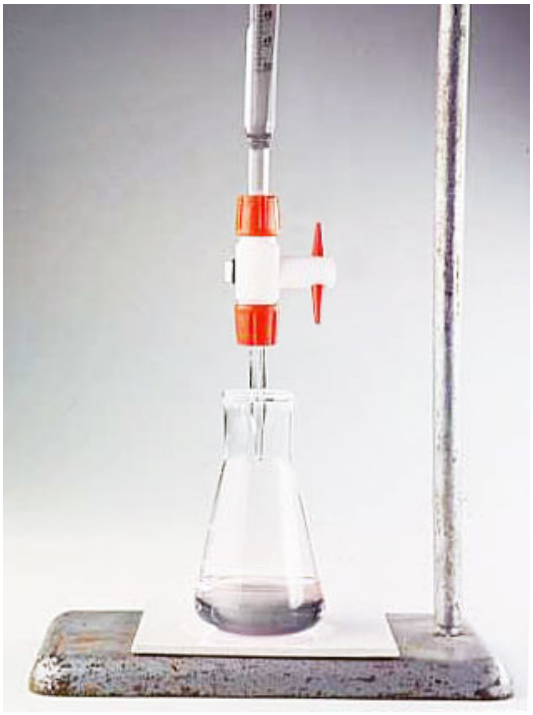
6.6 - Indicators, Neutralizations, and Titrations

pages 591-597 in Heath

pages 617-621 in Matter and Change



Neutralization Reactions

What happens when an acid, like HCl, is mixed with a base, like NaOH?

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow$

When an acid and a base combine, water and a salt is produced; this is called a neutralization reaction.

In general: acid + base → salt + water

A **salt** is an ionic compound containing a positive ion (other than $H^{+)}$ and a negative ion (other than OH^{-}).

If we wrote the above equation in ionic form we would get:

$H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$

If we write the net ionic equation,

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

Therefore, when a **strong acid and strong base** are mixed together in the proper amounts - such that the $[H^+] = [OH^-]$ - a neutral solution results in which pH = 7.

Therefore, the acid and base have neutralized each other and the acidic and basic properties no longer exist; these are only completely successful if one (or both) reactant is a strong acid or strong base.

Ex) Write the neutralization for the following acid-base reactions (make sure to balance):

a) HCl and KOH

b) Sulfuric acid and ammonium hydroxide

c) H_2CO_3 and sodium hydroxide

Indicators

An indicator is a substance that changes color under varying conditions of acidity. $InH \rightleftharpoons In^-_{(aq)} + H^+_{(aq)}$

These are less precise measurements than the pH scale because we judge the strength of the acid or base by the color of the indicator which is open to interpretation.

Indicators are either weak acids or bases; weak acids function in strong bases and visa versa. They will change color when added to a solution with a specific pH level.

We will use the pH Range of Common Indicators chart *(Table 15)* to answer questions about the general pH of a solution.

Ex) A given solution turns methyl orange yellow, litmus blue, and phenolphthalein pink. What is the pH range of the solution?

Ex) What color would methyl orange, litmus, and phenolphthalein turn when testing:
a) vinegar (pH = 3)

b) sea water (pH = 8)

Ex) A solution gave the following test results: methyl red turned yellow, phenol red turned red, and phenolphthalein was colorless. Give the pH range for the solution.

***To find the K_a for an indicator, we need to use the average pH the indicator reacts with, and then find the antilog.*

Ex) THINKING QUESTION: What is the K_a of bromocresol green?

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Extra Indicators:

Indicator	pH Range	Color at low end of range	Color at mid range	Color at high end of range
Metacresol Purple	1.2-2.8, 7.3-9.0	red	yellow	purple
Thymol Blue	2.1-2.8, 8.0-9.6	red	yellow	blue
Bromocresol Purple	5.2-6.8	yelow	light purple	purple
Cresol Red	2.0-3.0, 7.2-8.8	orange	amber	red
Malachite Green	11.4-13.0	green	light green	colorless

Titrations

A titration is a laboratory procedure used to determine the concentration of acidic or basic solutions with unknown concentrations.

During an acid-base titration an acid with a known concentration (standard solution) is slowly added to a base with an unknown concentration with a known volume (or vice versa).

-An indicator is also added to the solution which will signal (by a change in color) when the base has been neutralized.

Note that ***as soon as you see a color change*** *the titration is complete and the* $[H^+]$ *and* $[OH^-]$ *are proportionally equal.*

At that point - called the **equivalency point** - the titration is stopped (*end point*).

Titration Method:

1. Put a measured volume of an acidic (or basic) solution of unknown concentration in a beaker.
2. Put the pH meter into the solution. Read and record the initial pH of the solution.
3. A buret is filled with "titrating" basic (or acidic if unknown solution is basic) solution of known concentration. This is our standard solution.
4. Measured volumes of the standard solution are slowly added and mixed into the solution in the beaker. The pH is read and recorded after each addition.
5. Continue this process until the reaction reaches its equivalence point (a known pH or a change in color if an indicator was used)

***strong acid + strong base: equivalence point should be very close to 7*

By knowing the initial volume of the base, the volume of acid added, and the initial concentration of the acid we can calculate the concentration of the acid or base.

