Experiment 1- Heat of Neutralization

Title: Heat of Neutralization

Objective: To study the enthalpy changes (ΔH) of various acid -base neutralization.

Introduction:

Neutralization is the reaction between an acid and a base, and is an exothermic reaction.

The enthalpy of neutralization is the heat produced when an acid and a base react together in dilute aqueous solution to produce one mole of water. Strong acids and strong alkalis are completely dissociated in dilute solution, so the reaction between any strong acid and strong alkali may be represented as following:

$$H^+(aq) + OH^-(aq) \rightarrow H2O(l) \qquad \Delta H^O = -57.3 \text{ kJ mol}^{-1}$$

If a weak acid or alkali is used, or if both are weak, then the enthalpy of neutralization is usually lower than -57.3 kJ mol_{-1} This is because weak acids and weak alkalis are only slightly ionized in aqueous solution, and energy is absorbed in ionizing the un-ionized molecules.

$$CH3COOH(aq) + NH3(aq) \rightarrow CH3COONH4(aq) \qquad \Delta H^O = -32.0 \text{ kJ mol-}$$

The temperature rise due to the heat given out can be used to find the end -point of titration.

In this experiment, **TWO** methods are used to find the end-point of titration, which is then used to :

(i) find the molarity of a ammonia, and

(ii) the enthalpy change of neutralization.

Different combinations of acid and alkali are used and compared.

Procedures:
Neutralization between aqueous base and acid

Method 1:

1) The dry polystyrene cup was taken and two clean burettes were set in stands respectively.
2) Around 1.0M alkali solution and 1.0 M acid were respectively filled the two burettes by using filter funnels. The tips of the burettes were drained and the initial burette readings are recorded.
3) The specified volume of the alkaline solution was drained into the dry polystyrene cup according the following table.

Experiment No.	1	2	3	4	5
Vol.of~1.0MNH_3(aq)/cm^3	25.00	20.00	15.00	10.00	5.00
Vol. of 1.0M HCl(aq)/cm^3	5.00	10.00	15.00	20.00	25.00

4) The content in the polystyrene cup was equilibrated for a few minutes and the temperature of the solution was measured and recorded in Table1.
5) The specified amount of acid was quickly drained into the polystyrene cup.
6) The reaction mixture was swirled gently and its maximum temperature was measured immediately and recorded in Table1.
7) The content of polystyrene cup was empted and washed. Steps 3-6 with other combination of volume of alkali solution and acid were repeated.
8) A graph of concentration of the given alkali solution was plotted and the enthalpy change of neutralization were obtained

Method 2:

1) 25.00 cm^3 of the given alkali solution was pipette into a dry polystyrene cup.
2) The content in the polystyrene cup was equilibrated for a few minutes and the temperature of the solution was measured and recorded.
3) The acid was poured into burette to the mark' 0 cm^3' through a filter funnel.
4) 2.00 cm^3 of the acid was added from the burette into the polystyrene cup containing 25.00cm^3 alkali solution. The mixture was swirled gently and the maximum temperature was recoded.
5) Another 2.00 cm^3 acid was added into the polystyrene cup after the maximum temperature had been reached, and the maximum temperature was recorded again.
6) Step 5 was repeated until a total volume of 40 cm^3 of acid was added.
7) A graph was plotted and (i) the concentration of alkali solution and (ii) the enthalpy change of neutralization were determined.

Results:

Date of experiment: 23rd October, 2004
Temperature of the laboratory: 23.6°C
Alkali used in the experiment: $NH_3(aq)$
Acid used in the experiment: HCl(aq)

