

6.6 Introduction to Enthalpy of Reaction
Worksheet Key

- 1) A 85.2 g copper bar was heated to 221.32 °C and placed in a coffee cup calorimeter containing 425.0 mL of water at 22.55 °C. The final temperature of the water was recorded to be 26.15 °C.
 - a. How much heat was gained by the water?
 - b. How much heat was lost by the copper?
 - c. What is the specific heat of copper?
 - d. Was energy conserved in the process? Justify your answer.

- 2) A 100.0 mL sample of 0.76 M HCl at 23.0 °C was mixed with 100.0 mL of 0.76 M NaOH at 23.0 °C in a coffee cup calorimeter and the following reaction occurred.
$$\text{H}^+ (\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow \text{H}_2\text{O} (\text{l})$$
The temperature of the solution increased and a maximum temperature of 28.2 °C was recorder. Assume that no heat was lost to the surroundings, the volumes were additive, the specific heat capacity of the solution was 4.184 J/gK, and the density of the solution was 1.00 g/mL.
 - a. Calculate the enthalpy change, ΔH_{rxn} , for the formation of 1.0 mol H₂O in this reaction.
 - b. Is the reaction endothermic or exothermic?
 - c. Was energy conserved in the process? Justify your answer.

- 3) A coffee cup calorimeter contains 100.0 mL of 1.50 M Ba(NO₃)₂ at 25.0 °C. A student pours 100.0 mL of 1.50 M Na₂SO₄ at 25.0 °C into the calorimeter. A precipitate forms and the temperature rises to 29.7 °C. Assume that no heat was lost to the surroundings, the volumes were additive, the specific heat capacity of the solution was 4.184 J/gK, and the density of the solution was 1.00 g/mL.
 - a. This reaction could be represented as a complete ionic or a net ionic equation. Write the balanced chemical equation that should be used in association with the ΔH_{rxn} value for this reaction. Justify your choice.
 - b. Find the amount of heat that was lost or gained by the solution in the calorimeter.
 - c. Find the heat of reaction, ΔH_{rxn} .
 - d. Is the reaction endothermic or exothermic?

- 4) The specific heat capacity of copper is 0.385 J/(gK). If 353 J of heat are added to 3.6 moles of copper at 283 K, what is the final temperature of the sample of copper?

- 5) The specific heat capacity of iron 0.45 J/gK.
 - a. Find the molar heat capacity for iron.
 - b. If 1239 J of heat are added to 5.6 mole sample of Fe at 12.2 °C, what is the final temperature of the sample?

- 6) An experiment was conducted in order to determine the enthalpy change that occurs when 1.0 mole of ice at 0°C melts and becomes 1.0 mole of water at 0°C. The enthalpy change associated with this process is referred to as the heat of fusion, ΔH_{fus} , of ice. In the experiment, a 9.68 g sample of ice at 0°C was added to a coffee cup calorimeter containing 278.25 mL of distilled water. The temperature of the water was 22.485°C before the ice was added. The lowest temperature that was recorded after the ice had melted was 19.050°C.
- Find the amount of heat lost or gained by the water in the calorimeter.
 - In this experiment, the ice melted and then the temperature of the water produced by the ice increased from 0°C to 19.050°C. Calculate the amount of heat absorbed by the melted ice ($q_{\text{melted ice}}$) as its temperature increased from 0.000°C to 19.050°C.
 - Calculate the amount of heat that was gained by the ice during the melting process (q_{melting}). (Hint: $q_{\text{temp gain}} + q_{\text{melting}} = -q_{\text{w}}$)
 - Calculate the heat of fusion of ice, ΔH_{fus} .
 - Is the reaction endothermic or exothermic?
 - Energy was transferred from one system to another during this experiment. Identify the two interacting systems and outline the direction of energy flow.
 - Was energy conserved in the process? Justify your answer.
- 6) How much heat is released when 24.8 g of $\text{CH}_4(g)$ is burned in excess oxygen gas to produce carbon dioxide and water?
- $$\text{CH}_4(g) + 2 \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O}(g) \quad \Delta H_{\text{rxn}} = -802.3 \text{ kJ/mol}$$
- 7) How much heat is released or absorbed when 45.8 g of hydrogen gas reacts with excess nitrogen gas according to the chemical equation below?
- $$\text{N}_2(g) + 3 \text{H}_2(g) \rightarrow 2 \text{NH}_3(g) \quad \Delta H_{\text{rxn}} = -92.2 \text{ kJ/mol}$$
- 8) Suppose 391 kJ of heat is released when carbon monoxide gas reacts with nitrogen monoxide gas according to the thermochemical equation below.
- $$2 \text{CO}(g) + 2 \text{NO}(g) \rightarrow 2 \text{CO}_2(g) + \text{N}_2(g) \quad \Delta H_{\text{rxn}} = -746.6 \text{ kJ}$$
- How many grams of carbon monoxide were consumed during this reaction?
- 9) Use the thermochemical equation for the combustion of methane written below to answer the following question.
- $$\text{CH}_4(g) + 2 \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O}(g) \quad \Delta H_{\text{rxn}} = -802.3 \text{ kJ}$$
- How much heat is released when 24.8 g of $\text{CH}_4(g)$ is burned in excess oxygen gas to produce carbon dioxide and water?
- 10) Ammonia is produced from a reaction between hydrogen gas and nitrogen gas.
- $$\text{N}_2(g) + 3 \text{H}_2(g) \rightarrow 2 \text{NH}_3(g) \quad \Delta H_{\text{rxn}} = -92.2 \text{ kJ}$$
- Does the forward reaction release or absorb heat?
 - How much heat is released or absorbed when 45.8 g of hydrogen gas reacts with excess nitrogen gas according to the chemical equation above?
- 11) $\Delta H_{\text{rxn}} = +80.3 \text{ kJ}$ for the following reaction.
- $$\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}(s) + 2 \text{NH}_4\text{Cl}(s) \rightarrow \text{BaCl}_2(aq) + 2 \text{NH}_3(aq) + 10 \text{H}_2\text{O}(l)$$
- Is the forward reaction endothermic or exothermic?
 - How much heat is released or absorbed when 16.8 g of $\text{NH}_4\text{Cl}(s)$ reacts with excess $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}(s)$?
 - If this reaction could be reversed in order to produce 16.8 g of $\text{NH}_4\text{Cl}(s)$, how much heat would be released or absorbed during that process.