A Substantive Exercise

5.1 Which of the following are true for an exothermic reaction?

a. The enthalpy of the system decreases
b. ΔH has a negative sign
c. The enthalpy of the products is higher than that of the reactants
d. Heat is absorbed from the surroundings.

5.2 When 6.00 g of calcium chloride dissolves in 100.0 g of water, the temperature rises from 18.0 to 28.7° C. The reaction is: $CaCl_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2\ Cl^{-1}_{(aq)}$

a. Is the reaction exothermic or endothermic? b. What is the sign of ΔH?

5.3 Consider the reaction $Fe_{(s)} + Br_{2(l)} \rightarrow FeBr_{2(s)}$; $\Delta H = -249.8$ kJ

a. Is the reaction exothermic or endothermic?
b. Draw a diagram qualitatively showing the enthalpy change in this reaction.
c. Calculate ΔH when 10.0 g FeBr2 is formed
d. How many grams of iron must react to evolve 1.00 kJ of heat?

5.4 Consider the reaction $Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$; $\Delta H = -65.5$ kJ

a. Calculate ΔH when one mole of AgCl dissolves in water
b. What is ΔH when 1.00 g AgCl dissolves?

5.8 Given the reactons on the right $Na_{(s)} + 1/2\ Cl_{2(g)} \rightarrow Na_{(g)} + Cl_{(g)}$; $\Delta H = +230$ kJ

Calculate ΔH for the reaction $Na_{(g)} + Cl_{(g)} \rightarrow Na^{+}_{(g)} + Cl^{-}_{(g)}$; $\Delta H = +147$ kJ

$Na^{+}_{(g)} + Cl^{-}_{(g)} \rightarrow NaCl(s)$ $Na_{(s)} + 1/2Cl_{2(g)} \rightarrow NaCl_{(s)}$; $\Delta H = -411$ kJ

5.31 Which of the following are true for an endothermic reaction?

a. ΔH is positive b. Heat is transferred to the surroundings
c. The enthalpy of the system increase d. The temperature of the surroundings decreases

5.32 The temperature of 50.0 g of water drops from 18.0 to 9.5° C when 10.0 g KBr are dissolved in it.

a. Write a chemical reaction equation for this reaction
b. What is the sign of ΔH?

5.33 Nickel tetracarbonyl, $Ni(CO)_4$, decomposes upon heating:
$Ni(CO)_{4(g)} \rightarrow Ni_{(s)} + 4\ CO_{(g)}$; $\Delta H = +160.7$ kJ

a. Is the reaction exothermic or endothermic?
b. Draw a diagram qualitatively showing the enthalpy change in this reaction.
c. Calculate ΔH when 1.00 g $Ni(CO)_4$ decomposes
d. How many grams of $Ni(CO)_4$ decompose when 1.00 kJ of heat is absorbed?

14.4 Consider the reaction $Mg_3N_{2(s)} + 6\ H_2O_{(l)} \rightarrow 3\ Mg(OH)_{2(s)} + 2\ NH_{3(g)}$ $\Delta H = -691$ kJ
Calculate ΔH when 75.0 g Mg_3N_2 reacts with water.

14.5 Predict the sign of ΔS for

a. a candle burning b. ammonia vapor condensing
c. butter melting d. tea dissolving in water

14.6 Predict the sign ΔS° for each of the following reactions:

a. $CuSO_4 \bullet 5H_2O_{(s)} \rightarrow CuSO_{4(s)} + 5\ H_2O_{(g)}$

b. $2\ Cl_{(g)} \rightarrow Cl_{2(g)}$

c. $2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)}$

14.16 Oxygen can be made in the laboratory by reacting sodium peroxide with water:

$2\ Na_2O_{2(s)} + 2H_2O_{(l)} \rightarrow 4\ NaOH_{(s)} + O_{2(g)}$

$\Delta H = -126.0$ kJ; $\Delta G^\circ = -173.8$ kJ at 25° C

Calculate ΔS° for this reaction. Is the sign unreasonable? Why or why not?

