THERMOMETRIC TITRATIONS

Introduction

When an acid neutralises an alkali, a salt and water are formed. aqueous hydrogen ions, ($H_3O^{+1}{}_{(aq)}$), from the acid react with the hydroxide ions, ($OH^{-1}{}_{(aq)}$) from the alkali, forming water. For example, when hydrochloric acid and sodium hydroxide react:

$$H^{+1}{}_{(aq)} + Cl^{-1}{}_{(aq)} + Na^{+1}{}_{(aq)} + OH^{-1}{}_{(aq)} \longrightarrow Na^{+1}{}_{(aq)} + Cl^{-1}{}_{(aq)} + H_2O_{(l)}$$

Since the Na^{+1} and the Cl^{-1} are unchanged, i.e. they are spectator ions, thus the only chemical reaction that occurs is between H^{+1} and the $OH^{-1}{}_{(aq)}$:

$$H^{+1}{}_{(aq)} + OH^{-1}{}_{(aq)} \longrightarrow H_2O_{(l)}$$

The combination of H^{+1} and OH^{-1} ions is a bond making process, thus releasing energy. In this lab, the enthalpy changes for different neutralisation reactions will be measured. Because the number of moles of water formed varies according to the acid and alkali used, hence it is the convention to measure enthalpies of neutralisation in kilojoules per mole of water formed.

In thermometric titrations we make use of the fact that reactions in solution are accompanied by temperature changes, and thus it is possible to follow the course of a reaction using a thermometer. In the next experiment, you will perform two thermometric titrations.

You will titrate both hydrochloric acid and ethanoic acid in turn with a standardized solution of sodium hydroxide and record the temperature of the mixtures during the course of the titrations. In each case, a plot of temperature against time will enable you to determine the maximum temperature rise, from which you can calculate both the concentration of the acid and the enthalpy change of neutralization.

Aim

The purpose of this experiment is to determine the concentration of two acids: hydrochloric acid, HCl and ethanoic acid CH_3COOH by thermometric titration – and having done that, to calculate the enthalpy change for each reaction — the enthalpy change of neutralization.

Requirements

Safety Goggles, Pipette, 50.0 cm^3, Pipette Filler, Expanded polystyrene cup, Sodium hydroxide solution, 1 M NaOH (Standardized), Thermometer, 0-50 °C (in 0.1 °C), Burette, 50.0 cm^3 Filter funnel(small), Hydrochloric acid, ~ 2.0 M HCl, Ethanoic acid, ~ 2.0 M CH_3COOH

Hazard Warning

Sodium hydroxide solution is corrosive. Ethanoic acid and hydrochloric acid solutions are irritants. Therefore, you must:

1. Use the pipette filler supplied;
2. Wear safety goggles

Procedure

I: Titration of hydrochloric acid with standard sodium hydroxide solution

1. Using a pipette and filler, transfer 50.0 cm^3 of NaOH solution into the polystyrene cup. Allow to stand for a few minutes.
2. Record the temperature of the solution.
3. From a burette, add 5.0 cm^3 of HCl solution to the cup.
4. Stir the mixture with the thermometer and record its temperature. Work quickly to minimize heat loss to the surroundings.
5. Add successive 5.0 cm^3 portions of HCl solution, stirring the mixture and recording its temperature after each addition.
6. Record your results in **Data Table I**. Stop after the addition of 50.0 cm^3 of acid.

II: Titration of ethanoic acid with standard sodium hydroxide solution

1. Follow the same procedure as above, except use ethanoic acid in the burette. When filling the burette, remember to use correct rinsing procedures. (If in doubt, ask your teacher.)
2. Record your results in **Data Table II.**

Data Table I: Titration of hydrochloric acid

Volume added ($\pm$ 0.01 cm^3)	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
Temperature ($\pm$ 0.5 °C)											

Data Table II: Titration of ethanoic acid

Volume added ($\pm$ 0.01 cm^3)	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
Temperature ($\pm$ 0.5 °C)											

Calculations

1. Plot temperature (*y*-axis) against volume of acid added (*x*-axis) for each acid on the same graph.

2. Extrapolate the curves as shown in **Graph I**. The point at which they meet corresponds to both the volume of acid required for neutralization and to the maximum temperature.

3. Calculate the concentration of each of the acids.

4. From the maximum temperature rise, determine the quantity of energy released in each titration. Assume that the specific heat capacity of the solutions in the same as that for water, 4.18 kJ kg^{-1} K^{-1} and that the heat capacity of the cup is zero.

5. Calculate the standard enthalpy change of neutralization for each reaction.

Questions

1. The enthalpy change of neutralization for a very dilute strong acid (i.e. an acid which is completely ionized in solution) reacting with a very dilute strong base is constant at -57.6 kJ mol^{-1}, where mol^{-1} refers to one mole of water produced. Why is the value constant?

2. Experimental results for hydrochloric acid are usually a little less negative than -57.6 kJ mol^{-1}. Suggest two reasons for this.

3. Ethanoic acid is a weak acid, i.e. it is not completely ionized in the solution. Suggest a reason why the enthalpies of neutralization for reaction involving weak acids and /or weak bases are always less negative than for strong acids and bases.

Graph I