

Heat of Solution of a Solid

Overview

When a solid dissolves in water to form a solution energy changes occur. In this experiment, you will determine the heats of solution for two substances - ammonium nitrate and sodium acetate - using a simple styrofoam cup as a calorimeter.

Purpose

- To measure experimentally the amount of heat absorbed or released during the dissolving of ammonium nitrate and of sodium acetate in water.

Materials

styrofoam cup balance
thermometer 100 mL graduated cylinder
anhydrous sodium acetate, $\text{CH}_3\text{CO}_2\text{Na}$
ammonium nitrate, NH_4NO_3

Procedure

- Accurately find the mass of about 150 mL of tap water. Record this value and other measurements in the data table. Add the water to the styrofoam cup calorimeter.
- Accurately find the mass of about 15 g of solid ammonium nitrate.
- Find and record the initial temperature of the water. Record to the nearest 0.2°C .
- Dissolve the solid ammonium nitrate in the water, stirring with the thermometer. Record the maximum temperature difference from the initial reading.
- Rinse out the cup, dry it thoroughly, and repeat the experiment using a sample of about 15 g of sodium acetate in place of the ammonium nitrate.

Calculations

You will be calculating the **molar heat of solution** for each of the two solids. The molar heat of solution is the amount of heat associated with the dissolving of **one mole** of solute (the solute is the substance that gets dissolved).

A calculation table (next page) may be used to work through the required calculations.

Summary of calculations required:

- The **total heat of solution** can be calculated by determining the amount of heat absorbed or lost by the water during the experiment. This is calculated using the formula:

$$Q = m \times c \times \Delta T$$

heat absorbed/lost (joules) = mass of water (g) \times specific heat of water ($\text{J/g}\cdot^\circ\text{C}$) \times temperature change ($^\circ\text{C}$)

The specific heat of water is more-or-less a constant, with a value of $4.18 \text{ J/g}\cdot^\circ\text{C}$.

- Important Note:** The amount of heat absorbed (or lost) by the **water** is equal to the amount of heat lost (or absorbed) by the **solute**. Therefore, to determine the value for heat gained/lost by the solute, just reverse the sign for the value of heat gained/lost by the water.
 - The value for the amount of heat absorbed or lost by the solute will be converted into kJ.
- The **molar heat of solution**, expressed as kJ/mol, is determined by converting the mass of the solute used to moles:

$$\text{moles} = \frac{\text{mass(g)}}{\text{MolarMass(g/mol)}}$$

Total heat of solution tells us how much heat was gained or lost in our actual experiment with the mass of the substances actually used, while **Molar heat of solution** tells us how much energy would be gained or lost for **one mole** of the substance.

$$\text{molar heat solution} = \frac{\text{total heat solution}}{\text{moles solute used}}$$

Perform the necessary calculations by completing the calculations table.

Table 1. Data recording sheet

	Ammonium nitrate NH₄NO₃	sodium acetate CH₃CO₂Na
Mass of cup + water (g)		
Mass of empty cup (g)		
Mass of water (g)		
Mass of solid + container (g)		
Mass of empty container (g)		
Mass of solid used (g)		
Initial water temperature (°C)		
Final water temperature (°C)		
Change in water temperature (°C)		

Sample Data

Use the following sample data if you are not able to perform the experiment.

	Ammonium nitrate NH₄NO₃	sodium acetate CH₃CO₂Na
Mass of cup + water (g)	100.6 g	103.4 g
Mass of empty cup (g)	1.6 g	1.6 g
Mass of water (g)		
Mass of solid + container (g)	53.9 g	38.4 g
Mass of empty container (g)	23.3 g	23.2 g
Mass of solid used (g)		
Initial water temperature (°C)	20.2°C	19.8°C
Final water temperature (°C)	8.0°C	27.6°C
Change in water temperature (°C)		

Table 2. Calculating Molar Heat of Solution

	ammonium nitrate NH_4NO_3	sodium acetate $\text{CH}_3\text{CO}_2\text{Na}$
1. Total mass of water used (from Table 1)		
2. Change in water temperature (from Table 1)		
3. Specific heat of water	4.18 J/ g·°C	4.18 J/ g·°C
4. Energy absorbed/lost by the water (J) [see formula 1 : $Q = mc\Delta T$]		
5. Energy absorbed/lost by the solute (J) [same value, but opposite sign, as in calculation step 4]		
6. Energy absorbed/lost (kJ) [convert j into kJ]		
7. Molar mass of solute (g/mol)		
8. Moles of solute actually used (mol)		
9. Molar heat of solution (kJ/mol) [see formula 2]		

Questions

1. Both of the substances used in this experiment consist of ions. Give the chemical formulas of the two ions that make up each of the compounds used in this experiment:

(example: sodium chloride, NaCl, consists of: Na⁺ and Cl⁻ ions)

ammonium nitrate, NH₄NO₃: _____

sodium acetate, CH₃CO₂Na: _____

2. For each of the dissolving processes, state whether the overall process was endothermic (absorbed energy) or exothermic (released energy)

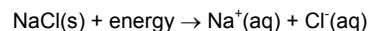
ammonium nitrate, NH₄NO₃:

sodium acetate, CH₃CO₂Na:

3. Write balanced equations for the dissociation of each ionic compound. Include both the physical states of all participants (s, l, g, aq) and the energy term. For the energy term - be sure to write it on the appropriate side of the equation, and give the value for this term that you obtained during your experiment.

example:

The equation for the solution process of sodium chloride, an endothermic solution process, is:



You calculated the value for the energy term (the final row in the calculation table). Include this value in your equation:

ammonium nitrate, NH₄NO₃:

sodium acetate, CH₃CO₂Na:

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4. The *percentage error*, E_r , is a way to measure the accuracy of your experimental work. Percent error is calculated as follows:

$$E_r = \frac{|\text{Observed} - \text{Expected}|}{\text{Expected}} \times 100\%$$

where: observed = value you obtained during your experiment
expected = actual or expected value.

Using the data obtained from your experiment and the following actual values for molar heats of solution, calculate your percentage errors for this experiment.

	Observed Value	Expected Value	Percentage Error
ammonium nitrate		+25.8 kJ/mol	
sodium acetate		-17.4 kJ/mol	