Enthalpy of Diluting a Strong Acid

The addition of a strong acid to water generates heat; that is, the reaction is exothermic. In this worksheet you will determine the change in temperature when H_2SO_4 is added to water and consider one of its implications.

When we add concentrated sulfuric acid to water the reaction H_2SO_4*(l)* → H^+*(aq)* + $HSO_4{}^-$*(aq)* takes place. Calculate ΔH^o for this reaction given that the standard state heats of formation for H_2SO_4*(l)*, H^+*(aq)*, and $HSO_4{}^-$*(aq)* are –813.989 kJ/mol$_{rxn}$, 0 kJ/mol$_{rxn}$ (defined), and –885.75 kJ/mol$_{rxn}$, respectively.

$$\Delta H^o = [\Delta H^o_{f,HSO_4^-} + \Delta H^o_{f,H^+}] - \Delta H^o_{f,H_2SO_4} = [(-885.75 + 0] - [(-813.989)] = -71.76 \text{ kJ/mol}_{\text{rxn}}$$

Now, suppose you carry out this reaction in a calorimeter by mixing 10.0 mL of concentrated (18.0 M) H_2SO_4 with sufficient water to give a final volume of 100.0 mL. The density of the resulting solution is 1.08 g/mL and its specific heat is 3.50 J/g • °C. If the initial temperature is 25.0°C, what is the mixture's final temperature? You may assume a perfect calorimeter that neither absorbs heat from nor loses heat to the surroundings.

To begin, we calculate q_{rxn}, which, in Joules, is

$$q_{rxn} = (-71.76 \text{ kJ/mol}_{\text{rxn}}) \times \frac{1 \text{ kJ/mol}_{\text{rxn}}}{\text{mol H}_2\text{SO}_4} \times \frac{18.0 \text{ mol H}_2\text{SO}_4}{\text{L}} \times 0.0100 \text{ L} \times \frac{1000 \text{ J}}{\text{kJ}} = -12916.8 \text{ J}$$

Then, using the equation for q_{soln}, we calculate the final temperature

$$q_{soln} = -q_{rxn} = mS\Delta T = mS(T_{final} - T_{initial})$$

$$+12916.8 \text{ J} = 100.0 \text{ mL} \times \frac{1.08 \text{ g}}{\text{mL}} \times \frac{3.50 \text{ J}}{\text{g} \bullet^o \text{C}} \times (T_{final} - 25.0^o \text{ C})$$

$$T_{final} - 25.0^o \text{ C} = 34.17^o \text{ C}$$

$$T_{final} = 59.2^o \text{ C}$$

Based on the result of your calculations, speculate on why instructions for preparing dilute solutions of strong acids always emphasize that one should add a strong acid to water instead of adding water to the strong acid.

The dissolution of a strong cid in water is strongly exothermic. To prevent the resulting system from overheating, we need to dissipate the energy quickly into a large volume of water. Adding a small amount of strong acid to a large volume of water accomplishes this. If we add a small amount of water to a large volume of strong acid, the acid's dissolution into the water may produce a ΔT that is sufficiently large that the water may boil and splash from the container, creating a safety hazard.