

## #30 Thermochemistry: Heat of Solution

**Purpose:** You will mix different salts with water and note any change in temperature. Measurements using beakers will be compared to measurements using polystyrene cups.

**Background:**

When the temperature increases upon mixing a solute (the salt) and solvent (water), heat is given off and the process of solution is *exothermic*. If the temperature decreases when a solution is prepared, heat is absorbed, and the process is *endothermic*.

Some commercial hot and cold packs work this way. A small inner bag containing water is put into another bag containing a fixed amount of salt. When the inner bag is crushed, the water and solid are mixed. From observing what happens when various different salts are mixed with water, you will find out which salts could be used to make cold packs and which could be used in hot packs.

**Apparatus:**

The salts are weighed using a top loading electronic balance. A timer is provided. A simple calorimeter is made from a thermometer & either a glass beaker or polystyrene cup.

**Safety and Waste Disposal:**

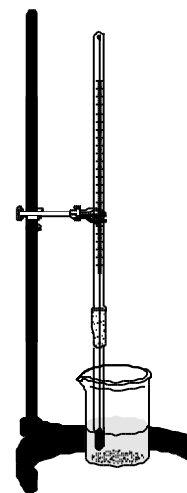
Safety glasses are always required in the laboratory. Ammonium nitrate,  $\text{NH}_4\text{NO}_3$ , is a skin irritant. Gloves must be worn. Waste bottles will be available to collect all used solutions.

**Procedure:**

Various salts are dissolved in water to observe heat changes. In Part A, a beaker is the reaction vessel as shown in the setup on the right.

Part A. Heat Changes on Dissolving Salts in Water (Beaker)

1. Fill a 250-mL beaker with distilled water.
2. Measure 50 mL of the distilled water into a 100-mL beaker, using the marks on the beaker. Position the thermometer as shown in the figure, so that the bulb is immersed in the water, but does not touch the bottom of the beaker. Note: The bottom of the curved water meniscus should be at the 50-mL mark.
3. Weigh 5.0 g of one of the salt compounds. Record the initial temperature of the water to the nearest half degree, that is,  $\pm 0.5^\circ\text{C}$ . Add the salt to the water, all at once, and start the timer. Swirl the flask to hasten the dissolving. Note: An amount between 4.96 g and 5.04 g is fine.
4. Record the temperature ( $\pm 0.5^\circ\text{C}$ ) when the increase or decrease stops, that is, when the temperature reaches a maximum or a minimum. This should take no more than two minutes, possibly less than one.
5. Pour used solution into labeled bottle. Rinse the beaker with water, then repeat Steps 2 through 4 with the other salts. Note: Record the starting temperature each time.



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### Part B. Heat Change on Dissolving Ammonium Nitrate in Water (Polystyrene Cup)

The heat change when 5.0 g ammonium nitrate dissolves in 50 mL water is measured again, but using an insulated reaction vessel made of polystyrene in place of the beaker

1. Measure 50 mL distilled water into a polystyrene cup using the mark on the 50-mL beaker. Record the starting temperature.
2. Adjust the thermometer and lid so that the thermometer is positioned just above the bottom of the cup. Add 5.0 g ammonium nitrate to the water, replace the lid with thermometer quickly and start the timer. Swirl the cup to hasten the dissolving.
3. Record the lowest temperature to the nearest half degree ( $\pm 0.5^{\circ}\text{C}$ ).
4. Compare the decrease in temperature using the polystyrene cup to the one measured using a beaker as container.

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**Data and Results** (Thermochemistry)

Name(s) \_\_\_\_\_

### Part A. Heat Changes on Dissolving Salts in Water (Beaker)

Amounts: 5.0 g salt in 50 mL water

Name of Salt	formula of salt	Initial temp $^{\circ}\text{C}$	max/min temp $^{\circ}\text{C}$	change in temp., $\Delta t$ $^{\circ}\text{C}$

### Part B. Heat Change on Dissolving Ammonium Nitrate in Water (Polystyrene Cup)

Amount: 5.0 g ammonium nitrate in 50 mL water

Initial temp $^{\circ}\text{C}$	minimum temp $^{\circ}\text{C}$	decrease in temp. $^{\circ}\text{C}$

### **Questions**

1. Which of the salts that were dissolved in water, could be used to make a cold pack? a hot pack?
2. When dissolving ammonium nitrate in water, what is the temperature decrease when using the beaker compared to the polystyrene cup?

*Instructor's Guide*  
(#30 thermochemistry)

**Equipment and Materials:**

Items	Amount/gp	Comment
Top-loading balances	1/ gp	
Weighing papers	4/gp	The salt must be added quickly. Can also use a weighing boat.
250-mL beaker	1	to store room temperature water
50-mL beaker	1 or 3	
spatula	3	For measuring salts
Thermometer (alcohol)	1	
Clamp and ring stand	1	To support thermometer
Sodium chloride (noniodized)	5 g	
Ammonium nitrate	10 g	
Calcium chloride, anhydrous	5 g	
polystyrene cups/lids	1	
distilled water	500 mL	Each group will need a minimum of 200 mL. Distilled water is more practical than tap water, since the tap water might require time to come to temperature equilibrium.
timer	1	

**Ideas and Information**

1. Hydrated calcium chloride,  $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ , can be dehydrated by heating on a hot plate until about 20% of the mass is removed.

