Chapter 32

Okay. You may be a master at calculating the pH of a solution but there still remains one little problem to solve...

How can you tell the concentrations of acids or bases of unknown strengths?

Think about it... 18M sulfuric acid (really nasty stuff) doesn't look any different than common vinegar! They are both clear and colorless liquids. And, if you had a container of 18M sulfuric acid in your kitchen, I certainly hope you wouldn't attempt to smell (bad idea) or taste (REALLY bad idea) the fluid.

So how do chemists determine the concentration of H^+ or OH^- ions in a solution?

Titrations

A **titration** is really a fancy word for a method used to neutralize an acid or a base (bring to pH of 7). Once neutralized, the fluid is generally safe to handle or dispose of.

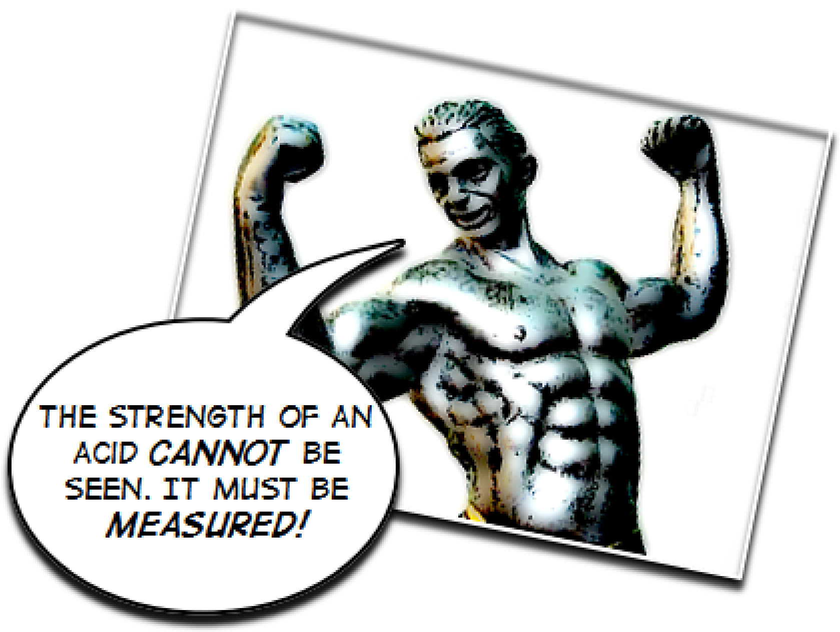
For example, if you had a basic solution and wanted to neutralize it to pH7 you would slowly add a measured amount of acid until the solution reached pH7. Once pH7 was achieved you would simply measure out the volume of acid you added and this would tell you how much base was originally within the solution.

Why are these amounts the same?

In order to answer this question, you will need to follow three steps:

1) Calculate the molarity of the acid or base that was added for the neutralization to occur.
2) Convert the number of moles of the neutralizing substance to the number of moles of the neutralized substance.
3) Calculate the molarity of the acid or base that was neutralized.

Look back on our study of molarity in Chapter 22. You should remember that molarity (M) is a measurement of the amount of moles of solute per liter of a solution. This tells us the "strength" or concentration of the acid or base solution.



In the first and third steps, we are asked to calculate the molarity of the acidic and basic component of our solution. Therefore we use the molarity equation:

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{liter of solution}}$$

Here's a typical problem you will encounter while calculating the neutralization of an acid or base:

30mL of a 0.1M NaOH solution was added to neutralize a 25 mL solution of HCl. What was the concentration of the HCl?

Before we get started, we are going to need to write out a balanced equation for this reaction:

$$NaOH + HCl \rightarrow NaCl + H_2O$$

Step #1:

Calculate the molarity of the base that was added for the neutralization to occur.

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{liter of solution}}$$

$$0.1M = \frac{\text{moles of NaOH}}{0.03L\ \text{NaOH}} = \mathbf{0.003\ moles\ NaOH}$$

Step #2:

Convert the number of moles of the neutralizing substance to the number of moles of the neutralized substance.

$$\frac{0.003\ \cancel{\text{moles NaOH}}}{} \left| \frac{1\ \text{mole HCl}}{\cancel{1\ \text{mole NaOH}}} \right. = \mathbf{0.003\ moles\ HCl}$$

Step #3:

Calculate the molarity of the acid or base that was neutralized.

$$M = \frac{0.003\ \text{moles HCl}}{25L\ \text{HCl}} = \mathbf{0.12M\ HCl}$$

Another way of completing these types of problems is to use the following simple equation:

$$M_A V_A = M_B V_B$$

$$(25mL)(?M)=(30mL)(0.1M)$$

$$= \mathbf{0.12M}$$

In the above example, a basic NaOH solution was used to neutralize an acidic HCl solution. However, you may be wondering one little thing...

How do you know when the pH level has reached neutrality? When do you know that the solution has a pH of 7?

This is a big problem! Remember... 18M HCl looks just like regular water! When you neutralize it to pH7, guess what it looks like...

Regular water!

Because of this, chemists have either created and/or discovered a variety of chemical **indicators** to help them identify the presence of acids or bases. Indicators are chemical compounds that change color in the presence of acids or bases.

