Chapter 06: Energy Relationships in Chemical Reactions

1. *Radiant energy* is
   A) the energy stored within the structural units of chemical substances.
   B) the energy associated with the random motion of atoms and molecules.
   C) solar energy, i.e. energy that comes from the sun.
   D) energy available by virtue of an object's position.

3. *Chemical energy* is
   A) the energy stored within the structural units of chemical substances.
   B) the energy associated with the random motion of atoms and molecules.
   C) solar energy, i.e. energy that comes from the sun.
   D) energy available by virtue of an object's position.

5. *Heat* is
   A) a measure of temperature.
   B) a measure of the change in temperature.
   C) a measure of thermal energy.
   D) a measure of thermal energy transferred between two bodies at different temperature.

7. An exothermic reaction causes the surroundings to
   A) warm up.
   B) become acidic.
   C) expand.
   D) decrease its temperature.
   E) release CO_2.

9. Calculate the amount of heat necessary to raise the temperature of 12.0 g of water from 15.4°C to 93.0°C. The specific heat of water = 4.18 J/g·°C.
   A) 0.027 J B) 324 J C) 389 J D) 931 J E) 3,890 J

11. A beaker contains 115 g of ethanol at 18.2°C. If the ethanol absorbs 1125 J of heat without losing heat to the surroundings, what will be the final temperature of the ethanol? The specific heat of ethanol is 2.46 J/g·°C.
    A) 4.08°C B) 14.1°C C) 18.4°C D) 22.2°C E) 36.4°C

13. If 325 g of water at 4.2°C absorbs 12.28 kJ, what is the final temperature of the water? The specific heat of water is 4.184 J/g·°C.
    A) 4.21°C B) 4.8°C C) 9.0°C D) 13.2°C E) 2,938°C

15. A piece of copper with a mass of 218 g has a heat capacity of 83.9 J/°C. What is the specific heat of copper?
A) 0.385 J/g·°C
B) 1.83×10^4 J/g·°C
C) 2.60 J/g·°C
D) 1.32 J/g·°C
E) 24.5 J/g·°C

17. Suppose a 50.0 g block of silver (specific heat = 0.2350 J/g·°C) at 100°C is placed in contact with a 50.0 g block of iron (specific heat = 0.4494 J/g·°C) at 0°C, and the two blocks are insulated from the rest of the universe. The final temperature of the two blocks
A) will be higher than 50°C.
B) will be lower than 50°C.
C) will be exactly 50°C.
D) is unrelated to the composition of the blocks.
E) cannot be predicted.

19. Naphthalene combustion can be used to calibrate the heat capacity of a bomb calorimeter. The heat of combustion of naphthalene is –40.1 kJ/g. When 0.8210 g of naphthalene was burned in a calorimeter containing 1,000. g of water, a temperature rise of 4.21°C was observed. What is the heat capacity of the bomb calorimeter excluding the water?
A) 32.9 kJ/°C B) 7.8 kJ/°C C) 3.64 kJ/°C D) 1.76 kJ/°C E) 15.3 kJ/°C

21. A 100. mL sample of 0.200 M aqueous hydrochloric acid is added to 100. mL of 0.200 M aqueous ammonia in a calorimeter whose heat capacity (excluding any water) is 480. J/K. The following reaction occurs when the two solutions are mixed.
$HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$
The temperature increase is 2.34°C. Calculate ΔH per mole of HCl and NH_3 reacted.
A) 154 kJ/mol
B) 1.96 kJ/mol
C) 485 kJ/mol
D) –1.96 kJ/mol
E) –154 kJ/mol

23. To which one of the following reactions occurring at 25°C does the symbol $\Delta H^\circ_f[H_2SO_4(l)]$ refer?
A) $2H(g) + S(g) + 4O(g) \rightarrow H_2SO_4(l)$
B) $H_2(g) + S(g) + 2O_2(g) \rightarrow H_2SO_4(l)$
C) $H_2SO_4(l) \rightarrow H_2(g) + S(s) + 2O_2(g)$
D) $H_2SO_4(l) \rightarrow 2H(g) + S(s) + 4O(g)$
E) $H_2(g) + S(s) + 2O_2(g) \rightarrow H_2SO_4(l)$