2. Heat of Solution is the heat that is given off or absorbed when one mole of a given substance is completely dissolved in a large volume of water. (strictly to infinite dilution)

Some heats of solution are listed below.

Compound	Heat of Solution kJ/mol
calcium chloride, anhydrous	- 81.3
sodium hydroxide	-44.0
sodium chloride	+3.9
ammonium chloride	+ 14.8
ammonium nitrate	+25.7

The dissolving of calcium chloride and ammonium nitrate are used in some brands of commercial hot and cold packs.



3. The molar heat of solution for ammonium nitrate can be calculated

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using the data from this experiment. The heat lost ( $q_{\text{measured}}$ ) when 5.0 g ammonium nitrate dissolves in 50 mL water is found, using the temperature decrease from Part B, the specific heat of the solution (close to that of water),  $4.18 \text{ J/g}^\circ\text{C}$ , and the mass of the solution in grams (assuming density of the solution =  $1.0 \text{ g/mL}$ ).

$$\begin{aligned}q_{\text{meas.}} = \text{heat lost} &= \Delta t \text{ }^\circ\text{C} \times 4.18 \text{ J/g}^\circ\text{C} \times \text{mass (g)} \\ &= 7.0 \text{ }^\circ\text{C} \times 4.184 \text{ J/g}^\circ\text{C} \times 55 \text{ g} \\ &= +1.6 \text{ kJ (for 5.0 g ammonium nitrate)}\end{aligned}$$

The calorimeter constant,  $C$ , for the polystyrene cup setup is  $15 \text{ J}^\circ\text{C}$ .

$$\begin{aligned}q_{\text{calorimeter}} &= C_{\text{calorimeter}} \text{ J}^\circ\text{C} \times \Delta t \text{ }^\circ\text{C} \\ &= 15 \text{ J}^\circ\text{C} \times 7.0 \text{ }^\circ\text{C} \\ &= 105 \text{ J} = 0.1 \text{ kJ}\end{aligned}$$

$$\begin{aligned}q_{\text{solution}} &= q_{\text{meas.}} + q_{\text{calorimeter}} \\ &= 1.6 \text{ kJ} + 0.1 \text{ kJ} \\ &= 1.7 \text{ kJ (for 5 g NH}_4\text{NO}_3\text{ )}\end{aligned}$$

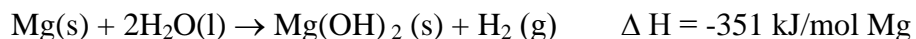
For dissolving 1 mol  $\text{NH}_4\text{NO}_3$  (molar mass 80 so,  $5.0 \text{ g NH}_4\text{NO}_3 = 0.0625 \text{ mol}$ )

$$\begin{aligned}\Delta H_{\text{solution}} &= 1.7 \text{ kJ}/0.0625 \text{ mol} \\ &= 27 \text{ kJ/mol}\end{aligned}$$

The known heat of solution for ammonium nitrate is  $+25.7 \text{ kJ/mol}$

### 4. Other Exothermic Processes used in Hot Packs

The reaction of magnesium with water is the basis of a product known as a Flameless Ration Heater or FRH.



The addition of iron and chloride ion increase the rate of this reaction significantly.

The crystallization of sodium acetate is exothermic. Supersaturated solutions of sodium acetate are also used as hot packs.

### Variation

Other salts can be substituted including the household products, sodium hydroxide and ammonium chloride

### Typical Results

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### Part A. Heat Changes on Dissolving Salts in Water (Beaker)

Amounts: 5.0 g salt in 50 mL water

Name of Salt	formula of salt	Initial temp °C	max/min temp °C	change in temp., $\Delta t$ °C
<i>Calcium chloride, anhydrous</i>	CaCl <sub>2</sub>	21.0	31.0	+ 10.0
<i>Sodium chloride</i>	NaCl	21.0	20.5	-0.5
<i>Ammonium nitrate</i>	NH <sub>4</sub> NO <sub>3</sub>	24.0	18.0	-6.0

### Part B. Heat Change on Dissolving Ammonium Nitrate in Water (Polystyrene Cup)

Amount: 5.0 g ammonium nitrate in 50 mL water

room temp °C	minimum temp °C	decrease in temp. °C
24.0	17.0	-7.0

### **Answers to Questions**

1. Which of the salts that were dissolved in water, could be used to make a cold pack?  
a hot pack?

Answer: ammonium nitrate: cold pack      calcium chloride: hot pack

2. When dissolving ammonium nitrate in water, what is the temperature decrease when using the beaker compared to the polystyrene cup?

Answer: The temperature decrease (-7.0 °C) in the insulated polystyrene cup > the decrease (-6.0 °C) in the beaker