# An Endothermic Reaction

## $Ba(OH)_2 \cdot 8\ H_2O + NH_4NO_3$

**Chemicals and Equipment Needed**

- Squirt bottle of d-$H_2O$
- $Ba(OH)_2 \cdot 8\ H_2O$ – **E2**
  - $Ba(OH)_2$ is the same thing
  - grind up in mortar if needed
- $NH_4NO_3$ – **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 $NH_3$ (g), so it must be done in a room with an in-bench hood.

**Preparation**

- Measure out 32 g $Ba(OH)_2 \cdot 8\ H_2O$ into the flask, label and stopper it. Weigh 17 g $NH_4NO_3$ 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 $NH_4NO_3$ to the flask, and shake vigorously to mix the solids. The flask will get cold and you will start to smell $NH_3$ (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 $\Delta T$. 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 $\Delta H$

$$Ba(OH)_2 \cdot 8\ H_2O\ (s) + 2\ NH_4NO_3\ (s) \rightarrow Ba(NO_3)_2\ (s) + 2\ NH_3\ (aq) + 10\ H_2O\ (\ell)$$

| | | | | | |
|---|---|---|---|---|---|
| $\Delta H^\circ_f$ (kJ/mol) | -3342 | -365.6 | -992.07 | -80.29 | -285.83 |
| $S^\circ_{298}$ (J/mol K) | 427 | 151.1 | 214 | 111 | 69.91 |
| $\Delta G^\circ_f$ (kJ/mol) | -2793 | -184.0 | -796.72 | -26.6 | -237.2 |

For the overall reaction:

$\Delta H^\circ_{298} = +62.3$ kJ $\quad \Delta S^\circ_{298} = 406$ J/K $\quad \Delta G^\circ_{298} = -60.9$ kJ



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- Why is the nitrate product insoluble?
  - The solubility of $Ba(NO_3)_2$ 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:

$$32\text{ g } Ba(OH)_2 \cdot 8\,H_2O \cdot \frac{1\text{ mole}}{315.5\text{ g}} \cdot \frac{10\text{ moles } H_2O}{1\text{ mole } Ba(OH)_2 \cdot 8\,H_2O} \cdot \frac{18.02\text{ g } H_2O}{1\text{ mole } H_2O} \cong 18\text{ mL } H_2O$$

- Thus the reaction yields about 26.5 g $Ba(NO_3)_2$ 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 Shakhashiri's *Chemical Demonstrations.*