25. When 0.560 g of Na(s) reacts with excess F_2(g) to form NaF(s), 13.8 kJ of heat is evolved at standard-state conditions. What is the standard enthalpy of formation ($\Delta H°_f$) of NaF(s)?
   A) 24.8 kJ/mol
   B) 570 kJ/mol
   C) –24.8 kJ/mol
   D) –7.8 kJ/mol
   E) –570 kJ/mol

27. Ethanol undergoes combustion in oxygen to produce carbon dioxide gas and liquid water. The standard heat of combustion of ethanol, C_2H_5OH(l), is –1366.8 kJ/mol. Given that $\Delta H°_f[CO_2(g)]$ = –393.5 kJ/mol and $\Delta H°_f[H_2O(l)]$ = –285.8 kJ/mol, what is the standard enthalpy of formation of ethanol?
   A) 3,010 kJ/mol
   B) –687.6 kJ/mol
   C) –277.6 kJ/mol
   D) 687.6 kJ/mol
   E) 1,367 kJ/mol

29. Octane (C_8H_{18}) undergoes combustion according to the following thermochemical equation:
   $2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$ $\quad \Delta H°_{rxn} = –11,020$ kJ/mol.
   Given that $\Delta H°_f[CO_2(g)]$ = –393.5 kJ/mol and $\Delta H°_f[H_2O(l)]$ = –285.8 kJ/mol, calculate the standard enthalpy of formation of octane.
   A) –210 kJ/mol
   B) –11,230 kJ/mol
   C) 22,040 kJ/mol
   D) –420 kJ/mol
   E) 420 kJ/mol

31. Styrene, C_8H_8, is one of the substances used in the production of synthetic rubber. When styrene burns in oxygen to form carbon dioxide and liquid water under standard-state conditions at 25°C, 42.62 kJ are released per gram of styrene. Find the standard enthalpy of formation of styrene at 25°C.
   (Given: $\Delta H°_f[CO_2(g)]$ = –393.5 kJ/mol, $\Delta H°_f[H_2O(l)]$ = –285.8 kJ/mol, $\Delta H°_f[H_2O(g)]$ = –241.8 kJ/mol)
   A) 323.8 kJ/mol
   B) –4249 kJ/mol
   C) –8730 kJ/mol
   D) –636.7 kJ/mol
   E) 147.8 kJ/mol

33. Calculate the standard enthalpy of formation of liquid methanol, $CH_3OH(l)$, using the following information:
$C(graph) + O_2 \rightarrow CO_2(g)$ $\Delta H° = –393.5$ kJ/mol
$H_2(g) + (1/2)O_2 \rightarrow H_2O(l)$ $\Delta H° = –285.8$ kJ/mol
$CH_3OH(l) + (3/2)O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H° = –726.4$ kJ/mol
A) –1,691.5 kJ/mol
B) –238.7 kJ/mol
C) 1691.5 kJ/mol
D) 47.1 kJ/mol
E) –47.1 kJ/mol

35. During volcanic eruptions, hydrogen sulfide gas is given off and oxidized by air according to the following chemical equation:
$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$
Calculate the standard enthalpy change for the above reaction given:
$3S(s) + 2H_2O(g) \rightarrow 2H_2S(g) + SO_2(g)$ $\Delta H° = 146.9$ kJ/mol
$S(s) + O_2(g) \rightarrow SO_2(g)$ $\Delta H° = –296.4$ kJ/mol
A) –1036.1 kJ/mol
B) –742.3 kJ/mol
C) –149.5 kJ/mol
D) 443.3 kJ/mol
E) 742.3 kJ/mol

