ACID - BASE TITRATION CURVES (#10.1)

The CCLI Initiative
Computers in Chemistry Laboratory Instruction

Learning Objectives

The objectives of this experiment are to ...

- understand the titration curves for the following solutions
- a weak acid: acetic acid, CH_3COOH.
- a strong acid: hydrochloric acid, HCl.
- an acidic commercial cleanser.
- a basic commercial cleanser.
- use the titration curves to calculate the percent of the active ingredients in the commercial cleansers.
- determine the K_a of a weak acid.

Background

A plot of the pH of a solution against the volume of "titrant" added is called a titration curve. The pH can be measured directly with a pH meter while titrant is added from a buret. For the acids used in this experiment the titrant will always be a 0.1 M solution of the strong base NaOH. From the form of the titration curve it can be determined whether the solution consists of a strong or weak acid. Furthermore, if it is a weak acid, the equilibrium constant for its dissociation can be calculated.

Strong acids

For a strong acid HA, the equilibrium constant K_a is so large that it is completely dissociated into H_3O^+ and A^- at usual concentrations, and hence the H_3O^+ concentration simply equals the acid concentration the titration has reduced the concentration of HA to less than 10^{-6} *M*. After this point the dissociation of water begins to govern the H_3O^+ concentration. At the exact equivalence point (where the moles of base added equal the initial moles of acid present), the H_3O^+ concentration comes entirely from this source and is therefore equal to 10^{-7} and the pH is seven.

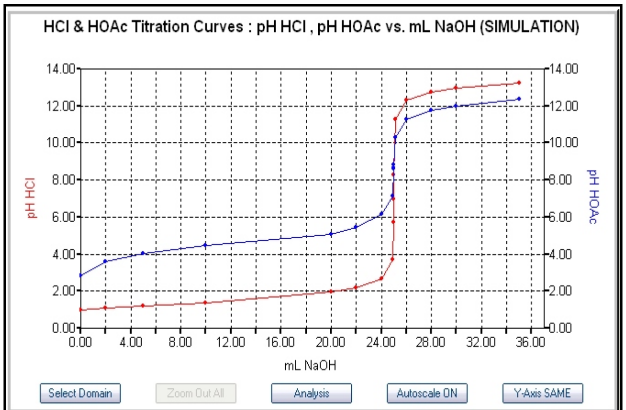

Figure 1. Comparison of strong (HCl) versus weak (HOAc) titration curves

Weak acids

For a weak acid the equilibrium constant for reaction (1) is small (between 10^{-2} and 10^{-7}), so that the concentration of $[H_3O^+]$ and hence the pH is governed by Ka. The titration curve d the student obtains should be different from that obtained when the same concentration of strong acid is titrated. Three points along the titration curve are considered and the conditions existing in solution are reviewed.

Zero titrant:

Halfway to the equivalence point:

The equivalence point:

Acid-Base titration of commercial cleansers

Potentiometric titration can be applied to the determination of acidic and basic compounds in household cleansers. The cleansers generally contain one or two acids or bases and their concentrations can be determined from the one or two equivalence points on the titration curves. The acidic household cleansers usually contain hydrochloric acid, phosphoric acid, sodium bisulfate, or hydroxyacetic acid, which remove alkaline scale deposits and stains. The basic cleansers usually contain ammonium hydroxide, sodium hydroxide, sodium hypochlorite or sodium carbonate. The weaker bases cut grease while the stronger bases and oxidizing agents dissolve animal matter such as hair, grease, and foodstuffs.

Two cleansers will be studied, Lysol® (Reckitt Benckiser (UK) Limited) is an acidic cleanser, containing hydrochloric acid as an active ingredient and Liquid Plumr® (The Clorox Company) a two component basic cleanser containing sodium hydroxide and sodium hypochlorite (NaOCl). Sodium hypochlorite is an oxidizing each of these can be calculated from the titration data.

Interpreting the pH titration curve

An example of a pH titration curve obtained using the lab interface is shown in Figure 1. A strong base (NaOH) was added to a strong acid (HCl). The equivalence point is the point at which the pH versus volume curve is the steepest. The curve shown in Figure 1 was obtained with as a drop counter titration, obtaining 356 data points in less than 5

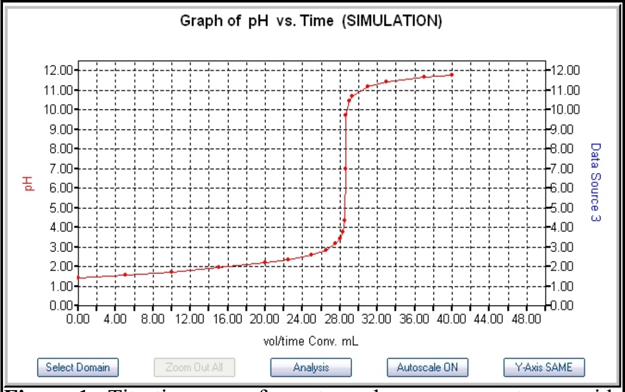

Figure 1. Titration curve for a strong base versus a strong acid.

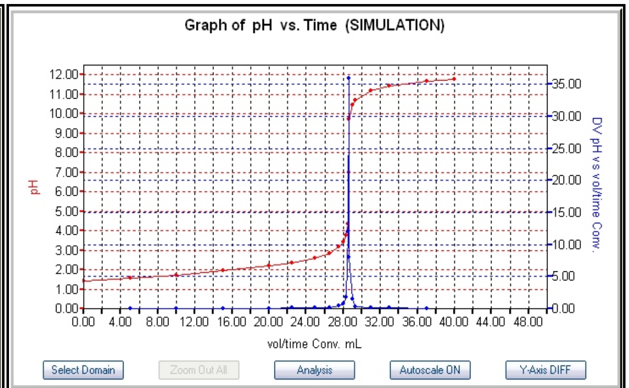

Figure 2. pH vs Volume with derivative superimposed.

minutes, then the drops converted to volume. If you do a manual titration, you will have far fewer data points and take a longer time.

The **Spreadsheet** makes it easy to find the equivalence point of a titration curve. Since the equivalence point is the steepest point of the curve, taking the derivative of the curve will make the equivalence point readily apparent. Click on **Plot a Derivative** function in the **Analysis** option and select pH vs Volume. Figure 2 shows an example of what the derivative looks like when superimposed on the titration curve from Figure 1.

The sodium hydroxide solution supplied is about 2.5 *M*. Using a graduated cylinder, measure 10 mL of 2.5 *M* NaOH into a 250 mL volumetric flask. Make up to the mark with de-ionized water and mix well. Rinse and fill the buret with this dilute solution of NaOH.

Calibrating the pH probe

Instructions are give for calibrating the pH electrode and three pH values, 4, 7 and 10.

Titration of the acids

All the acids supplied will be about 0.1 ***M***. Instructions are give for doing a manual or an automatic titration by time or by drop counter.

Titration of Lysol

Instructions and **Cautions** are given for this titration**.**

Titration of Liquid Plumr

Instructions and **Cautions** are given for this titration**.**

Data Analysis

Guidance is given for the data analysis for all sections of the experiment.

Instructor Resources Provided

1. Sample Report Sheets providing the format to organize the data collection with sample data.
2. Questions to consider, answer and turn-in with suggested answers.
3. Tips and Traps section to assist the instructor with potential problems and solutions.
4. Sample ***MicroLAB*** screen shots and graphs.
5. Laboratory preparation per student station.

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