

Guide to Chapter 8. Thermochemistry: Chemical Energy

(Asswers in brown)

We will spend three lecture days on this chapter and will only do selected parts of it. Note that we will breeze through Sections 1 – 6 and then focus on Sections 7 - 12. Here is the plan:

- Day 1. Briefly cover Section 1 – 6 and then 7 and 12 (units on thermal energy, quantitative energy calculations).
- Day 2 we do calculations involving calorimetry and heats of formation (Sections 8 and 10).
- Day 3 we will cover Hess’s law and bond energies (Sections 9 and 11).

Read the introductory paragraph to Chapter 8 and Sections 8.1 – 8.6. We will use the one-page summary for these sections (given at the end of this guide)

Learning Objective 1: Memorize the definition of the standard state (25 °C and 1 atm). If solutions are involved, standard state is 1 molar.

No problems from this material.

Read Section 8.7 Enthalpies of Physical and Chemical Change.

Learning Objective 2: Know the types of energy associated with a chemical reaction (thermal, light, and electrical)

Learning Objective 3: Understand enthalpy as a type of energy. Distinguish between an exothermic and an endothermic reaction. Know units on enthalpy.

Learning Objective 4: Be able to solve problems involving enthalpy and stoichiometry of a reaction. Calculate $\Delta H$ per gram or per mole. Calculate the energy transferred for a given amount of a chemical substance in a reaction.

Learning Objective 5: Be able to predict the sign (+ or -) for enthalpy changes relating to phase changes

Learning Objective 6: Be able to predict if a process requires energy (endothermic) or releases energy (exothermic)

Do Problems 8 and 9 at the end of the section.

Do the following end-of-chapter problems: 48, 50, 52, 58

Problem Club Question A. A chemical process requires 125 kcal. Convert this to kJ.
Answer: 523 kJ

Problem Club Question B. Describe each of these processes as exothermic or endothermic: (a) boiling water in a kitchen; (b) burning a sheet of paper; (c) a piece of potassium reacting with water; (d) melting metal for welding
Answer: (a) endothermic  (b) exothermic  (c) exothermic  (d) endothermic

Problem Club Question C. The combustion of 1.0-mol benzene, $C_6H_6$, in oxygen liberates $3.268 \times 10^3$ kJ of heat. (a) What is the balanced equation? (b) How much heat is released when 10 g of benzene are combusted? (c) What is $\Delta H$ in units of kJ/mol $CO_2$?
Answer: 2 $C_6H_6 + 15 O_2(g) \rightarrow 12 CO_2(g) + 6 H_2O(g)$ (b) 421 kJ  (c) 545 kJ/mol $CO_2$

Problem Club Question D. Consider the dissociation of copper oxide. (a) Calculate $\Delta H$ when one gram of copper is formed. (b) Calculate $\Delta H$ when 58-g of CuO is consumed.
Answer: (a) 2.48 kJ  (b) 115 kJ

Problem Club Question E (ACS Style) Answer: A

Dr. Mattson, General Chemistry, Chm 203, Guide to Chapter 8. Thermochemistry: Chemical Energy
Read Section 8.12 Fossil fuels, fuel efficiency, and heats of combustion.

Learning Objective 7: Be able to write chemical reactions associated with the term combustion.

Read Section 8.8 Calorimetry and Heat Capacity.

Learning Objective 8: Understand the concept of specific heat and heat capacity.

Learning Objective 9: Be able to solve problems involving calorimetry and specific heat/heat capacity (bomb or coffee cup calorimeter).

Do Problems 10 – 12 at the end of the section.

Do the following end-of-chapter problems: 54, 56, 60.

Problem Club Question F. The specific heat of solid platinum is 0.133 J/g deg. Calculate the temperature change if a 37.0-g sample of platinum absorbs 125 J.
Answer: 25.4 degrees

Problem Club Question G. A sample of iron with a mass of 67.8 g absorbs 175 J of energy as the temperature of the iron increases from 24.00 °C to 29.75 °C. What is the specific heat of iron?
Answer: 0.449 J/g deg

Problem Club Question H. When 1.34 g of potassium bromide dissolves in 74.0-g water in a coffee-cup calorimeter, the temperature drops from 18.000 °C to 17.279 °C. Assuming that all of the heat absorbed in the solution process comes from the water (SH = 4.184 J/g deg). What is the heat of solution for potassium bromide (in units of kJ/mol)?
Answer: +20.2 kJ/mol

Problem Club Question I. When 5.00 mL of ethyl alcohol, C₂H₅OH (d = 0.789 g/mL) is burned in a bomb calorimeter, the temperature in the bomb rises from 19.75 °C to 28.67 °C. The calorimeter heat capacity (including water) is 13.24 kJ/deg. Calculate ΔH for the combustion of one mole of ethyl alcohol.
Answer: -1380 kJ

Problem Club Question K. (ACS-Style) Answer: B

Problem Club Question L. (ACS-Style) Answer: A

Read Section 8.9 Hess’s law.

