Guide to Chapter 8. Thermochemistry: Chemical Energy

(Answers 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 ^{o}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 ΔH 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 enthapy 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 3.268×10^3 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 ΔH in units of kJ/mol CO_2?

Answer: 2 $C_6H_6 + 15\ O_2(g) \longrightarrow 12\ CO_2(g) + 6\ H_2O(g)$ (b) 421 kJ (c) 545 kJ/mol CO_2

Problem Club Question D. Consider the dissociation of copper oxide. (a) Calculate ΔH when one gram of copper is formed. (b) Calculate ΔH when 58-g of CuO is consumed.

$$2\ CuO(s) \longrightarrow 2\ Cu(s) + O_2(g) \qquad \Delta H = +315\ kJ$$

Answer: (a) 2.48 kJ (b) 115 kJ

Problem Club Question E.(ACS Style) Answer: A

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.O-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 ^{o}C to 29.75 ^{o}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 ^{o}C to 17.279 ^{o}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, C_2H_5OH (d = 0.789 g/mL) is burned in a bomb calorimeter, the temperature in the bomb rises from 19.75 ^{o}C to 28.67 ^{o}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 J. A 4.00-g sample of salicylic acid, $C_7H_6O_3$ is burned in a bomb calorimeter with a heat capacity of 2.046×10^4 J/deg. The combustion produces 87.7 kJ of heat and the temperature after the combustion is 26.10 ^{o}C. Calculate the initial temperature.
Answer: 21.81 ^{o}C

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)

$A + 2B \rightarrow 2C$ $\quad\quad \Delta H = -90$ kJ

$D + E \rightarrow C$ $\quad\quad \Delta H = -230$ kJ

$D \rightarrow B$ $\quad\quad \Delta H = -105$ kJ

A $\longrightarrow$ 2 E $\qquad\qquad$ ***ΔH = ?***

Answer: +160 kJ

Problem Club Question N. Given these two reactions:

$$X(s) + O_2(g) \longrightarrow XO_2(g) \qquad \Delta H^o = -297\ kJ$$

$$2\ X(s) + 3\ O_2(g) \longrightarrow 2\ XO_3(g) \qquad \Delta H^o = -792\ kJ$$

Calculate ΔH^o for the reaction

$$XO_2(s) + {}^1/_2\ O_2(g) \longrightarrow XO_3(g) \qquad \Delta H^o = ?$$

Answer: -99 kJ

Problem Club Question O. Given:

$$C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H = -393.5\ kJ$$

$$H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(l) \qquad \Delta H = -286\ kJ$$

$$CH_4(g) + 2\ O_2(g) \longrightarrow CO_2(g) + 2\ H_2O(l) \qquad \Delta H = -890.3\ kJ$$

Calculate ΔH for the reaction:

$$C(s) + 2\ H_2(g) \longrightarrow CH_4(g)$$

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 ΔH_f° for a compound. Know that these calculations are variants of Hess's Law. Use the table of ΔH_f to calculate $\Delta H_{reaction}$.

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: $2\ H_2(g) + N_2(g) + {}^3/_2\ O_2(g) \longrightarrow NH_4NO_3(s)$

Problem Club Question R. Use the ΔH_f table to calculate ΔH_{rxn} for the reaction $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$. (b) Is the reaction exothermic or endothermic?

Answer: (a) +178 kJ $\qquad$ (b) endothermic

Problem Club Question S. Magnesium sulfate can be prepared by reacting magnesium oxide with sulfur trioxide. Calculate ΔH for this reaction. (ΔH_f = -1278 kJ for $MgSO_4$)

Answer: -288 kJ

Problem Club Question T. Consider this reaction: $2\ Al_2O_3(s) \longrightarrow 4\ Al(s) + 3\ O_2(g) \qquad \Delta H^o = 3351\ kJ$. Calculate the heat of formation of aluminum oxide.

Answer: -1676 kJ

Problem Club Question U. (challenge) When one mole of ethylene gas, C_2H_4, is burned in oxygen and hydrogen chloride, the products are liquid ethylene chloride, $C_2H_4Cl_2$ and liquid water, 319 kJ of heat is evolved. Using the ΔH_f 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 ΔH for the following gas phase reactions.

(a) $CH_4 + F_2 \rightarrow CH_3F + HF$

(b) $H_2O + Cl_2 \rightarrow HOCl + HCl$

(c) $H_2O + 2\ F_2 \rightarrow OF_2 + 2\ HF$

(d) $NH_3 + 3\ Cl_2 \rightarrow NCl_3 + 3\ HCl$

(e) $C_2H_4 + Cl_2 \rightarrow CH_2ClCH_2Cl$

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