37. Given the thermochemical equation $2SO_2 + O_2 \rightarrow 2SO_3$, $\Delta H°_{rxn} = –198$ kJ/mol, what is the standard enthalpy change for the decomposition of one mole of SO_3?
A) 198 kJ/mol
B) –99 kJ/mol
C) 99 kJ/mol
D) 396 kJ/mol
E) –198 kJ/mol

39. Pentaborane $B_5H_9(s)$ burns vigorously in O_2 to give $B_2O_3(s)$ and $H_2O(l)$. Calculate $\Delta H°_{rxn}$ for the combustion of 1 mol of B_5H_9.
$\Delta H°_f[B_2O_3(s)] = –1,273.5$ kJ/mol
$\Delta H°_f[B_5H_9(s)] = 73.2$ kJ/mol
$\Delta H°_f[H_2O(l)] = –285.8$ kJ/mol
A) –1,2735 kJ/mol
B) –4,543 kJ/mol
C) –18,170 kJ/mol
D) –9,086 kJ/mol
E) –8,448 kJ/mol

41. The combustion of butane produces heat according to the equation
$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$ $\Delta H°_{rxn} = –5,314$ kJ/mol
What is the heat of combustion per gram of butane?
A) –32.5 kJ/g
B) –45.7 kJ/g
C) –91.5 kJ/g
D) –2,656 kJ/g
E) –15,440 kJ/g

43. The combustion of butane produces heat according to the equation
$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$ $\Delta H°_{rxn}$ = –5,314 kJ/mol
How many grams of butane must be burned to release 1.00×10^4 kJ of heat?
A) 30.9 g B) 61.8 g C) 109 g D) 153 g E) 219 g

45. Given that $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$, $\Delta H°_{rxn}$ = –64.8 kJ/mol, how many grams of CaO must react in order to liberate 525 kJ of heat?
A) 6.92 g B) 56.1 g C) 455 g D) 606 g E) 3.40×10^4 g

47. An average home in Colorado requires 20. GJ of heat per month. How many grams of natural gas (methane) must be burned to supply this energy?
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H°_{rxn}$ = –890.4 kJ/mol
A) 1.4×10^3 g
B) 3.6×10^5 g
C) 7.1×10^{-4} g
D) 2.2×10^4 g
E) 1.4×10^4 g

49. Determine the heat given off to the surroundings when 9.0 g of aluminum reacts according to the equation $2Al + Fe_2O_3 \rightarrow Al_2O_3 + 2Fe$, $\Delta H°_{rxn}$ = –849 kJ/mol.
A) 7.6×10^3 kJ
B) 2.8×10^2 kJ
C) 1.4×10^2 kJ
D) 5.6×10^2 kJ
E) 2.5×10^3 kJ

51. Ethanol (C_2H_5OH) burns according to the equation
$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$, $\Delta H°_{rxn}$ = –1367 kJ/mol.
How much heat is released when 35.0 g of ethanol is burned?
A) 1,797 kJ B) 1,367 kJ C) 9.61×10^{-4} kJ D) 4.78×10^4 kJ E) 1,040 kJ

53. Calcium oxide and water react in an exothermic reaction:
$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$ $\Delta H°_{rxn}$ = –64.8 kJ/mol
How much heat would be liberated when 7.15 g CaO(s) is dropped into a beaker containing 152g H_2O?
A) 1.97×10^{-3} kJ B) 8.26 kJ C) 508 kJ D) 547 kJ E) 555 kJ

55. At 25°C, the standard enthalpy of formation of KCl(s) is –435.87 kJ/mol. When one mole of KCl(s) is formed by reacting potassium vapor and chlorine gas at 25°C, the standard enthalpy of reaction is –525.86 kJ/mol. Find ΔH° for the sublimation of potassium, $K(s) \rightarrow K(g)$, at 25°C.
   A) –345.88 kJ/mol
   B) 45.00 kJ/mol
   C) 345.88 kJ/mol
   D) 89.99 kJ/mol
   E) –525.86 kJ/mol

57. According to the first law of thermodynamics:
   A) Energy is neither lost nor gained in any energy transformations.
   B) Perpetual motion is possible.
   C) Energy is conserved in quality but not in quantity.
   D) Energy is being created as time passes. We have more energy in the universe now than when time began.