Learning Objective 10: Be able to perform Hess's Law problems.

Do Problems 13 – 15 at the end of the section.

Do the following end-of-chapter problems: 28, 66

Problem Club Question M. Given the following equations, calculate ΔH for the last one (in bold)
\[ A + 2B \rightarrow 2C \quad \Delta H = -90 \text{ kJ} \]
\[ D + E \rightarrow C \quad \Delta H = -230 \text{ kJ} \]
\[ D \rightarrow B \quad \Delta H = -105 \text{ kJ} \]
Problem Club Question N. Given these two reactions:

\[ X(s) + O_2(g) \rightarrow XO_2(g) \quad \Delta H^\circ = -297 \text{ kJ} \]
\[ 2X(s) + 3O_2(g) \rightarrow 2XO_3(g) \quad \Delta H^\circ = -792 \text{ kJ} \]

Calculate \( \Delta H^\circ \) for the reaction

\[ XO_2(s) + \frac{1}{2}O_2(g) \rightarrow XO_3(g) \quad \Delta H^\circ = ? \]

Answer: -99 kJ

Problem Club Question O. Given:

\[ C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -393.5 \text{ kJ} \]
\[ H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l) \quad \Delta H = -286 \text{ kJ} \]
\[ CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \quad \Delta H = -890.3 \text{ kJ} \]

Calculate \( \Delta H \) for the reaction:

\[ C(s) + 2H_2(g) \rightarrow CH_4(g) \]

Answer: -75.2 kJ

Problem Club Question P. (ACS-Style) Answer: -1561 kJ

Read Section 8.10 Standard Heats of Formation.

Learning Objective 11: Define and write balanced chemical equations for \( \Delta H_f^\circ \) for a compound. Know that these calculations are variants of Hess’s Law. Use the table of \( \Delta H_f^\circ \) to calculate \( \Delta H_{\text{reaction}} \).

Do Problems 16 and 17 at the end of the section.

Do the following end-of-chapter problems: 97, 101a

Problem Club Question Q. Write the equation for the heat of formation of ammonium nitrate.

Answer: \( 2H_2(g) + N_2(g) + \frac{3}{2}O_2(g) \rightarrow \text{NH}_4\text{NO}_3(s) \)

Problem Club Question R. Use the \( \Delta H_f^\circ \) table to calculate \( \Delta H_{\text{rxn}} \) for the reaction \( \text{CaCO}_3(s) \rightarrow \text{CaO}(s) + \text{CO}_2(g) \). (b) Is the reaction exothermic or endothermic?

Answer: (a) +178 kJ (b) endothermic

Problem Club Question S. Magnesium sulfate can be prepared by reacting magnesium oxide with sulfur trioxide. Calculate \( \Delta H \) for this reaction. (\( \Delta H_f^\circ = -1278 \text{ kJ for MgSO}_4 \))

Answer: -288 kJ

Problem Club Question T. Consider this reaction: \( 2Al_2O_3(s) \rightarrow 4Al(s) + 3O_2(g) \quad \Delta H^\circ = 3351 \text{ kJ} \).

Calculate the heat of formation of aluminum oxide.

Answer: -1676 kJ

Problem Club Question U. (challenge) When one mole of ethylene gas, \( \text{C}_2\text{H}_4 \), is burned in oxygen and hydrogen chloride, the products are liquid ethylene chloride, \( \text{C}_2\text{H}_4\text{Cl}_2 \) and liquid water, \( 319 \text{ kJ} \) of heat is evolved. Using the \( \Delta H_f^\circ \) table, calculate the heat of formation for ethylene chloride. (Hint: Write eqn first.)

Answer: -165 kJ

Problem Club Question V. (ACS-Style) Answer: A.
**Problem Club Question W. (ACS-Style)** Answer: B

**Problem Club Question X. (ACS-Style)** Answer: No correct answer given! Answer is -2510 kJ

**Read Section 8.11 Bond dissociation energies.**

Learning Objective 12: Be able to perform calculations using bond dissociation enthalpies.

Do Problems 18 and 19 at the end of the section.

Do the following end-of-chapter problems: 74

**Problem Club Question Y.** Use the bond energy table in Chapter 7 to estimate $\Delta H$ for the following gas phase reactions.

(a) $\text{CH}_4 + F_2 \rightarrow \text{CH}_3F + HF$

(b) $\text{H}_2O + Cl_2 \rightarrow \text{HOCI} + HCl$

(c) $\text{H}_2O + 2 F_2 \rightarrow OF_2 + 2 HF$

(d) $\text{NH}_3 + 3 Cl_2 \rightarrow NCl_3 + 3 HCl$

(e) $\text{C}_2\text{H}_4 + Cl_2 \rightarrow \text{CH}_2\text{ClCH}_2\text{Cl}$

Answer: a. -451 kJ; b. +71 kJ; c. -262 kJ; d. +3 kJ; e. -156 kJ

**Problem Club Question Z. (ACS-Style)** Answer: D

**Skip Sections 8.12 – 8.14**