Determination of the heat of reaction of hydrochloric acid with sodium hydroxide

Theory

In this experiment a known number of moles of hydrochloric acid is mixed with an equal number of moles of sodium hydroxide in an insulated container. The rise in temperature of the mixture is then measured and from this the heat of reaction is calculated.
The equation for the reaction is

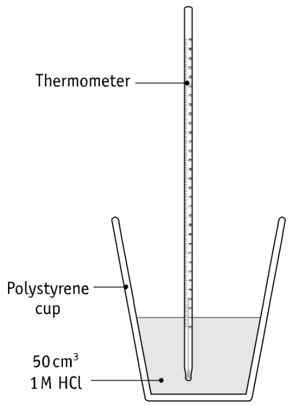
$$HCl + NaOH \rightarrow NaCl + H_2O$$

Procedure

<u>NB</u>: Wear your safety glasses.

Using a graduated cylinder, place 50 cm^3 of the 1 M hydrochloric acid solution into one of the polystyrene cups. Using a second graduated cylinder, place 50 cm^3 of the 1 M sodium hydroxide solution into the second polystyrene cup.

Measure the temperature of the hydrochloric acid solution. Using a second thermometer, measure the temperature of the sodium hydroxide solution.



When both solutions are at the same temperature, quickly add the base to the acid, stirring well. Take care to avoid any loss of liquid due to splashing.

Place a lid on the polystyrene cup and with continuous swirling record the maximum temperature reached.

Summarise your results as follows:

Temperature of HCl solution before mixing	=	°C
Temperature of NaOH solution before mixing	=	°C
Highest temperature reached after mixing	=	°C
Temperature rise	=	°C
Number of moles of acid used	=	
Number of moles of base used	=	

Now use the equation **heat liberated = m c ΔT** (where m = mass in kg of the solution, c is the specific heat capacity of the solution, and ΔT is the temperature rise) to calculate the heat liberated.

Calculate the heat of reaction, i.e. the heat liberated when one mole of acid reacts fully. Because the reaction is exothermic, your answer should be given a negative sign.

Note: In your calculations assume that the density of the solution is the same as the density of water, i.e. that 100 cm^3 of the solution has a mass of 100 g or 0.1 kg. Also assume that the specific heat capacity of the solution is the same as that of water, i.e. 4.2 kJ kg^{-1} K^{-1}. Knowing the heat liberated when the number of moles of acid used in this experiment was neutralised, it is now possible to calculate the amount of heat that would be liberated when one mole of the acid is neutralised i.e. the heat of reaction.

student questions

What precautions are used in this experiment to minimise heat loss to the surroundings?

A polystyrene cup is used because the specific heat capacity of polystyrene is negligible. The use of a lid on the cup further reduces heat loss.

Chemistry data books give the heat of reaction of one mole of hydrochloric acid with one mole of sodium hydroxide as -57 kJ per mole. Why do you think your answer is different from this?

The values obtained by the students may not be -57 kJ per mole because

(i) graduated cylinders (which are not very accurate) are used to measure the volumes of acid and base respectively,
(ii) the concentrations of the solutions used are not known to a high degree of accuracy, and
(iii) a number of assumptions made in carrying out the experiment may introduce errors. These assumptions are
   a) the specific heat capacity of the polystyrene calorimeter is zero,
   b) there is no loss of heat to the surroundings,
   c) the specific heat capacity of the final solution is the same as that of water and
   d) the densities of the acid and base are equal to the density of water.

If 1 M nitric acid solution is used instead of 1 M hydrochloric acid solution in this experiment, or if 1 M potassium hydroxide solution is used instead of 1 M sodium hydroxide solution, similar values are obtained for the heat of reaction. Explain why this happens.

Hydrochloric acid and nitric acid are both strong monobasic acids, and are fully dissociated in water. Potassium hydroxide and sodium hydroxide are both strong monoprotic bases, and are also fully dissociated in water. In all the experiments referred to, the only reaction that occurs is that between the hydrogen ions formed when the acid dissociates in water and the hydroxide ions formed when the base dissociates in water:

$$H^+ + OH^- \rightarrow H_2O$$

Consequently, the heat of reaction is the same.