14.18 Discuss the effect of temperature change upon the spontaneity of the following reactions at 1 atm:

a. $2\ PbO_{(s)} + 2\ SO_{2(g)} \rightarrow 2\ PbS_{(s)} + 3\ O_{2(g)}$

$\Delta H = +839.4$ kJ; $\Delta S^\circ = +0.203$ kJ/K

b. $N_2H_{4(l)} \rightarrow N_{2(g)} + 2\ H_{2(g)}$

$\Delta H = -50.4$ kJ; $\Delta S^\circ = +0.330$ kJ/K

c. $2\ As_{(s)} + 3\ F_{2(g)} \rightarrow 2\ AsF_{3(l)}$

$\Delta H = -1897.9$ kJ; $\Delta S^\circ = -0.318$ kJ/K

14.19 At what temperature does ΔG° become zero for each of the reactions in Problem 14.18? Explain the significance of your answers.

14.34 Consider the reaction $2\ PbO_{(s)} + 2\ SO_{2(g)} \rightarrow 2\ PbS_{(s)} + 3\ O_{2(g)}$ $\Delta H = +839.4$ kJ

a. Calculate ΔH when 10.0 g PbS is formed

b. Given that the heats of formation of lead(II) sulfide and sulfur dioxide are -100 kJ/mole and -297 kJ per mole respectively, calculate the heat of formation of PbS.

14.35 Predict the sign of ΔS for

a. the freezing of water

b. evaporation of a seawater sample to dryness

c. weeding a garden

d. separating air into its components

14.36 Predict the sign of ΔS° for each of the following reactions:

a. $N_{2(g)} + 3H_{2(g)} \rightarrow 2\ NH_{3(g)}$

b. $H_{2(g)} + Cu^{2+}_{(aq)} \rightarrow 2\ H+_{(aq)} + Cu_{(s)}$

c. $CaCl_{2(s)} + 6\ H_2O_{(g)} \rightarrow CaCl_2 \bullet 6H_2O_{(s)}$

14.46 Sodium carbonate, also called "washing soda," can be made by heating sodium hydrogen carbonate:

$2\ NaHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + CO_{2(g)} + H_2O_{(g)}$

$\Delta H = +128.9$ kJ; $\Delta G^\circ = +33.1$ kJ at 25° C

a. Calculate ΔS° for this reaction. Is the sign reasonable?

b. Calculate ΔG° at 0 K; at 1000 K

14.48 Discuss the effect of temperature upon the spontaneity of the following reactions at 1 atm:

a. $Al_2O_{3(s)} + 2\ Fe_{(s)} \rightarrow 2\ Al_{(s)} + Fe_2O_{3(s)}$

$\Delta H = +847.6$ kJ; $\Delta S^\circ = +41.2$ J/K

b. $CO_{(g)} \rightarrow C_{(s)} + 1/2\ O_{2(g)}$

$\Delta H = +110.5$ kJ; $\Delta S^\circ = -89.7$ J/K

c. $SO_{3(g)} \rightarrow SO_{2(g)} + 1/2\ O_{2(g)}$

$\Delta H = +99.1$ kJ; $\Delta S^\circ = +94.8$ J/K

Substantive Answers

5.1 a. t b. t c. f d. f

5.2 a. exob. -
5.3 a. exo b. refer to text c. -11.56 kJd. .22 g

5.4 a. +65.5 kJ b. +.46 kJ
5.8 -788 kJ

5.31 a. t b. f c. t d. t

5.32 a. KBr(s) ----> K+(aq) + Br-(aq) b. +
5.33 a. endo b. see text c. .941 kJ d. 1.06 g
14.4 a. -513.6 kJ b. -461.2 kJ
14.5 a. +, b. -, c. +, d. +

14.6 a. +, b. -, c. -
14.16 a. .16 kJ/K no--entropy should increase
b. 81.5 J/K c. -505 kJ
14.18 a. Temp increase creates spontaneity
b. Always spontaneous regardless of T
c. Increasing T creates nonspontaneity

14.19 a. 4134 K
b. The reaction goes to completion
c. 5968 K
When change in free energy is 0 the reaction is at equilibrium.

14.34 a. +17.5 kJ, b. -222 kJ/mole
14.35 a. -, b. +, c. -, d. -
14.36 a. -, b. -, c. -

14.51 a. 353.4 kJ, 242.9 kJ, 132.4 kJ, 21.9 kJ, -88.6 kJ
b. 840 K
14.46 a. .321 kJ/K b. 128.9 kJ, -192 kJ

14.48 a. reaction becomes spontaneous at high T
b. nonspontaneous at all T
c. reaction becomes spontaneous at high T