

Hess's Law and Enthalpies of Formation

Combining equations and calculating ΔH from formation data

Name _____ Class _____ Date _____

STANDARD ENTHALPIES OF FORMATION, ΔH_f° (KJ/MOL, 25 °C)

$\text{CO}_2(\text{g}) -393.5 \cdot \text{CO}(\text{g}) -110.5 \cdot \text{H}_2\text{O}(\text{l}) -285.8 \cdot \text{H}_2\text{O}(\text{g}) -241.8 \cdot \text{CH}_4(\text{g}) -74.6$

$\text{C}_2\text{H}_4(\text{g}) +52.4 \cdot \text{C}_2\text{H}_6(\text{g}) -84.0 \cdot \text{C}_3\text{H}_8(\text{g}) -103.8 \cdot \text{C}_2\text{H}_5\text{OH}(\text{l}) -277.6 \cdot \text{C}_6\text{H}_{12}\text{O}_6(\text{s}) -1273.3$

$\text{NH}_3(\text{g}) -45.9 \cdot \text{NO}(\text{g}) +91.3 \cdot \text{CaCO}_3(\text{s}) -1207.6 \cdot \text{CaO}(\text{s}) -634.9 \cdot \text{Fe}_2\text{O}_3(\text{s}) -824.2 \cdot \text{Al}_2\text{O}_3(\text{s}) -1675.7$

Elements in their standard states: 0 • $M(\text{C}_6\text{H}_{12}\text{O}_6) = 180.16 \text{ g/mol}$

$\Delta H^\circ = \sum n\Delta H_f^\circ(\text{products}) - \sum n\Delta H_f^\circ(\text{reactants})$. Show units in every step.

A. Understanding

1. State Hess's law and explain why it is true.

2. Which of these have $\Delta H_f^\circ = 0$? $\text{O}_2(\text{g})$, $\text{O}_3(\text{g})$, $\text{N}_2(\text{g})$, $\text{H}_2\text{O}(\text{l})$, $\text{Fe}(\text{s})$, $\text{C}(\text{graphite})$, $\text{CO}_2(\text{g})$

B. Combining equations

3. Given: $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{NO}(\text{g})$, $\Delta H = +182.6 \text{ kJ}$, and $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{NO}_2(\text{g})$, $\Delta H = -116.2 \text{ kJ}$. (a) Find ΔH for $\text{N}_2(\text{g}) + 2\text{O}_2(\text{g}) \longrightarrow 2\text{NO}_2(\text{g})$. (b) Hence find ΔH_f° of $\text{NO}_2(\text{g})$.

C. Using enthalpies of formation

4. Calculate ΔH° for: (a) $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \longrightarrow \text{C}_2\text{H}_6(\text{g})$ (b) $\text{CaCO}_3(\text{s}) \longrightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$ (c) $\text{Fe}_2\text{O}_3(\text{s}) + 2\text{Al}(\text{s}) \longrightarrow \text{Al}_2\text{O}_3(\text{s}) + 2\text{Fe}(\text{s})$ (the thermite reaction)

5. Calculate ΔH° for the combustion of propane: $\text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \longrightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{l})$

6. Calculate ΔH° for $4\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \longrightarrow 4\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{g})$, the first step in making nitric acid.

7. Use the table to find ΔH° for $\text{H}_2\text{O}(\text{l}) \longrightarrow \text{H}_2\text{O}(\text{g})$. What does this value represent?

D. Challenge

8. The combustion of ethanol, $\text{C}_2\text{H}_5\text{OH}(\text{l}) + 3\text{O}_2(\text{g}) \longrightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l})$, has $\Delta H^\circ = -1366.8\text{ kJ}$. Use this and the table (ignoring the ethanol value) to calculate ΔH_f° of ethanol.

9. Calculate ΔH° for the combustion of glucose, $\text{C}_6\text{H}_{12}\text{O}_6(\text{s}) + 6 \text{O}_2(\text{g}) \longrightarrow 6 \text{CO}_2(\text{g}) + 6 \text{H}_2\text{O}(\text{l})$, and the energy released when 10.0 g of glucose is oxidized in the body.