

Answer on Question #43895 - Chemistry - Other

Question:

Calculate the heat when 150 ml of .500 M HCl is mixed with 450 ml of .100 M barium hydroxide. Assuming the temperature of both solutions was initially 25°C and that the final mixture has a mass of 600 g and specific heat of water, calculate the final temperature of the mixture?

$$c_i(\text{Ba}(\text{OH})_2) = 0.100 \frac{\text{mol}}{\text{L}}$$

$$V(\text{Ba}(\text{OH})_2) = 450.0 \text{ mL}$$

$$c_i(\text{HCl}) = 0.500 \frac{\text{mol}}{\text{L}}$$

$$V(\text{HCl}) = 150.0 \text{ mL}$$

$$m(\text{solution}) = 600.0 \text{ g}$$

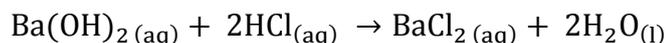
$$t_1(\text{HCl}) = t_1(\text{Ba}(\text{OH})_2) = 25^\circ\text{C}$$

$$c_p(\text{H}_2\text{O}) = 4.1813 \frac{\text{J}}{\text{g}\cdot\text{K}}$$

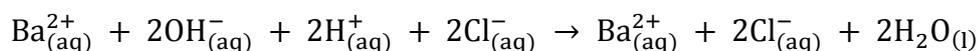
$$t_2(\text{solution}) = ?$$

Solution:

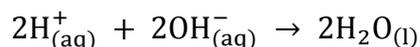
1. Write the reaction as a molecular equation:



2. Then the overall ionic equation for the reaction:



3. The net ionic equation for the reaction:



4. When we mix strong acid with strong base, we obtain the heat from the reaction of water synthesis. The standard enthalpy of neutralization for such reaction is constant $\Delta H_N^\ominus = -56000 \frac{\text{J}}{\text{mol}}$. This value shows us the change of enthalpy during water synthesis. We can calculate the heat released from such reaction by the equation:

$$Q = -\frac{\Delta H_N^\ominus}{n_i(\text{H}_2\text{O})}$$

5. The amount of water can be found from the equation:

$$n_i(\text{H}_2\text{O}) = n_i(\text{HCl}) = \frac{n_i(\text{Ba}(\text{OH})_2)}{2}$$

6. We compare the amount of acid and base and find that the base is in excess:

$$n_i(\text{Ba}(\text{OH})_2) = c_i(\text{Ba}(\text{OH})_2) \cdot V(\text{Ba}(\text{OH})_2) = 0.100 \frac{\text{mol}}{\text{L}} \cdot \frac{450.0 \text{ mL}}{1000} = 0.045 \text{ mol}$$

$$n_i(\text{HCl}) = c_i(\text{HCl}) \cdot V(\text{HCl}) = 0.500 \frac{\text{mol}}{\text{L}} \cdot \frac{150.0 \text{ mL}}{1000} = 0.075 \text{ mol}$$

The stoichiometric ratio $\frac{n_i(\text{Ba}(\text{OH})_2)}{n_i(\text{HCl})}$ is 1 : 2, so for full acid neutralization we need to have

$$n_i(\text{Ba}(\text{OH})_2) = \frac{n_i(\text{HCl})}{2} = \frac{0.075 \text{ mol}}{2} = 0.0375 \text{ mol}$$

The stoichiometric ratio $\frac{n_i(\text{HCl})}{n_i(\text{H}_2\text{O})}$ is 1 : 1, so

$$n_i(\text{H}_2\text{O}) = n_i(\text{HCl}) = 0.075 \text{ mol}$$

7. Find heat released after reaction:

$$Q = -\Delta H_N^\ominus \cdot n_i(\text{H}_2\text{O}) = -(-56000) \frac{\text{J}}{\text{mol}} \cdot 0.075 \text{ mol} = 4200.0 \text{ J}$$

8. Then we can calculate the temperature difference after the reaction:

$$Q = c_p(\text{H}_2\text{O}) \cdot m(\text{H}_2\text{O}) \cdot \Delta T$$

$$\Delta T = \frac{Q}{c_p(\text{H}_2\text{O}) \cdot m(\text{H}_2\text{O})} = \frac{4200.0 \text{ J}}{600 \text{ g} \cdot 4.1813 \frac{\text{J}}{\text{g} \cdot \text{K}}} = 1.67 \text{ K}$$

$$\Delta T = \Delta t = 1.67^\circ\text{C}$$

9. Find the final temperature of the mixture:

$$\Delta t = t_2(\text{solution}) - t_1(\text{HCl})$$

$$t_2(\text{solution}) = \Delta t + t_1(\text{HCl}) = 25^\circ\text{C} + 1.67^\circ\text{C} = 26.67^\circ\text{C}$$

Answer: The final temperature of the mixture is 26.67°C.