59. The enthalpy change when a strong acid is neutralized by strong base is –56.1 kJ/mol. If 135 mL of 0.450 M HI at 23.15°C is mixed with 145 mL of 0.500 M NaOH, also at 23.15°C, what will be the maximum temperature reached by the resulting solution? (Assume that there is no heat loss to the container, that the specific heat of the final solution is 4.18 J/g·°C, and that the density of the final solution is that of water.)
   A) 26.06°C B) 29.19°C C) 32.35°C D) 20.24°C E) 36.57°C

61. Calculate the amount of work done, in joules, when 2.5 mole of H_2O vaporizes at 1.0 atm and 25°C. Assume the volume of liquid H_2O is negligible compared to that of vapor. (1 L·atm = 101.3 J)
   A) 6,190 kJ B) 6.19 kJ C) 61.1 J D) 5.66 kJ E) 518 J

63. Calculate the amount of work done against an atmospheric pressure of 1.00 atm when 500.0 g of zinc dissolves in excess acid at 30.0°C.
   $Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$
   A) w = +22.4 kJ
   B) w = +24.9 kJ
   C) w = 0
   D) w = –2.52 kJ
   E) w = –19.3 kJ

65. Which of the following processes *always* results in an increase in the energy of a system?
   A) The system loses heat and does work on the surroundings.
   B) The system gains heat and does work on the surroundings.
   C) The system loses heat and has work done on it by the surroundings.
   D) The system gains heat and has work done on it by the surroundings.
   E) None of these is always true.

67. For which of these reactions will the difference between ΔH° and ΔE° be the smallest?
    A) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
    B) $4PH_3(g) \rightarrow P_4(g) + 6H_2(g)$
    C) $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$
    D) $CO_2(g) + 2H_2O(l) \rightarrow CH_4(g) + 2O_2(g)$
    E) $P_4(s) + 10Cl_2(g) \rightarrow 4PCl_5(s)$

69. The *bond enthalpy* of the Br–Cl bond is equal to ΔH° for the reaction
    $BrCl(g) \rightarrow Br(g) + Cl(g)$.
    Use the following data to find the bond enthalpy of the Br–Cl bond.

$Br_2(l) \rightarrow Br_2(g)$	ΔH° = 30.91 kJ/mol
$Br_2(g) \rightarrow 2Br(g)$	ΔH° = 192.9 kJ/mol
$Cl_2(g) \rightarrow 2Cl(g)$	ΔH° = 243.4 kJ/mol
$Br_2(l) + Cl_2(g) \rightarrow 2BrCl(g)$	ΔH° = 29.2 kJ/mol

    A) 219.0 kJ/mol
    B) 203.5 kJ/mol
    C) 14.6 kJ/mol
    D) 438.0 kJ/mol
    E) 407.0 kJ/mol

71. The heat of solution of ammonium chloride is 15.2 kJ/mol. If a 6.134 g sample of NH_4Cl is added to 65.0 mL of water in a calorimeter at 24.5°C, what is the minimum temperature reached by the solution? (The specific heat of water = 4.18 J/g·°C; the heat capacity of the calorimeter = 365. J/°C.)
    A) 27.1°C B) 18.6°C C) 19.7°C D) 21.9°C E) 30.4°C

73. Ozone (O_3) in the atmosphere can be converted to oxygen gas by reaction with nitric oxide (NO). Nitrogen dioxide is also produced in the reaction. What is the enthalpy change when 8.50L of ozone at a pressure of 1.00 atm and 25°C reacts with 12.00 L of nitric oxide at the same initial pressure and temperature? [$\Delta H°_f(NO)$ = 90.4 kJ/mol; $\Delta H°_f(NO_2)$ = 33.85 kJ/mol; $\Delta H°_f(O_3)$ = 142.2 kJ/mol]
    A) –69.2 kJ B) –19.7 kJ C) –1690 kJ D) –97.6 kJ E) –167 kJ