ScienceCube

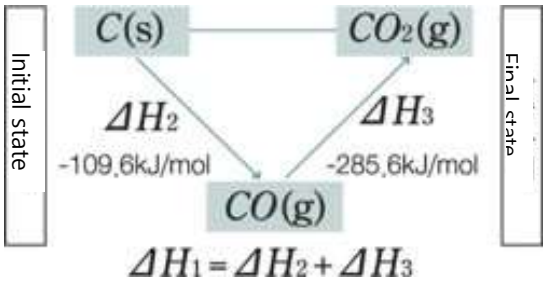
Hess's Law

Using a temperature sensor, you can measure the reaction heat of three different reactions and demonstrate the validity of Hess's Law.

Fundamental Concept

Hess's Law

Hess's Law states that the total enthalpy change during the course of a chemical reaction is the same regardless of the number of steps in the reaction. As shown in the figure below, the reaction heat of carbon burning to form carbon dioxide is equal to the sum of the reaction heats of carbon burning to form carbon monoxide and then carbon monoxide burning to form carbon dioxide.



In this experiment, we will use three reactions to verify that the reaction heat of one reaction equals the sum of the reaction heats of two other reactions according to Hess's Law.

(1) Solid sodium hydroxide dissolves in water to form an aqueous solution of ions.

$$\mathrm{NaOH(s)} \rightarrow Na^{+}(aq) + OH^{-}(aq) \qquad \Delta H_1 = ?$$

(2) Solid sodium hydroxide reacts with hydrochloric acid to form water and sodium chloride.

$$\mathrm{NaOH(s)} + H^{+}(aq) + Cl^{-}(aq) \rightarrow H_2O(l) + Na^{+}(aq) + Cl^{-}(aq) \qquad \Delta H_2 = ?$$

(3) Sodium hydroxide solution reacts with hydrochloric acid to form water and sodium chloride.

$$Na^+(aq) + OH^-(aq) + H^+(aq) + Cl^-(aq) \rightarrow H_2O(l) + Na^+(aq) + Cl^-(aq) \qquad \Delta H_3 = ?$$

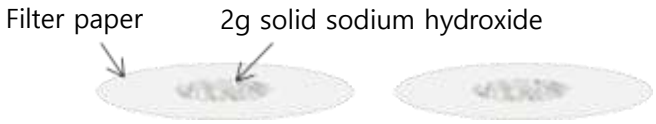
Experiment

Materials Needed

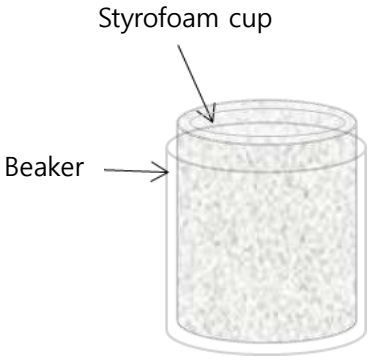
Smart Sensor Box, Science# Program (smart device), Temperature sensor, 100 mL water, 4 g solid sodium hydroxide, Filter paper, 50 mL 1 M NaOH, 50 mL 1 M HCl, 100 mL 0.5 M HCl, Stand, Clamp, Glass rod, Styrofoam cup, 1000 mL beaker, Electronic balance, Calculator

Experiment Setup

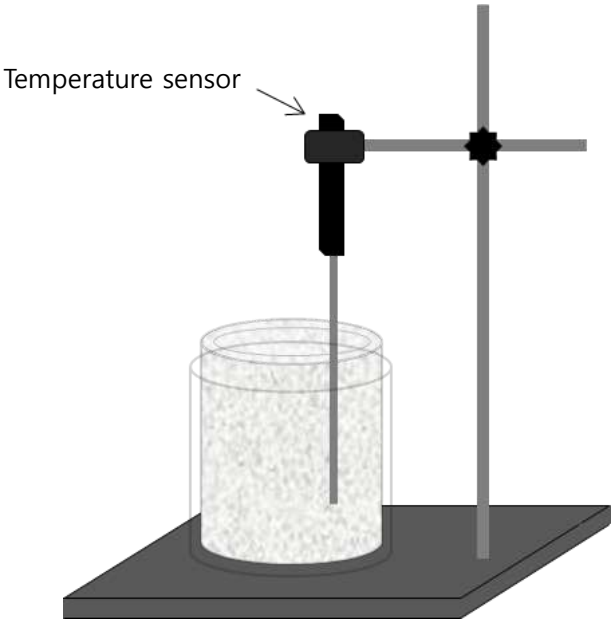
1. Use the electronic balance to measure and divide 4 g of solid sodium hydroxide into two portions of 2 g each on filter paper.



