Acids & Bases

Acid-Base Titration

OVERVIEW

Often we want to determine the concentration of a solution. One way to do so is to carrying out an analytical procedure known as a **titration**. During a titration a carefully measured volume of the solution with the unknown concentration (called the analyte) is reacted with a second solution (the **titrant**) whose concentration is known (a **standard solution**). By knowing how much of the standard solution is required to react completely – no more, no less – with the solution with the unknown concentration we can calculate that solution's concentration.

The point at which stoichiometrically equal amounts of the two solutions have been combined is called the **equivalence point**. When we neutralize an acid with a base, this will occur when $[H^+] = [OH^-]$. By using an appropriate indicator we can detect this point by noting when the indicator changes colour. This will be used to signify the **end point** of the titration. A balanced equation and simple calculations will then allow us to determine the concentration of the solution.

PURPOSE

- To determine the concentration of a solution of NaOH by titration with a standard solution of HCl.
- To determine the concentration of a sample of white vinegar by titration with a standard solution of NaOH

SAFETY

- Acids and bases are corrosive substances. Safety goggles must be worn. Be sure to report any spills to your teacher so they may be cleaned up properly.

EQUIPMENT AND MATERIALS

two 50-mL burets
buret stand and clamps
Erlenmeyer flask, 125-mL
Erlenmeyer flask, 250-mL
wash bottle
distilled water
10-mL graduated cylinder
10-mL volumetric pipette (optional)

0.100*M* HCl standard solution
NaOH solution with unknown concentration
vinegar (acetic acid, $HC_2H_3O_2$)
phenolphthalein
distilled water

PROCEDURE

Part A. Titration of Base of Unknown Concentration

1. Wash two burets with detergent solution. Rinse them thoroughly.

2. With a grease marking pencil or tape identify which buret is to hold each solution, the acid or base.

   Rinse each buret with about 10 mL of solution that it is to hold – rinse the acid-containing buret with the HCl solution and the base-containing buret with the NaOH solution. Allow the acid or base to run out of the buret tip to rinse them.

3. Fill each buret with the proper solution and allow the some of each solution to run out of the buret tip. Make sure no drop remains hanging on the buret. Be sure there are no air bubbles in the tips.

   It is very important that you accurately read and record the initial and final volumes. It is ***not*** necessary that the burets be filled to the very top mark (0.0 mL) at the start of the titration, but it is important that the level never go below the bottom mark (50.0 mL). Be sure to read the bottom of the meniscus at eye level. You may find it helpful to hold a white card with a large black streak or rectangle behind the buret to make it easier to read.

4. Place the 125-mL Erlenmeyer flask beneath the acid buret. Add 10.0 mL of acid to the flask. Use your rinse bottle to make sure all drops make it to the bottom of the flask; rinse any drops that remain on the sides of the flask. Read the buret carefully and record both the initial and final volumes from the buret into your data table.

5. Add 10-mL of distilled water to the flask.

6. Add three drops of phenolphthalein to the flask, and swirl the flask to mix thoroughly.

7. Move the flask so it it beneath the base buret. Place the flask on a sheet of white paper so a colour change will be more readily observed.

8. After recording the initial volume of base in the buret, begin the titration by adding NaOH to the flask. For your initial trial you may want to add the base fairly quickly until you notice a pink colour appearing in the flask. Swirling the flask should make the pink colour disappear. At that point begin adding the NaOH more slowly, swirling the flask after each drop is added. As soon as a faint pink colour becomes permanent, stop the titration – the end point has been reached. Do NOT continue until a darker pink colour has been reached – if that happens you've gone past the end point.

   If you do go past the end point, add a few drops of acid (be sure to record the new volume used), then add more base.

   Record the final volume of base in the buret.

9. Repeat the titration, performing at least four trials. Be sure to rinse the Erlenmeyer flaks well between trials.

   For your other trials add the base more slowly as you near the end point in order to get more accurate readings. You do not need to refill burets between trials.

