Determination of the Enthalpy of Neutralisation of HCl and NaOH

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Objective

To determine the molar enthalpy of neutralisation, ΔH_{neut}, for the reaction between hydrochloric acid and sodium hydroxide, and to compare the measured value against the accepted literature value for a strong acid–strong base neutralisation [1].

Method

50 mL of 1.0 mol L^{-1} HCl and 50 mL of 1.0 mol L^{-1} NaOH were each brought to room temperature and their initial temperatures recorded separately. The NaOH solution was added rapidly to the HCl in an insulated calorimeter, stirred continuously, and the temperature was recorded every 15 seconds for 5 minutes.

The overall reaction is:

$$\text{HCl (aq)} + \text{NaOH (aq)} \longrightarrow \text{NaCl (aq)} + \text{H}_2\text{O (l)} \tag{1}$$

Data

Table 1: Temperature readings during neutralisation

Time (s)	Temperature (°C)
0	21.4
15	24.8
30	27.1
45	27.9
60	28.0
90	27.8
120	27.5

The maximum temperature (extrapolated back to the moment of mixing to correct for heat loss) was taken as 28.3 °C, giving a temperature change of $\Delta T = 6.9\,^{\circ}\text{C}$.

Calculations

Assuming the combined solution has the density and specific heat capacity of water ($\rho = 1.00\,\text{g mL}^{-1}$, $c = 4.18\,\text{J g}^{-1}\,\text{K}^{-1}$), the heat released is:

$$q = mc\Delta T = (100\ \text{g})(4.18\,\text{J g}^{-1}\,\text{K}^{-1})(6.9\ \text{K}) = 2884\,\text{J} \tag{2}$$

Moles of water formed (limiting reagent, either acid or base, both 0.050 mol):

$$n = 0.050\,\text{L} \times 1.0\,\text{mol L}^{-1} = 0.050\,\text{mol} \tag{3}$$

Molar enthalpy of neutralisation:

$$\Delta H_{\text{neut}} = -\frac{q}{n} = -\frac{2884\,\text{J}}{0.050\,\text{mol}} = -57.7\,\text{kJ mol}^{-1} \tag{4}$$

Results and Discussion

Table 2: Comparison with the literature value

Source	ΔH_{neut} (kJ mol^{-1})
This experiment	-57.7
Literature [1]	-57.3

The measured value of $-57.7\,\text{kJ mol}^{-1}$ agrees with the accepted literature value of $-57.3\,\text{kJ mol}^{-1}$ to within 0.7%. The small discrepancy is most likely due to heat loss to the calorimeter and surroundings despite insulation, and to the extrapolation used to estimate the maximum temperature, since the reaction rate at these concentrations is fast enough that some heat is lost before the true peak temperature is reached.

Conclusion

The molar enthalpy of neutralisation of HCl and NaOH was measured as $-57.7\,\text{kJ mol}^{-1}$, consistent with the expected value for a strong acid–strong base reaction, confirming that the reaction is exothermic and that the result is independent of the specific acid and base used, as both dissociate completely in solution.

References

[1] Peter Atkins, Julio de Paula, and James Keeler. *Atkins' Physical Chemistry*. Oxford University Press, Oxford, 11 edition, 2018.