Natural indicators like boiled rose petals and red cabbage are easily created in the kitchen. More recently, chemists have created their own types of pH indicators. These items include the high-end electronic pH indicators which very accurately measure the amount of H^+ in a solution to cheaper to easy-to-use items such as **Litmus paper** (which turns red in the presence of an acid and blue in a base.) Another manmade chemical, **phenolphthalein**, is a clear liquid while in the presence of an acid but turns pink when mixed with a base.

Since the concentration of H^+ within a solution can be increased or decreased rather easily, the use of indicators are very handy during titrations.

Furthermore, once added to a solution, phenolphthalein does not break down into simpler substances; therefore, it can change the color of the solution from pink to clear as many times as possible.

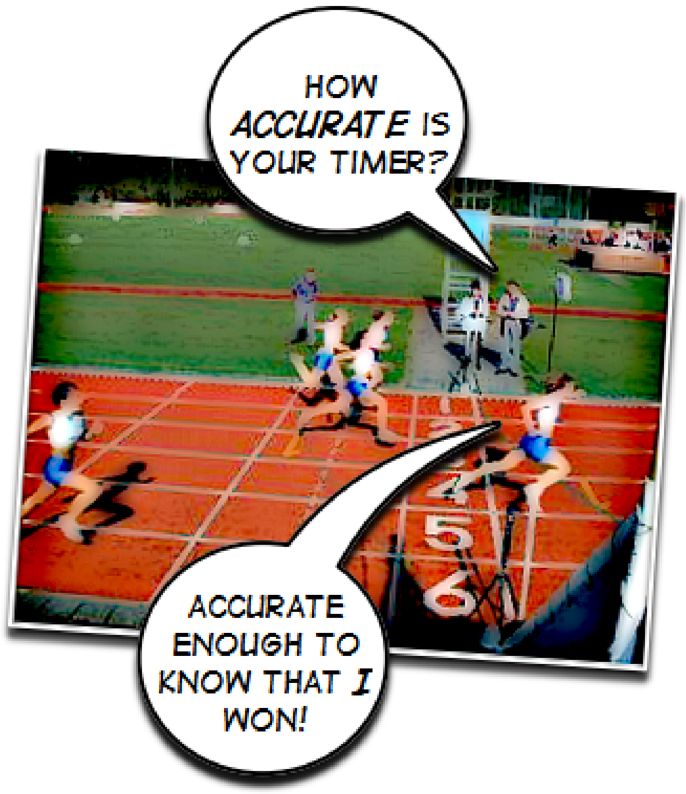
Let's say you have placed your indicator into a base of unknown concentration. You are carefully adding a measured amount of acid into the basic solution when suddenly the color of the base begins to change. What do you do?

First of all, the point in which the color change begins to appear is known as the **endpoint**. This is the point in which you should stop titrating!

You are probably thinking this is not the most accurate method of determining when a solution of unknown strength has reached a pH of exactly 7…

And you are right!

It is nearly impossible to reach the **equivalence point** (the point in which the volume of acid equals the volume of base) through titration when the endpoint is identified. Therefore, when chemists titrate they attempt to get as close to the equivalence point as possible and follow up with the most accurate pH meter they have in their lab.



If you haven't figured this out yet, science builds models and procedures that give us the most accurate and precise measurements about the natural world. Even though our results are not 100% perfect, we do seem to get pretty darn close most of the time!

Titrations practice

1) If it takes 26 mL of 0.1 M NaOH to neutralize 125 mL of an HCl solution, what is the concentration of the HCl?

2) If it takes 61 mL of 0.05 M HCl to neutralize 345 mL of NaOH solution, what is the concentration of the NaOH solution?

3) If it takes 62 mL of 0.5 M KOH solution to completely neutralize 130 mL of sulfuric acid solution (H_2SO_4), what is the concentration of the H_2SO_4 solution? (Hint: you will need to divide your answer by 2 since there are 2 hydrogen atoms to be given off with H_2SO_4)

4) Can I titrate a solution of unknown concentration with another solution of unknown concentration and still get a meaningful answer? Defend your answer:

5) How many mL of a 3M NaOH solution are required to completely neutralize 45.0 mL of 1.5M H_2SO_4?

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

(Hint: when using the $M_1V_1 = M_2V_2$ equation on these types of problems, you will need to multiply your M_1V_1 and M_2V_2 values by the number of moles of each compound. For example, in this problem you would multiply your M_1V_1 product by 1 for H_2SO_4 and you would multiply your M_2V_2 product by 2 for NaOH)

6) What is the molarity of a solution of $Ca(OH)_2$ if 15.0 mL of the solution is required to neutralize 37.2.0 mL of 2M HCl?

$$2HCL + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$$

7) What volume of 0.27M phosphoric acid is required to neutralize 42.0mL of 0.05M barium hydroxide?

$$2H_3PO_4 + 3Ba(OH)_2 \rightarrow Ba_3(PO_4)_2 + 6H_2O$$

8) Calculate the **mass** of aluminum hydroxide required to completely react with 13.5 mL of 0.45M HCl. (Hint: Use stoichiometry)

$$Al\ (OH)_3 + 3HCl \rightarrow AlCl_3 + 3H_2O$$