Beatty Secondary School
Science Department (Chemistry Unit)
Chemistry 6092

35

Name: ________________________________ (   )   Date: _______________

Class: 4E___

Practical 4: E2 – Thermometric Titration

Skills: **MMO**: Manipulation, measurement, and observation **PDO**: Presentation of data and observations **ACE**: Analysis, conclusions and evaluation

Aim: To find the concentration of an alkali using temperature changes.

Apparatus and chemicals:

burette
measuring cylinder
distilled water
250 cm^3 beaker
funnel
styrofoam cup with lid
50 cm^3 of solution **U**
clamp and stand
thermometer
60 cm^3 of solution **V**

Solution **U** contains 0.500 mol/dm^3 of sulfuric acid.

Solution **V** is aqueous sodium hydroxide of unknown concentration.

When acids react with alkalis, heat is produced because the reaction is exothermic.

When aqueous sodium hydroxide is steadily added to a volume of sulfuric acid, the temperature rises until all the acid has reacted. At this point, even if more alkali is added, there is no further increase in temperature as all the acid has been neutralised. You are to add solution **V** to a volume of solution **U**, recording the temperature changes by the following procedure. From the results, you are to find the concentration of sodium hydroxide in solution **V**.

Procedure:

1 Put the alkali **V** into a burette.

2 Use a measuring cylinder to place 50 cm^3 of solution **U** into a styrofoam cup. Using a thermometer, measure the temperature of the solution in the cup and record this value (T_0) in an appropriate table under the results section.

3 Add 5.0 cm^3 of solution **V** from the burette into the styrofoam cup. Gently stir the mixture with the thermometer and record the maximum temperature reached (T_1). You should reach the maximum temperature in about half a minute.

4 ***Without delay***, add another 5.0 cm^3 of solution **V** from the burette into the styrofoam cup and stir the mixture. Record the maximum temperature (T_1) reached in the table.

5 Repeat Step **4** with further 5.0 cm^3 portions of solution **V** until a total of 45.0 cm^3 of solution **V** has been added to the styrofoam cup. Record all the results in your table.

Results:

Total volume of solution **U** used = **50.0 cm^3**

Initial temperature (T_0) of solution **U** = **29.5 °C**

total volume of V added / cm^3	maximum temperature (T_1) reached / °C	total temperature change / °C

[5]

Plot a graph of total temperature change in the styrofoam cup against total volume of solution **V** added to the cup. Draw **two** intersecting straight lines passing through the points. One of the lines must pass through the origin.

[4]

Calculations:

1 Answer the following questions with reference to your graph plotted.

(a) What is the maximum temperature change in the styrofoam cup?

maximum temperature change = …………………….. °C

(b) What is the minimum volume of solution **V** that produces this greatest temperature change?

volume of solution **V** = …………………….. cm^3

This volume of solution **V** neutralises 50 cm^3 of solution U.

[2]

2 Solution **U** contains 0.500 mol/dm^3 of H_2SO_4. One mole of H_2SO_4 reacts with two moles of NaOH.

Use the answer in **1(b)** to calculate the concentration, in mol/dm^3, of NaOH in solution **V**.

No of mol of H_2SO_4 = $0.5 \times \frac{50}{1000}$

= 0.0250 mol

Comparing mole ratio:

H_2SO_4	**:**	**NaOH**
1	**:**	**2**
0.0250	**:**	**0.0500**

Concentration of NaOH =

concentration of NaOH in solution **V**: …………………….. mol/dm^3

[2]

Questions:

1 Explain why a styrofoam cup was used instead of a glass container.

Styrofoam cup is a better insulator than glass to reduce heat loss to the surroundings.

2 State the purpose of putting the styrofoam cup into a 250 cm^3 beaker.

It is to provide stability to the cup to prevent the cup from toppling over.

3 Identify one key source of experimental error and explain how it affects the results.

Heat loss to the surroundings resulting in a lower temperature measured than expected.

4 **(a)** What is the limiting reactant used in the reaction?