Method 1

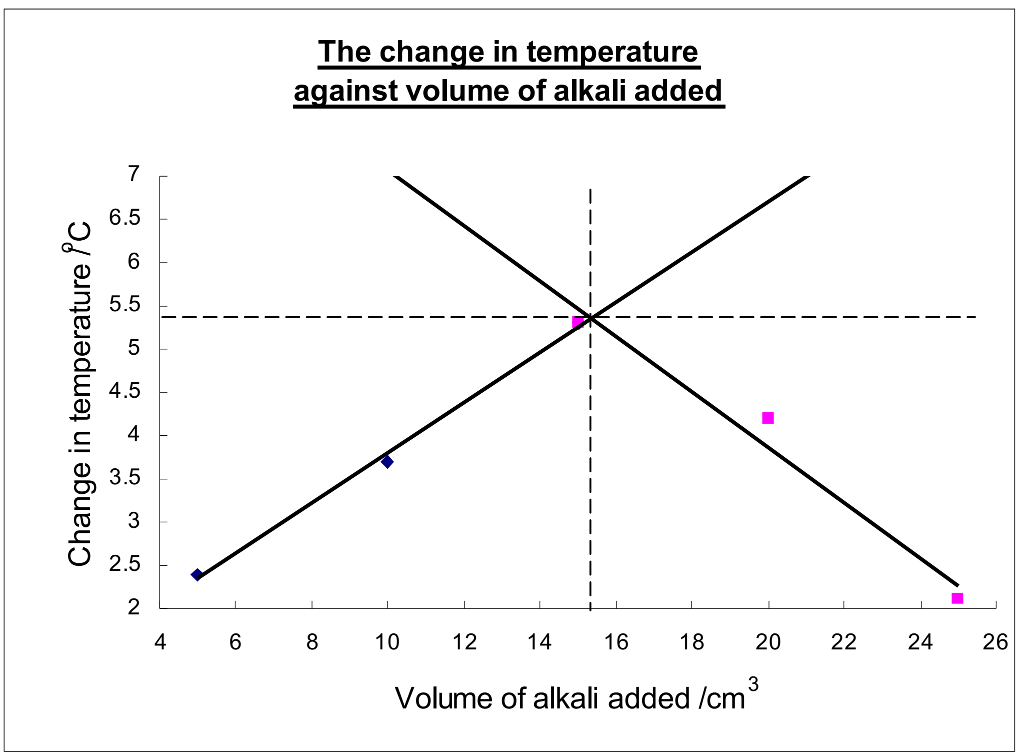
Table1: The temperature change of mixing HCl and NH3

Experiment No.	1	2	3	4	5
Vol.of~1.0M NH_3(aq)/cm^3	25.00	20.00	15.00	10.00	5.00
Vol. of 1.0M HCl(aq)/cm^3	5.00	10.00	15.00	20.00	25.00
Initial temperature / °C	**22.00**	**22.20**	**22.20**	**22.30**	**22.50**
Max. temperature/ °C	**24.40**	**25.90**	**27.50**	**26.50**	**24.60**
Change in temperature/ °C	**2.40**	**3.70**	**5.30**	**4.20**	**2.10**

From the results obtained, the maximum change in temperature of neutralization is 5.30°C by mixing 15.00cm^3 of HCl(aq) and 15.00cm^3 of NH_3(aq).

1. According to the above data, the change in temperature versus the volume of NH_3 (aq) added was plotted on Graph(I).

Graph (I).



2. Calculate the molarity of the alkali solution from the data in Method 1.

No. of moles of hydrochloric acid in $15cm^3$ of 1.0 mol/dm^3 solution
= the molarity of acid x the volume of acid added
= 1.0 $moldm^{-3}$ x (15/ 1000) cm^3
= 0.015 mol

Since

$$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$$
$$OH^- + HCl + NH_4^+ \rightarrow NH_4Cl + H_2O$$
$$NH_3^+ + HCl \rightarrow NH_4Cl$$

No. of mole of HCl = No. of mole of NH_3
=0.015 mol

, and when 15.2 cm^3 of NH_3 was added, it gave the greatest change of temperature
Therefore, the molarity of the alkaline solution is
= 0.015 mol / (15.2 cm^3/ 1000)
= 0.987 mol/dm^3

3. Determine the enthalpy change of neutralization ($KJmol^{-1}$) in this case.
(Given: Density of water = $1g/cm^3$, specific heat capacity of water = 4.184 $Jg^{-1}K^{-1}$)

Total volume of solution = (15 .20 + 14.8) cm^3.
Heat produced = specific heat capacity x mass of solution x temperature
= - 4.184 $Jg^{-1}K^{-1}$ x (30 cm^3) x 5.4K
= -0.6771KJ
Enthalpy change of neutralization (ΔH) = -0.6771KJ / 0.015 mol
= - 45.19 $KJmol^{-1}$

