Endothermic Reaction

Recommended for Chapter(s): 10

Demo #024

Materials NOT in box

1. Safety goggles

Procedure

1. (Prep) Place a small amount of water on the board.
2. Opt 1: Combine the $Ba(OH)_2 \cdot 8H_2O$ (12-14 g) and NH_4SCN (6-7 g) that are in the small clear bottles in the beaker and place the beaker on the wet board.
   Opt 2: Combine the $Ba(OH)_2 \cdot 8H_2O$ (12-14 g) and NH_4Cl (4-5 g) that are in the small clear bottles in the beaker and place the beaker on the wet board.
1. Stir the contents of the beaker with the glass stirring rod until the mixture starts turning into a liquid.
2. As the reaction occurs $NH_3(aq)$ is produced. As soon as you are done stirring the mixture place parafilm over the beaker to contain the odor.

Safety

1. Wear safety goggles.

Clean Up

1. Return the materials to the cart in the demonstration library room.

Stockroom Notes

1. Rinse the contents of the beaker down the drain with plenty of water.
2. Replace the glassware with clean glassware.
3. Refill the $Ba(OH)_2 \cdot 8H_2O$, NH_4SCN, and NH_4Cl glass jars up to the indicated line with $Ba(OH)_2 \cdot 8H_2O$, NH_4SCN or NH_4Cl.
4. If needed refill any materials that have been used up.
5. Return items to demonstration tub.
6. Return tub to the demonstration library.
    a. Return the goggles to the goggle box.
    b. The wooden plank sits on top of the demonstration box.

Discussion

The advantage of performing option 1 is that the reaction occurs faster (~1 min) than option 2 (~2 min). The advantage of performing option 2 is that all of the thermodynamic data is available for the reaction.

The demonstration can be used to reinforce what the signs of ΔH, ΔG, and ΔS represent. After the reaction is performed, students can be asked to determine the signs of the thermodynamic properties. ΔG must be less than 0 because the reaction is spontaneous. ΔH must be greater than 0 because the reaction is endothermic, therefore, the system absorbs heat from the surroundings which is visibly observed by the beaker freezing to the wood. ΔS must be greater than 0 because three moles of reactants turns into 13 moles of products for option 1 and 11 moles of product for option 2 (see below). This reaction is an example of an entropy driven reaction; even though the reaction is endothermic it proceeds because the change in entropy is so great.

The reaction that happens in option 1 is seen below.

$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4SCN(s) \rightarrow Ba(SCN)_2(aq) + 2NH_3(aq) + 10H_2O(l)$

The reaction that happens in option 1 is seen below.

$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4Cl(s) \rightarrow BaCl_2 \cdot 2H_2O(s) + 2NH_3(aq) + 8H_2O(l)$

Using the following thermodynamic data, students should be able to determine ΔH, ΔG, and ΔS before performing the reaction.

	$\Delta H°_f \left(\frac{kJ}{mol}\right)$	$S°\left(\frac{J}{molK}\right)$	$\Delta G°_f\left(\frac{kJ}{mol}\right)$
$Ba(OH)_2 \cdot 8H_2O(s)$	-3342	427	-2793
$NH_4Cl(s)$	-314	95	-203
$BaCl_2 \cdot 2H_2O(s)$	-1460.	203	-1297
$NH_3(aq)$	-80.	111	-27
$H_2O(l)$	-286	70.	-237

$$\Delta H^\circ_{rxn} = \sum \Delta H^\circ_f(prod) - \sum \Delta H^\circ_f(reac)$$

$$\Delta H^\circ_{rxn} = \Delta H^\circ_f(BaCl_2 \cdot 2H_2O) + 2\Delta H^\circ_f(NH_3) + 8\Delta H^\circ_f(H_2O) - \Delta H^\circ_f(Ba(OH)_2 \cdot 8H_2O) - 2\Delta H^\circ_f(NH_4Cl)$$

$$\Delta H^\circ_{rxn} = -1460.\frac{kJ}{mol} + 2(-80.\frac{kJ}{mol}) + 8(-286\frac{kJ}{mol}) - -3342\frac{kJ}{mol} - 2(-314\frac{kJ}{mol}) = 62\frac{kJ}{mol}$$

The ΔH value indicates that the reaction is an endothermic reaction.

$$\Delta G^\circ_{rxn} = \sum \Delta G^\circ_f(prod) - \sum \Delta G^\circ_f(reac)$$

$$\Delta G^\circ_{rxn} = \Delta G^\circ_f(BaCl_2 \cdot 2H_2O) + 2\Delta G^\circ_f(NH_3) + 8\Delta G^\circ_f(H_2O) - \Delta G^\circ_f(Ba(OH)_2 \cdot 8H_2O) - 2\Delta G^\circ_f(NH_4Cl)$$

$$\Delta G^\circ_{rxn} = -1297.\frac{kJ}{mol} + 2(-27.\frac{kJ}{mol}) + 8(-237\frac{kJ}{mol}) - -2793\frac{kJ}{mol} - 2(-237\frac{kJ}{mol}) = -48\frac{kJ}{mol}$$

The ΔG value indicates that the reaction is spontaneous.

$$\Delta S^{\circ}_{rxn} = \sum \Delta S^{\circ}_{prod} - \sum \Delta S^{\circ}_{reac}$$

$$\Delta S^{\circ}_{rxn} = \Delta S^{\circ}_{BaCl_2 \cdot 2H_2O} + 2\Delta S^{\circ}_{NH_3} + 8\Delta S^{\circ}_{H_2O} - \Delta S^{\circ}_{Ba(OH)_2 \cdot 8H_2O} - \Delta S^{\circ}_{NH_4H}$$

$$\Delta S^{\circ}_{rxn} = 203 \tfrac{J}{molK} + 2\left(111 \tfrac{J}{molK}\right) + 8\left(70. \tfrac{J}{molK}\right) - 427 \tfrac{J}{molK} - 2\left(95 \tfrac{J}{molK}\right) = 368 \tfrac{J}{molK}$$

The ΔS value indicates that the entropy increases during the reaction

Materials for demo 024

1. $Ba(OH)_2 \cdot 8H_2O$
2. NH_4SCN
3. NH_4Cl
4. Parafilm
5. 150 mL Beaker
6. Two Metal spatulas
7. Glass stirring rod
8. Pre-measured bottles for $Ba(OH)_2 \cdot 8H_2O$, NH_4SCN, NH_4Cl
9. Water bottle
10. Wooden Plank