Acid-Base Titration

In the chemistry laboratory, it is sometimes necessary to experimentally determine the concentration of an acid solution or a base solution. A procedure for making this kind of determination is called an ACID-BASE TITRATION. In this procedure, a solution of known concentration, called a STANDARD solution is used to neutralize a precisely measured volume of the solution of unknown concentration to which one or two drops of an indicator have been added. If the solution of unknown concentration is acidic, a standard base solution is added to the acid solution until it is neutralized. If the solution of unknown concentration is basic, a standard acid solution is added to the base solution until it is neutralized.

When carrying out an acid-base titration, you must be able to recognize when to stop adding the standard solution. That is, you must be able to recognize when neutralization has occurred. This is the purpose of the INDICATOR. A sudden color change due to the indicator signals that neutralization has occurred. At this point, the number of HYDROGEN (H^+) ions from the acid is equal to the number of HYDROXIDE (OH^-) ions from the base. The point at which this occurs is called the END-POINT of the titration. When the endpoint is reached, the volume of the standard solution is carefully determined. Then the measured volumes of the two solutions and the known concentration of the standard solution can be used to calculate the concentration of the other solution.

At the end-point of the experiment, the volume of the acid multiplied by the molarity of its hydrogen ions will equal the volume of the base multiplied by the molarity of its hydroxide ions. Calculations will be based on the following formula:

(volume of acid)(molarity of H^+) = (volume of base)(molarity of OH^-)

or, more simply…

$$V_A M_{H+} = V_B M_{OH-}$$

Knowing three of these quantities we can calculate the fourth. If the acids and the base in the experiment have one hydrogen ion and one hydroxide ion, respectively, the molarity of hydrogen ion is the same as the molarity of the acid, and the molarity of hydroxide ion is the same as the molarity of the base.

Example #1:

5.0 mL of acetic acid, $HC_2H_3O_2$, is completely neutralized by 7.5 mL of 2.0 M NaOH. What is the molarity of the acid?

Given: $V_A = 5.0\ mL$ $M_{H+} = ?$ $V_B = 7.5\ mL$ $M_{OH-} = 2.0\ M$

$$M_{H^+} = \frac{(V_B)(M_{OH^-})}{(V_A)} = \frac{(7.5\ mL)(2.0M)}{5.0mL} = 3.0M$$

Example #2:

What volume of 0.50 M KOH is needed to completely neutralize 15.0 mL of 1.75 M HCl?

Given: $V_A = 15.0\ mL$ $M_{H+} = 1.75\ M$ $V_B = ?$ $M_{OH-} = 0.50\ M$

$$V_{OH^-} = \frac{(V_A)(M_{H^+})}{(M_{OH^-})} = \frac{(15.0\ mL)(1.75M)}{0.50M} = 52.5mL$$

Example #3:

What volume of 2.0 M HNO_3 can be neutralized by 20.0 mL of 1.5 M $Ca(OH)_2$?

Given: $V_A = ?$ $M_{H+} = 2.0\ M$ $V_B = 20.0\ mL$ $M_{OH-} = 3.0\ M$***

***Note: Because this base has TWO hydroxide ions in its formula, the concentration of OH^- is TWICE the concentration of the base itself!

$$V_{H^+} = \frac{(V_B)(M_{OH^-})}{(M_{H^+})} = \frac{(20.0\ mL)(3.0M)}{2.0M} = 30mL$$

Practice Problems

What is the molarity of a solution of NaOH if 25 mL of 1.2 M HCl is required to neutralize 15 mL of the base?	What volume of 1.5 M HCl is required to completely neutralize 18 mL of 2.0 M KOH?
If 150 mL of 1.0 M HCl is completely neutralized by 25 mL of NaOH solution, what is the molarity of the NaOH?	How many mL of 3.0 M HNO_3 can be completely neutralized by 75 mL of 1.5 M $Mg(OH)_2$ solution?
How many mL of 2.5 M H_2SO_4 solution can be neutralized by 250 mL of 1.0 M $Ca(OH)_2$ solution?	40.0 mL of a 0.80 M solution of H_2SO_4 completely neutralizes 100 mL of NaOH. What is the molarity of the NaOH solution?
What volume of 1.5 M $Ca(OH)_2$ is needed to neutralize 36 mL of 3.0 M phosphoric acid, H_3PO_4?	☹ ☹ ☹ 85 mL of 0.75 M NaOH is completely neutralized by 15 mL of H_2SO_4. What is the molarity of the H_2SO_4 <u>solution</u>?