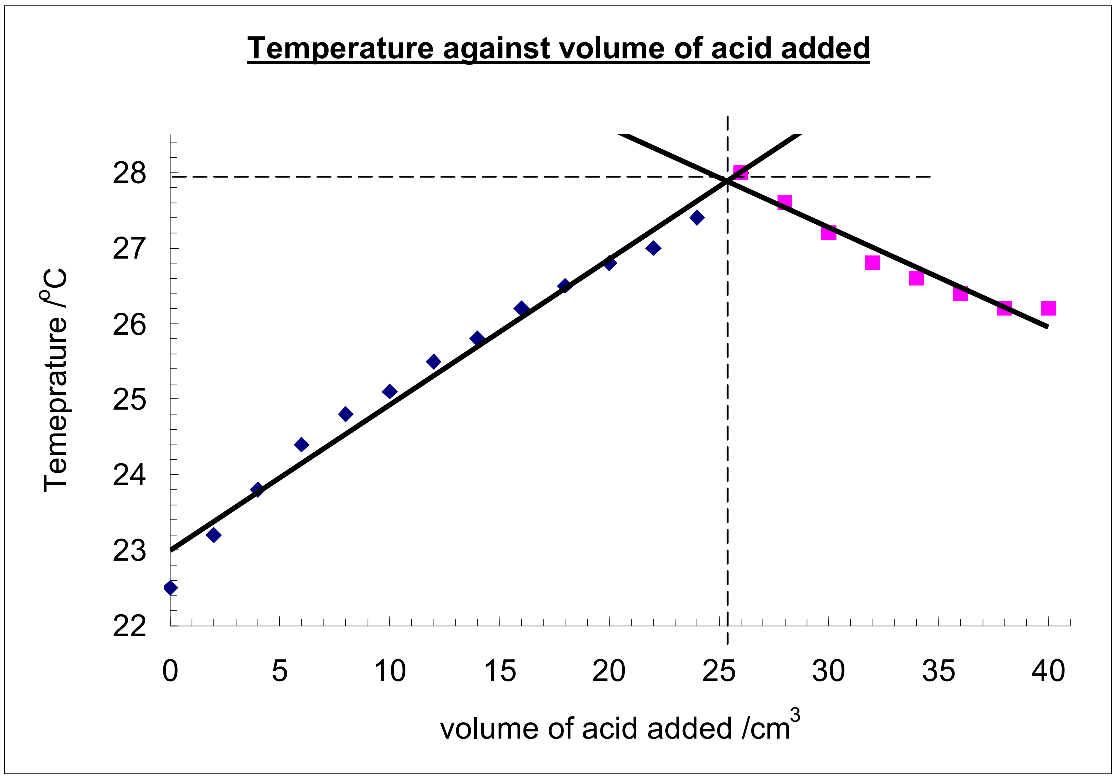
Therefore, the reaction is exothermic and the enthalpy change of neutralization is - 45.19 $KJmol^{-1}$.

Method 2

Vol.of HCl (aq) added /cm^3	0.0	2.0	4.0	6.0	8.0	10.0	12.0
Max Temp/°C	22.5	23.2	23.8	24.4	24.8	25.1	25.5
Vol. of HCl(aq) added/cm^3	**14.0**	**16.0**	**18.0**	**20.0**	**22.0**	**24.0**	**26.0**
Max Temp/°C	25.8	26.2	26.5	26.7	26.8	27	27.3
Vol. of HCl(aq) added/cm^3	**28.0**	**30.0**	**32.0**	**34.0**	**36.0**	**38.0**	**40.0**
Max Temp/°C	27.2	27.0	26.8	26.6	26.4	26.2	26.2

4. Using the above data in Method 2, the temperature against volume of acid (aq) added was plotted on Graph (II).

Graph (II)



5. Calculated the molarity of the alkali solution from the data in Method 2.

No. of moles of hydrochloric acid in $25.5cm^3$ of 1.0 mol/dm^3 solution
= the molarity of acid x the volume of acid added
= 1.0 $moldm^{-3}$ x (25.5/ 1000) cm^3
= 0.0255 mol

Since

$$NH_3^+ + HCl \rightarrow NH_4Cl$$

No. of mole of HCl = the no. of mole of NH_3
= 0.0255 mol

, and when $25cm^3$ of NH_3 was added, it gave the greatest change of temperature

Therefore, the molarity of the alkaline solution is
= 0.0255mol / (25/ 1000) cm^3
= 1.02mol/dm^3

6. Determine the enthalpy change of neutralization ($KJmol^{-1}$) in this case.
(Given: Density of water = $1g/cm^3$, specific heat capacity of water = 4.184 $Jg^{-1}K^{-1}$)

Total volume of solution = (25+ 25.5) cm^3 = $50.5cm^3$, and
The temperature changed = (28.0 – 22.5) °C = 5.5°C

Heat produced = specific heat capacity x mass of solution x temper ature
= - 4.184 $Jg^{-1}K^{-1}$ x (50.5 cm^3) x5.5K
= -1.161KJ

Enthalpy change of neutralization (ΔH) = -1.161KJ / 0.0255mol
= - 45.53 $KJmol^{-1}$

Therefore, the reaction is exothermic and the enthalpy change of neutralization is –45.53$KJmol^{-1}$.

