Investigation 9.A: Determining the Enthalpy of a Neutralization Reaction Answer Key

Answers to Analysis Questions

1. You should calculate the heat absorbed by the solutions using the equation $Q = mc\Delta t$. You can assume that the density of the solution is about the same as water, 1.00 g/mL. Therefore, the mass (m) of your reaction mixture is 100 g. You can also assume that the specific heat capacity of the solutions are the same as the specific heat capacity of water, 4.19 J/g•°C. Because the final temperature should be higher than the initial temperature, $Q_{solution}$ should be a positive value, expressed in joules. The accepted value for the heat of neutralization between a strong acid and a strong base is –55.9 kJ/mol of $H_3O^+(aq)$. Using this value and assuming no heat losses, the expected value for the enthalpy change of the system can be calculated:

$$\Delta H = n\Delta_r H$$

$$= \left(0.05\,\text{L HCl(aq)}\right)\left(\frac{1.00\,\text{mol HCl(aq)}}{\text{L HCl(aq)}}\right)\left(\frac{-55.9\,\text{kJ}}{\text{mol HCl(aq)}}\right)$$

$$= -2.80\,\text{kJ}$$

The temperature change predicted by the reaction can be calculated from this value. The sign must be changed since the thermal energy released by the system = –(thermal energy absorbed by the surroundings). Since the total volume of the solution is 100 mL, the mass of the water in the calorimeter is 100 g.

$$Q = mc\Delta t$$

$$\Delta t = \frac{Q}{mc}$$

$$= \frac{2.80\times10^3\,\text{J}}{\left(100\,\text{g}\right)\left(\frac{4.19\,\text{J}}{\text{g•°C}}\right)}$$

$$= 6.68\,^\circ\text{C}$$

This is a maximum value, because there will certainly be heat losses. A value for Δt significantly different from 6.68 °C (especially if the value is greater) indicates a mistake, either in experimental procedure or in calculating the temperature difference.

2. The value for energy released by the reaction should be –2.80 kJ. Your value is likely to be 10% lower or more, depending on the calorimeter used. The answer should have three significant digits, based on the initial values used.

3. Amount of HCl(aq) = amount of NaOH(aq) = (1.00 mol/L)(0.0500 L) = 0.0500 mol

4. You should include the following equation:

$HCl(aq) + NaOH(aq) \rightarrow H_2O(\ell) + NaCl(aq)$.
You may also include ionic and net ionic equations to emphasize that a neutralization reaction has taken place. Because the temperature of the solution in the calorimeter increases, you should state that the reaction was exothermic (released energy).

Investigation 9.A: Determining the Enthalpy of a Neutralization Reaction Answer Key (continued)

Answers to Conclusion Questions

5. You will calculate the enthalpy of neutralization using the formulas
$Q = mc\Delta t$ and $\Delta H = n\Delta_r H$
where n is the number of moles calculated in Analysis Question #3, 0.0500 mol, m is the mass of water in the calorimeter, which should be approximately 100 g, c is the specific heat capacity of water, 4.19 J/g•°C, and Δt is the temperature change of the water, which should be approximately 7 °C. Your answer should be approximately –56 kJ/mol. In general, heat will be lost from the system, resulting in a smaller temperature change and a smaller enthalpy change. Errors of 10-15% should be expected.
$HCl(aq) + NaOH(aq) \rightarrow H_2O(\ell) + NaCl(aq)$ $\Delta H = -56$ kJ/mol

Answers to Application Questions

6. Neutralizing an acid spill on skin with a base is dangerous, because the base itself can burn the skin. Also, the heat produced by the neutralization reaction can be dangerous. By diluting the acid, this will minimize the damage caused by the corrosiveness of the acid and not cause any further damage.

7. **(a)** The enthalpy change would be different because the dissolving of sodium hydroxide has an associated enthalpy change of its own.

(b) The enthalpy change would have been higher because the dissolving of sodium hydroxide is an exothermic process.

(c) You should outline a procedure that is similar to the procedure in Investigation 9.A. The difference is that in Step 4, you would accurately obtain 2.0 g sodium hydroxide pellets (which is equivalent to 0.0500 mol of NaOH(s), the same quantity used in this investigation). In Step 5, you would add 100.0 mL of 0.50 mol/L HCl to the calorimeter. You would record the temperature of the acid, and then quickly add the pellets to the acid. Steps 6 and 7 follow unchanged.

(d) $HCl(aq) + NaOH(s) \rightarrow H_2O(\ell) + NaCl(aq)$
ΔH will be greater.