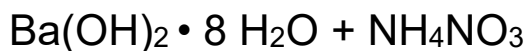


An Endothermic Reaction



Chemicals and Equipment Needed

- Squirt bottle of d-H₂O
- Ba(OH)₂ • 8 H₂O – **E2**
 - Ba(OH)₂ is the same thing
 - grind up in mortar if needed
- NH₄NO₃ – **E2**
 - grind up in mortar if needed
- 500 mL wide mouth Erlenmeyer flask – **P2**
 - For alternate thermometer demo, use a 300 mL tall beaker
- Stopper to fit Erlenmeyer – **U3**
- Cardboard square – **L2**

Hazards

- This demonstration produces NH₃ (g), so it must be done in a room with an in-bench hood.

Preparation

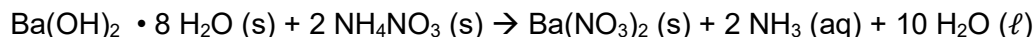
- Measure out 32 g Ba(OH)₂ • 8 H₂O into the flask, label and stopper it. Weigh 17 g NH₄NO₃ into a weigh boat, wrap with aluminum foil and label.
- Set the demo near the in-bench hood. Let the instructor know that the demo produces ammonia gas
- Warn the instructor not to wet the cardboard square too early. If the water soaks into the cardboard it doesn't freeze very well

Presentation

- Add the NH₄NO₃ to the flask, and shake vigorously to mix the solids. The flask will get cold and you will start to smell NH₃ (g) as the reaction occurs and the solids dissolve in the water of hydration
- Squirt enough water on the cardboard to get it visibly wet, then set the flask on top
- After a minute or two, the flask should freeze to the cardboard
 - An alternate presentation would be to measure the temperature of the reactants and products with a digital thermometer to determine ΔT . You may need to triple the reactant amounts.

Discussion

- Thermodynamic data are provided below to show why this endothermic reaction is spontaneous – the large increase in entropy offsets the positive ΔH



ΔH°_f (kJ/mol)	-3342	-365.6	-992.07	-80.29	-285.83
S°_{298} (J/mol K)	427	151.1	214	111	69.91
ΔG°_f (kJ/mol)	-2793	-184.0	-796.72	-26.6	-237.2

For the overall reaction:

$$\Delta H^\circ_{298} = +62.3 \text{ kJ}$$

$$\Delta S^\circ_{298} = 406 \text{ J/K}$$

$$\Delta G^\circ_{298} = -60.9 \text{ kJ}$$

- Why is the nitrate product insoluble?
 - The solubility of $\text{Ba}(\text{NO}_3)_2$ is:
 - 8.7 g/ 100 mL at 20°C
 - 34.2 g/ 100 mL at 100°C
 - Calculate the volume of water liberated in the reaction:

$$32 \text{ g Ba}(\text{OH})_2 \cdot 8 \text{ H}_2\text{O} \cdot \frac{1 \text{ mole}}{315.5 \text{ g}} \cdot \frac{10 \text{ moles H}_2\text{O}}{1 \text{ mole Ba}(\text{OH})_2 \cdot 8 \text{ H}_2\text{O}} \cdot \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mole H}_2\text{O}} \cong 18 \text{ mL H}_2\text{O}$$

- Thus the reaction yields about 26.5 g $\text{Ba}(\text{NO}_3)_2$ in 10 mL H_2O , which exceeds the solubility of the barium nitrate
 - Nitrate compounds are always technically soluble, but Barium salts are often only slightly soluble

Clean-Up

- Barium salts are toxic and **CANNOT** go down the sink. Discard products in WWC, along with any rinses from the flask or beaker. Clean up right after class

Reference: This is demonstration 1.3 in Volume 1 of Shakhshiri's *Chemical Demonstrations*.