Further question:

7. What assumptions have been made when calculating the enthalpy change of neutralization in this experiment?

Ans: -no heat loss to the surroundings

-the specific heat capacity of the solution involved is equal to that of water

-the density of the solutions is equal to that of water

-the specific of the polystyrene cup is neglecte d

-the temperature and the pressure in the lab are kept constant as the standard condition (25°C, 1atm)

8. Which method, 1 or 2, provides a more accurate result in the determination of (a) the concentrations of alkali solution; and (b) the enthalpy cha nge of neutralization? Explain.

Ans: As for (a), method 2 is more accurate rather than method 1. Since we obtained more data and it has a larger variation in the experiment, so more data are used to calculate the concentration of alkaline and the results become more accurate.

As for (b), method 1 is more accurate than method 2. Because the experiment we carried out in method 1 is taken a shorter time than method 2. Also, the titration in method 1 is done by separately instead of continuously. So, the heat loss in method 1 is less than method 2. Therefore, the more accurate results can be obtained.

9. Combinations of acid-alkali neutralization result from other classmates.

The combination of acid- alkali neutralization

Group Number	Combination of acid and alkali	Enthalpy change of neutralization ($KJmol^{-1}$)
1	HCl and NaOH	-57.10
2	HNO_3 and NaOH	-57.00
3	CH_3COOH and NaOH	-54.00
4	HCl and NH_3	-45.19
5	HNO_3 and NH_3	-56.00
6	H_2SO_4 and NH_3	-55.64
7	CH_3COOH and NH_3	-50.21

10. According to the results in the above table, comment on the relationship between the enthalpy change of neutralization and the combination of acid and

alkali used.

Ans: From the results obtained, it shows that the value of the enthalpy change of neutralization become less exothermic when it goes from upward to downward in the table. It is because when a strong acid and a strong base react together, the ions are completely ionized, there is no energy consumed for bond breaking (ionized the molecules). Similarly, when a weak base and weak acid react together, it consumes a large amount of energy that is used for bond breaking (ionized the molecules), and this process is endothermic causing less energy released to the system. Therefore, the values of the enthalpy change of neutralization become less exothermic (smaller value) from strong acid-strong base to weak acid-weak base.

Discussion:

From the results obtained, it shows that when an acid and alkaline mix together, an exothermic reaction will be involved.

Yet, the value of standard enthalpy change depends on the strength of the acid and alkaline. As a strong acid reacts with the strong base, the enthalpy value is quite large. Since the molecules are completely ionized and it does not require too much energy for ionize the molecules. So, more energy will be released.

On the other hand, as a strong acid react with weak base or a weak acid react with strong base, the reaction consume more energy than "strong acid-strong base" reaction. Take ammonia as an example, because ammonia only partially ionized and it provides only some of the free OH^- ions for neutralization, and so more energy is required for ionized the molecules, so less energy is released to the system.

Similarly, the weak acid with a weak base requires a largest amount of energy for ionization. Since both of the weak acid and base is required energy to carry out ionization.

Therefore, the value we obtained is smaller than that of the combination of strong acid and strong base but larger than that of combination of weak acid and weak base. As some of the energy is used in dissociating the non-ionized weak base molecules so that neutralization can proceed.

There are some possible errors in the experiment. First, there are heat loss to the surroundings due to the evaporation and convection. Second, the heat capacity of vacuum flask or expanded polystyrene cup is neglected. Third, the specific heat capacity of the product solution is assumed to be the same as that of water. Forth, the ordinary thermometer is not precise enough. Fifth, human errors were involved during in the investigation of temperature value.

There are number of improvement for the experiment. For instance, we can find the heat capacity of the vacuum flask, expanded polystyrene cup or the solution. We can also replace a thermometer with a more precise one. Taking the reading by the same person to achieve the results in order to minimize the errors

Conclusion:

From the results obtained, the value of enthalpy change of neutralization with hydrochloric acid and ammonia is in a medium range when compare to the combination with another strong acid-strong base and weak acid-weak base. In method1, the molarity of ammonia is 0.987mol/dm^3 and the value of enthalpy change of neutralization is - 45.19 KJmol^{-1}. In method 2, the molarity of ammonia is 1.02mol/dm^{3}and the value of enthalpy change of neutralization is - 45.53 KJmol^{-1}

References:

1. W.H.Skoog, (1996) Fundamentals of Analytical Chemistry, 7th ed., P.17
2. P.W.Atkins (1996) The Elements of Physical Chemistry, 2nd ed., P.49-70

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