***If a weak acid and a strong base are titrated, the equivalence point will be >7 (excess* $[OH^-]$*; limited* $[H^+]$*)*

***If a weak base and a strong acid are titrated, the equivalence point will be <7 (limited* $[OH^-]$*;excess* $[H^+]$*)*

For a given balanced neutralization equation:

X acid + Y base → salt + water

our formula will be: $\mathbf{YM_aV_a = XM_bV_b}$

Where:
X, Y are coefficients of the acid and base in the BALANCED chemical equation
M_a, M_b = molarity of the acid, base
V_a, V_b = volume of the acid, base

Ex) During a titration 75.8 mL of a 0.100 M standard solution of HCl is titrated to end point with 100.0 mL of a NaOH solution with an unknown concentration. What is the concentration of the NaOH solution?

Ex) A 20.0 mL solution of strontium hydroxide, $Sr(OH)_2$, is placed in a flask and a drop of indicator is added. The solution turns colour after

Choosing an Indicator

**The color change of the indicator selected for a specific acid-base titration should coincide closely with the equivalence point of the titration

Ex) Choose the most correct indicator given:
200.0 mL of 0.125M potassium hydroxide solution is added to 100.0 mL of 0.100M nitric acid solution. Which indicator is matched with the color in the new solution?
*remember that indicators work based on pH

a) Methyl Orange-solution is orange
b) Thymol Blue-solution is orange
c) Indigo Carmine-solution is green
d) Phenolphtalein-the solution is colorless

Resulting pH from Imperfect Titrations

When an acid and a base are mixed together, it is rare that there is a perfect ratio between the two.

If that is the case, one of the reactants (either the acid or the base) will run out, leaving some of the other reactant around.

- If the acid is left over, the resulting solution will be slightly acidic. If the base is left over then the solution will be slightly basic.

In order to determine the pH of the resulting solution we need to determine which substance will run out and which will be left over. Recall from Chem 20 that the substance that runs out is a **limiting reagent** and the substance that is left over is called the **excess** substance.

Once you find out which is in excess, we find out the number of moles that should be left over after the reaction takes place and do a calculation to determine the $[H^+]$ or $[OH^-]$. A pH calculation follows.

Ex) If you mix 50.0 mL of 0.200 M HCl and 49.9 mL of 0.200 M NaOH, what is the resulting pH?

Ex 2) What is the resulting pH if 25.0 mL of 0.200 M $Ca(OH)_2$ and 49.9 mL of 0.200 M HCl are mixed?

6.6 Indicators, Neutralizations and Titrations Assignment

1. What is the approximate pH of a solution that is:
   a. yellow in methyl red, yellow in phenol red, and yellow in alizarin yellow?

   b. yellow in methyl red, red in phenol red, and red in alizarin yellow?

2. Write **balanced** neutralization reactions for the following:
   a. the reaction between acetic acid, $HC_2H_3O_2$ and potassium hydroxide, KOH

   b. the reaction between nitric acid, HNO_3 and calcium hydroxide, $Ca(OH)_2$

3. If 25.00 mL of a 0.100 M NaOH solution is required to neutralize 15.00 mL of a solution of HCl, what is the molarity of the acid?

4. What is the concentration of a calcium hydroxide solution, $Ca(OH)_2$, if 30.00 mL of the base is completely neutralized by 10.0 mL of 0.0200 M HCl?

5. What is the molarity of a 25.0 mL solution of HCl that is titrated to an end point by 10.0 mL of a 0.200 M solution of NaOH?

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

6. What is the concentration of a 50.0 mL solution of $Ba(OH)_2$ that is titrated to an end point by 15.0 mL of a 0.00300 M solution of HCl?

$2\ HCl(aq) + Ba(OH)_2(aq) \rightarrow BaCl_2(aq) + 2\ H_2O\ (l)$

7. What is the molarity of a 21.0 mL nitric acid solution that completely neutralizes 25.0 mL of a 0.300 M solution of NaOH?

$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$

8. What is the concentration of a 45.0 mL solution of KOH that is completely neutralized by 15.0 mL of a 0.500 M H_2SO_4 solution?

$H_2SO_4 + 2\ KOH \rightarrow\ K_2SO_4 + 2\ H_2O$

9. A neutral solution is produced when 42.00 mL of a 0.150 M NaOH solution is used to titrate 50.00 mL of a sulfuric acid (H_2SO_4) solution. What is the concentration of the sulfuric acid solution before titration?

10. 0.080 moles of solid NaOH are added to 0.1L of a 1M HCl solution. Which reactant is in excess? Determine the $[H^+]$ and $[OH^-]$ at equilibrium.

11. Calculate the pOH resulting from mixing 75.0mL of 0.200M HBr with 225.0 mL of 0.150M KOH.