Part B. Titration of Vinegar

1. Using the volumetric pipette (or another clean buret), add exactly 10.0 mL of vinegar to a clean 250-mL Erlenmeyer flask.

2. Add 100 mL of distilled water to the flask and three drops of phenolphthalein.

3. Titrate the vinegar with the NaOH solution used in Part A. If necessary add more NaOH to the buret before beginning the titration. Record the initial volume of base in the buret.

4. As before, the end point will be reached as soon as a permanent, pale pink colour appears in the flask. Record the final volume of base.

5. Repeat the titration at least two more times.

RESULTS

Copy Data tables 1 and 2, as shown on the last page of this lab, into your data notebook.

CALCULATIONS

Part A. Titration of Base of Unknown Concentration

To calculate the concentration of the unknown base we must begin with a balanced equation. The reaction between hydrochloric acid and sodium hydroxide is:

$$HCl + NaOH \;?\; NaCl + H_2O$$

Stoichiometrically we see that one mole of the acid reacts with one mole of the base. Because of this one-to-one relationship we can use the following formula to calculate the unknown concentration:

$$M_{acid} \times V_{acid} = M_{base} \times V_{base}$$

Rearrange the equation to solve for the unknown concentration of the base:

$$M_{base} = \frac{M_{acid} \times V_{acid}}{V_{base}}$$

For each trial in Part A, determine the molarity of the NaOH solution, [NaOH]. Show your calculations in a table similar to the one shown below. Calculate the average for your trials.

Table 3. Calculating the concentration of the sodium hydroxide solution.

Trial	Calculations	[NaOH]
	$M_{base} = \frac{M_{acid} \times V_{acid}}{V_{base}}$	
1		
2		
3		
4		
Average	-----	

Collect the data from the rest of the class. Calculate the class average:

Table 4. Class data for the concentration of the sodium hydroxide solution.	
Group	**[NaOH]**
1	
2	
3	
etc.	
Average	

Part B. Titration of Vinegar

The reaction between sodium hydroxide and vinegar – acetic acid, $HC_2H_3O_2$ – is represented by:

$$HC_2H_3O_2 + NaOH \rightarrow NaC_2H_3O_2 + H_2O$$

Again there is a 1:1 relationship between the acid and the base. As before we can determine the concentration of the unknown solution – in this case the acetic acid – if we know the volume and molarity of the base and the volume of the acid used:

$$M_{acid} = \frac{M_{base} \times V_{base}}{V_{acid}}$$

Using the molarity of the base you calculated in Part A of the lab, determine the molarity of the acetic acid. Show your calculations in Table 5, which you should copy into your notebook.

Table 5. Calculating the concentration of the vinegar solution.		
Trial	**Calculations**	**$[HC_2H_3O_2]$**
	$M_{acid} = \frac{M_{base} \times V_{base}}{V_{acid}}$	
1		
2		
3		
4		
Average	-----	

Collect the data from the rest of the class. Calculate the class average:

Table 6. Class data for the concentration of the vinegar solution.	
Group	**[NaOH]**
1	
2	
3	
etc.	
Average	

CONCLUSIONS AND QUESTIONS

1. How did the results for each of your trials for the titration of the sodium hydroxide compare? Were the results similar or did they vary a great deal?

2. What are some of the major sources of error with this experiment?

3. The volume of water added during this experiment – to rinse droplets of acid from the buret or as water dded to the acid in the flask – does not affect the calculations and thus does not need to be accounted for. Why not?

Data Tables.

Table 1. Titration of NaOH with Unknown Concentration

	Trial 1		Trial 2		Trial 3		Trial 4	
	HCl	NaOH	HCl	NaOH	HCl	NaOH	HCl	NaOH
initial volume								
final volume								
volume used								

Table 2. Titration of Vinegar

	Trial 1		Trial 2		Trial 3		Trial 4	
	Vinegar	NaOH	Vinegar	NaOH	Vinegar	NaOH	Vinegar	NaOH
initial volume	-		-		-		-	
final volume	-		-		-		-	
volume used	10.0		10.0		10.0		10.0	