2. Place the Styrofoam cup inside the beaker.

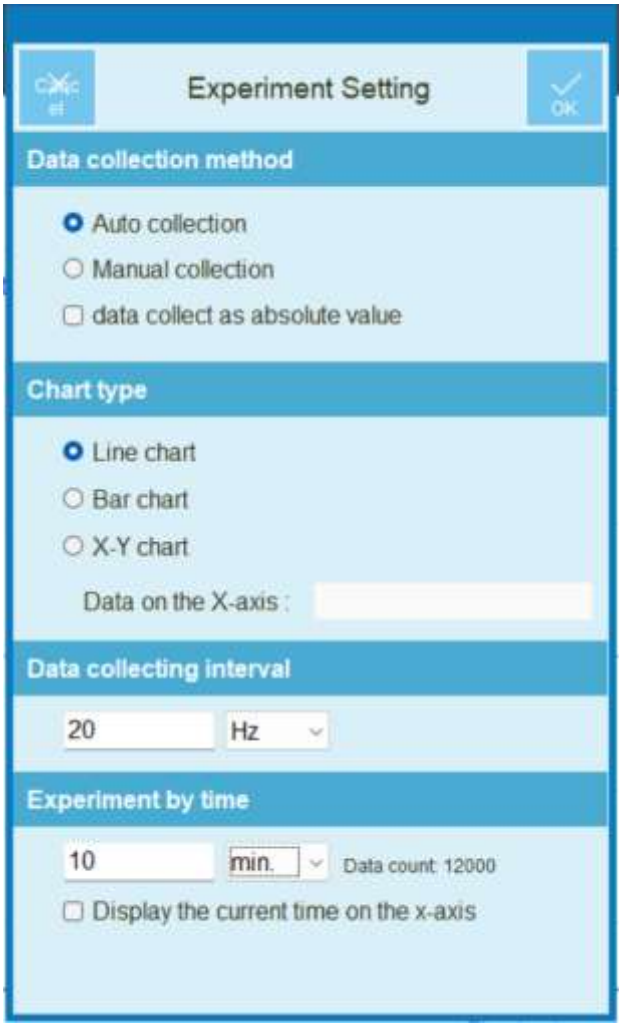


3. Fix the temperature sensor in the stand and place it in the Styrofoam cup.



Interface Setup

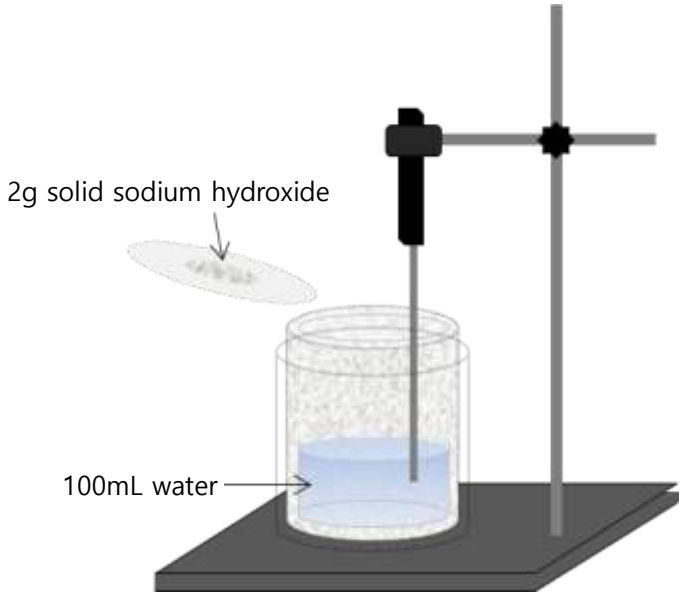
1. Run Science#.
2. Connect the temperature sensor to the interface.
3. Press the button and configure the experiment settings as shown below or press the auto setup button.



