^+ is the stronger acid; for bases of equal concentration, the one that produces OH^- is the stronger base. Because the concentrations of H_3O^+ and OH^- are inversely proportional, as shown here

$$[H_3O^+] \times [OH^-] = 1\times10^{-14}$$

we can describe acidity and basicity in terms of the concentration of H_3O^+. The concentration of H_3O^+ in a neutral solution is 1×10^{-7} M. For an acidic solution, $[H_3O^+]$ is greater than 1×10^{-7} M and for a basic solution, $[H_3O^+]$ is less than 1×10^{-7} M. The concentration of H_3O^+ can vary over a large range; for this reason we report it as a pH value where $pH = -\log[H_3O^+]$



The pH of a neutral solution is 7.00. For an acidic solution the pH is less than 7.00, and for a basic solution the pH is greater than 7.00. The figure to the right shows pH values for some solutions familiar to you. Note that "pure" rain is slightly acidic due to the presence of dissolved CO_2, which makes it a very dilute solution of carbonic acid, H_2CO_3. For the same reason, the deionized water in lab is slightly acidic.

There are a variety of ways to measure a solution's pH, including sensors with signals that are proportional to pH (a glass pH electrode is one example of such a sensor), organic dyes—such as bromothymol blue and phenolphthalein—whose color depends on pH (we call these compounds pH indicators), and pH paper whose color changes in response to a solution's pH (essentially just filter paper soaked in a solution of a pH indicator and dried).

Using the method demonstrated in lab, determine the pH for each of the 1 M solutions of acids and bases available to you (16 in total). In the space below, rank the acids from most acidic to least acidic, and rank the bases from most basic to least basic. If you cannot determine a difference in pH for two or more solutions, simply group them together; thus, you might have a list that looks like this: A (strongest acid) > B, C > D (weakest acid).

Acid–Base Reactivity: Strength vs. Concentration

When an acid or base reacts, we can characterize its reaction in two ways: how quickly the reaction occurs and the extent to which the reaction occurs. We will explore these two aspects of acid-base reactivity through a simple experiment.

> Place 5 mL of 1 M HCl in a test tube. Add a small piece of Mg to the test tube and record how long it takes for the Mg to dissolve. If the reaction is not complete after 10 min, estimate the amount of Mg that remains unreacted. Record your observations in your lab notebook. Repeat using 1 M HNO_3, 1 M $HC_2H_3O_2$, 1 M NH_4Cl, 0.1 M HCl, and 0.1 M $HC_2H_3O_2$. Try to use pieces of Mg of approximately equal size. In the interest of time, you may wish to run all six reactions simultaneously.

Based on your data, how does an acid's strength and/or concentration affect how quickly it reacts with Mg? How does an acid's strength and/or concentration affect the extent to which it reacts with 1 M NaOH?

Waste Disposal

Place all waste in the appropriate container.