EXPERIMENT 0

Acid-Base Titration

A. Goal

The goal of this experiment is to calculate the *molar concentration* of a sample of acetic acid by means of a standard chemical procedure known as *titration*. In order to do that you will react the weak acid with a basic solution of sodium hydroxide (NaOH), which has a known concentration. You will also use phenolphthalein as an *indicator*.

B. Materials

- ☐ 5 mL glass-pipet
- ☐ 50 mL buret
- ☐ buret clamp and stand
- ☐ acetic acid s and NaOH
- ☐ phenolphthalein

C. Background

Titrations

Titration is a chemical technique used to calculate the unknown molarity of an acid or base. It is based on the principle that acids neutralize bases and we can figure out the molarity of the unknown chemical (the titrate) by knowing the reacting amounts. A titration uses chemical equipment: a burette, Erlenmeyer, and an indicator (see Figure 1). The unknown chemical is called the titrate and the known chemical is called the titrant. The goal of a titration is to calculate the volume of titrant needed to neutralize the titrate. We reach the endpoint of a titration when the titrant and titrate completely neutralize. At the end point, the mixture of titrant and titrate has a specific PH. Even though the chemical procedure in the lab is similar when titrating strong or weak acids or bases, the calculations needed to calculate the PH at the endpoint differ. This section will cover the principles and calculations involved in titrations.

Figure 1 An acid base titration using phenolphthalein as indicator. From left to right, before, at and after the end point.

Neutralization Reactions

Titrations involve a neuralization reaction in which an acid neutralizes a base. Acids produce protons H^+ and bases hydroxyls OH^- that neutralize forming water, H_2O. More importantly, they react in very specific ratios. Let us take a look at the reaction of hydrochloric acid with sodium hydroxide to produce water and sodium chloride:

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)} \qquad \text{Neutralization Reaction}$$

In this reaction, one mole of HCl reacts with one mole of NaOH. The fact that one more reacts with one more can be used as a principle for acid-base titration. We will have to use the stoichiometry of the reaction to calculate the volume of titrant needed to neutralize the titrate. Imagine you have an unknown sample of HCl and you need to know the amount of acid in the solution. If you know that this sample reacts with a specific amount of NaOH as you know that they react in a one-2-one ratio then you would know the acidic content. This is the idea behind titration: a laboratory procedure in which an unknown sample is neutralized with a known solution. A chemical *indicator*, which changes color depending on the acidity of the medium, is used to visually reveal the moment in which the acid and the base are completely neutralized. The point at which the indicator changes color is called the *equivalency point* or the *endpoint*. At the endpoint, the acid and the base are neutralized.

Endpoint formula

At the *equivalence point*, also called the *stoichiometric point*, the moles of acid and the moles of the base are the same. A simple formula is extensively used to calculate the unknown acid concentration in a titration:

$$\boxed{n_H \cdot c_a \cdot V_a = n_{OH} \cdot c_b \cdot V_b} \tag{1}$$

where:

$n_H \cdot c_a \cdot V_a$ and $n_{OH} \cdot c_b \cdot V_b$ is moles of protons and hydroxyls, respectively

c_a and V_a is acid concentration and volume respectively

c_b and V_b is base concentration and volume respectively

n_H and n_{OH} is the number of protons of the acid and hydroxyls of the base

Regarding the units in this formula, the units in V_a and V_b can either be L or mL. They just need to be the same units. This formula can be used for example when we titrate a given acid amount with a known base and we arrive at the volume of base needed to the endpoint to calculate the molarity of the acid. This formula can also be used when we titrate a known acid with a known base and we need to calculate the volume of titrant needed to reach the endpoint.

Equation 1 can also be used to identify if we already passed the endpoint in a titration. For example, we titrate 2mL of 3M H_2SO_4 (titrant) with 2mL of 1M NaOH (titrate). The question would be: are be before, after, or at the endpoint? We have that to neutralize completely the titrant (H_2SO_4), and using Equation 1 we would need:

$$2 \cdot 3M \cdot 2mL = 1 \cdot 1M \cdot V_b$$

that is we would need 12 mL of the base. Therefore, as we only used 2mL we would be before the endpoint and we would have not reached the endpoint.