Data Collection

[ReactionA] $\mathbf{NaOH(s)} \rightarrow \boldsymbol{Na^{+}(aq)} + \boldsymbol{OH^{-}(aq)}$

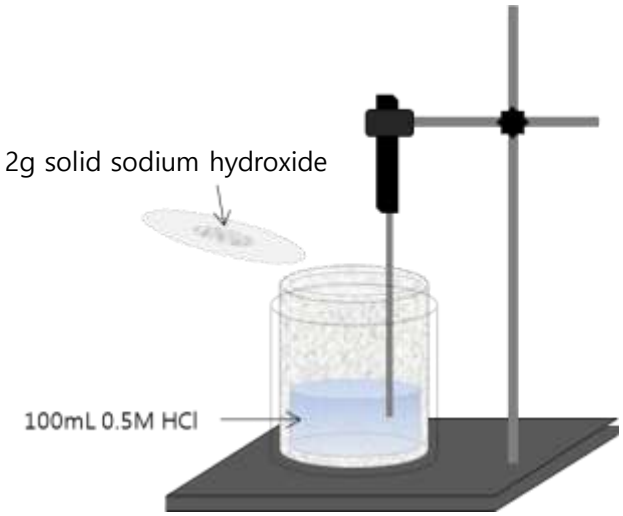
1. Add 100 mL of water to the Styrofoam cup.
2.  Press the button to start data collection.
3. Add 2 g of solid sodium hydroxide to the water and stir with the glass rod.



4. When the reaction finishes and the temperature stabilizes, press the button  to stop data collection.
5. Record the initial temperature (t1) and the maximum temperature (t2).

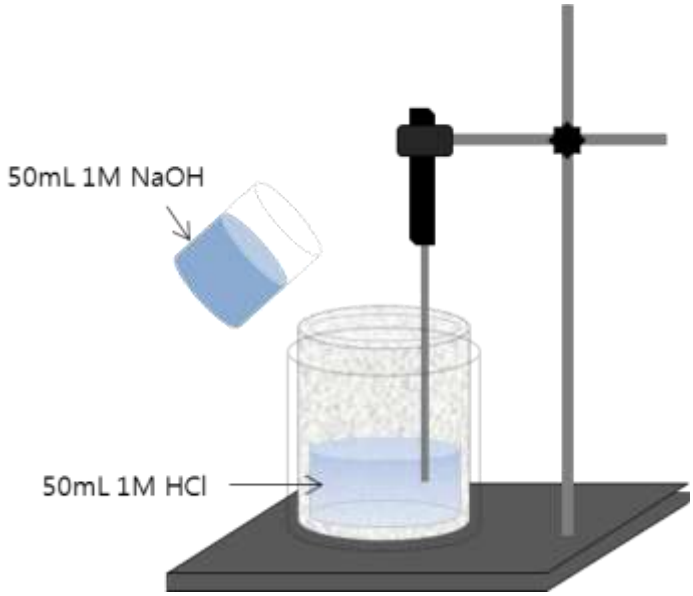
[Reaction B] $\mathbf{NaOH(s)} + \boldsymbol{H^+(aq) + Cl^-(aq) \rightarrow H_2O(l) + Na^+(aq) + Cl^-(aq)}$

6. Add 100 mL of 0.5 M HCl solution to the Styrofoam cup instead of water and repeat steps 1-5..



[Reaction C] $\boldsymbol{Na^+(aq) + OH^-(aq) + H^+(aq) + Cl^-(aq) \rightarrow H_2O(l) + Na^+(aq) + Cl^-(aq)}$

7. Mix 50 mL of 1 M HCl solution with 50 mL of 1 M NaOH solution and repeat steps 1-5.



Data Analysis

Recording Data

1. Complete the table below using the results from the three reactions.

	Reaction A	Reaction B	Reaction C
Solid mass (g)			
Liquid mass (g)			
Total mass (m)			
Initial temperature (t1)			
Maximum temperature (t2)			
Temperature change (Δt)			

Applying Data

1. Complete the Table for Each Reaction Using the Chemical Formulas.

	Reaction A	Reaction B	Reaction C
Heat q [$q=C_p \cdot m \cdot \Delta t$] ※ C_p=4.18 J/g°C			
Enthalpy change ΔH [ΔH = -q]			

2. To verify the experimental results, sum the enthalpy changes (ΔH) of Reaction A and Reaction C. Compare this sum to the enthalpy change of Reaction B and calculate the percentage error.

Experimental value (Reaction A + Reaction C)	
Expected theoretical value (Reaction B)	
Error (%)