Sulfuric acid

(b) Predict the effect of using 1.0 mol/dm^3 of sulfuric acid for solution **U** on the maximum temperature change measured in 1**(a)**. Explain your answer.

The greatest temperature change will be larger than expected [1]. As the concentration of H^+ ions doubles, twice the amount of product will be formed, leading to twice the amount of thermal energy released [1].

5 The amount of heat produced in a neutralisation reaction can be calculated using the relationship.

amount of heat produced (joules)	=	**total volume of liquid in the cup (cm^3)**	×	**temperature rise (°C)**	×	**4.2**

(a) Calculate the amount of heat produced in the neutralisation reaction.

Amount of heat = (50 + graph volume) × (graph temperature rise) × 4.2
=

amount of heat: ……………………..[2]

(b) How many moles of sulfuric acid were used in the reaction in the cup?

moles of H_2SO_4: **0.0250 mol** [1]

(c) Using your answers from **5(a)** and **5(b)**, calculate the amount of heat produced by the reaction of 1 mole of sulfuric acid in kilojoules.

Amount of heat = (5a) ÷ 0.0250
=

amount of heat: ……………………..[1]

(d) Using your results from **5(c)**, calculate the amount of heat produced by the neutralisation of 1 mole of hydrogen ions in kilojoules.

$$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$$

Amount of heat = (5c) ÷ 2
=

amount of heat: ……………………..[1]

(e) Theoretically, the value in **5(d)** is 57.0 kJ/mol. This value is referred to as the heat of neutralisation. Explain why and how your answer in **5(d)** differs from this value.

The experimental value is lower than expected [1]. This is because heat lost to the surroundings might have led to a lower maximum temperature measured, leading to a lower calculated value of the heat of neutralisation [1].

(f) Explain, in terms of ions, why the heat of neutralisation is the same when both the acid and alkali are strong but not when either one of them is weak.

Strong acids and alkalis ionise completely in water to form a high concentration of H^+ and OH^- ions respectively. As such, there are H^+ and OH^- ions available for neutralisation to release thermal energy [1]. However, weak acids and alkalis ionise partially in water to form a low concerntration of H^+ and OH^- ions [1].
Hence, part of the thermal energy released is used to ionise the weak acids or alkalis, leading to a smaller amount of heat energy released during neutralisation [1].

6 When an acid H_xA is dissolved in water, it ionises as shown below.

$$H_xA \rightarrow xH^+ + A^{x-}$$

You are given a 1 mol/dm³ solution of H_xA, describe a method by which the value of x can be determined. This method must **not** involve measuring temperature. Otherwise, you can assume all the apparatus and reagents normally found in a school laboratory are available.

You should include the measurements you would take and explain how you would use your results to calculate the value of x. State any assumptions made.

1. **Pipette 25.0 cm³ of H_xA of concentration 1 mol/dm³ into a conical flask and add a few drops of methyl orange.**

2. **Fill a burette with aqueous sodium hydroxide of 1 mol/dm³ concentration. Record the initial reading of the alkali in the burette as v_0 cm³.**

3. **Titrate the acid solution with aqueous sodium hydroxide until the first drop of acid just turns the indicator colour orange. Record the final volume in the burette reading as v_1 cm³. The volume of alkali used would be $v_a = (v_1 - v_0)$ cm³**

   Assumption:

   Only acid H_xA in the conical flask reacts with aqueous sodium hydroxide. There are no other impurities present to react with aqueous sodium hydroxide.

4. **Repeat the experiment until at least two consistent burette readings are obtained. Calculate the average of the volumes of the alkali, v_{avg}.**

5. **H_xA and NaOH react according to the following equation:**

$$H_xA + xNaOH \rightarrow Na_xA + xH_2O$$

6. **Calculate the number of moles of H_xA using the formula**

$$\text{No. of mol of } H_xA\text{, a} = 1 \times \frac{25}{1000}$$

7. **Calculate the number of moles of NaOH using the formula**

$$\text{No. of mol of NaOH, b} = 1 \times \frac{V_{avg}}{1000}$$

8. **Determine the value of x using the formula**

$$x = \frac{b}{a}$$