Sample Problem 1

A 50mL sample of an unknown acid is neutralized with 25 mL of a NaOH 3M solution. Calculate the molarity of the unknown acid.

SOLUTION

We will use Equation 1, given: $c_b = 3$M, $V_b = 25mL$ and $V_a = 50mL$.

$$c_a \cdot 50mL = 3M \cdot 25mL$$

and the results is 1.5M.

STUDY CHECK

A 15mL sample of an unknown acid is neutralized with 45 mL of a NaOH 1M solution. Calculate the molarity of the unknown acid.

D. Procedure

1. Acetic acid titration

Step 1: – Obtain a 5 mL glass-pipet and a 50 mL buret with a stand and buret clamp.

Step 2: – Obtain about 30 mL of acetic acid solution (vinegar) in a 50 mL beaker and about 80 mL of the NaOH solution in a clean, dry Erlenmeyer flask. Keep the NaOH solution containing Erlenmeyer closed with a rubber stopper.

Step 3: – Clean your buret and fill it with the NaOH solution using a plastic funnel.

Step 4: – Record the initial volume in the buret as 0mL. Read accordingly to the tool precision, including your significant or estimated value.

Step 5: – Pipet 5.00 mL of acetic acid into a clean 125 mL Erlenmeyer flask that has 20 mL of distilled water and 2 drops of phenolphthalein.

Step 6: – Record the molarity of the NaOH solution (c_b) indicated in the lable of the stock solution bottle. This value will be the same for all experiments.

Step 7: – Place the flask under the buret. Use a piece of white paper under the flask to distinguish better the color change.

Step 8: – Add the NaOH solution from the buret in 1 mL portions, while swirling the solution in the flask.

Step 9: – The titration is completed when an addition of 1 mL causes the color to change from colorless to any shade of pink. Record the final buret volume.

Step 10: – Repeat the steps above four times and average the resulting acetic acid concentration.

Step 11: – Make sure you dispose of the solutions and leftovers in the corresponding disposals.

Calculations

1 Record the initial volume of the buret. This value is not necessarily 0.00 mL.

2 Record the final volume of the buret, after you reached the end point.

3 The volumen of NaOH used should be: 2 − 1

4 You can calculate the molarity of the acetic acid solution by means of:

$$c_a = \frac{3 \cdot c_b}{5\text{ mL}}$$

where c_b is the given molarity of the NaOH solution found in the bottle.

5 Is the average of the 4 concentrations calculated.

$$\frac{\sum 4}{4}$$

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Pre-lab Questions

Acid-Base Titration

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1. A 10.00 mL sample of aqueous HCl requires 31.00 mL of 0.0900 M NaOH to reach the endpoint. What is the molar concentration of HCl. The equation for the reaction is:

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

2. The molarity of a vinegar solution is 0.90 M. Calculate the number of acetic acid moles in 10. mL of this solution. Write down your result using scientific notation.

3. Nitric acid (HNO_3) is an acid with three protons. Suppose you titrate 5.00 mL of of this acid with NaOH 0.10 M. Knowing that the end point is reached after 25.00 mL of the base is added, find the molarity of the acid solution.

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Results
EXPERIMENT

Acid-Base Titration

1. Acetic acid titration

		1	2	3	4
1	Initial Buret Volume (mL)				
2	Final Buret Volume (mL)				
3	NaOH Volume used (mL)				
4	CH_3COOH Concentration (M)				

5	Mean CH_3COOH Concentration (M)	

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Post-lab Questions

Acid-Base Titration

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1. You need to prepare a sample containing 0.20 g of $CuSO_4$ from a solution that is 10.% $CuSO_4$ by mass. What mass of solution do you need?

2. A 10.00 mL sample of aqueous HNO_3 requires 20.00 mL of 0.201 M NaOH to reach the endpoint. Calculate the molarity of HNO_3.

3. You titrate a vinegar sample–an acetic acid solution in water–with 0.30 M NaOH. Using 10. mL of vinegar, you reach the endpoint after adding 10. mL of the base. Indicate the molarity of the acetic acid solution.