Chapter 6: Thermochemistry

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.
   Ans: C Category: Easy Section: 6.1

2. *Thermal 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.
   Ans: B Category: Easy Section: 6.1

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.
   Ans: A Category: Easy Section: 6.1

4. *Potential 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.
   Ans: D Category: Easy Section: 6.1

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.
   Ans: D Category: Medium Section: 6.2

6. An endothermic reaction causes the surroundings to
   A) warm up.
   B) become acidic.
   C) condense.
   D) decrease in temperature.
   E) release CO_2.
   Ans: D Category: Easy Section: 6.2

7. An exothermic reaction causes the surroundings to
   A) warm up.
   B) become acidic.
   C) expand.
   D) decrease its temperature.
   E) release CO_2.
   Ans: A Category: Easy Section: 6.2

8. Copper metal has a specific heat of 0.385 J/g·°C. Calculate the amount of heat required to raise the temperature of 22.8 g of Cu from 20.0°C to 875°C.
   A) 1.97×10^{-5} J B) 1.0×10^{-2} J C) 329 J D) 7.51 kJ E) 10.5 kJ
   Ans: D Category: Medium Section: 6.5

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
   Ans: E Category: Medium Section: 6.5

10. How much heat is required to raise the temperature of 2,500 g of water from 27°C to 72°C? The specific heat of water is 4.184 J/g·°C.
    A) 0.19 kJ B) 10. kJ C) 280 kJ D) 470 kJ E) 750 kJ
    Ans: D Category: Medium Section: 6.5

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
    Ans: D Category: Medium Section: 6.5

12. How many degrees of temperature rise will occur when a 25.0 g block of aluminum absorbs 10.0 kJ of heat? The specific heat of Al is 0.900 J/g·°C.
    A) 0.44°C B) 22.5°C C) 225°C D) 360°C E) 444°C
    Ans: E Category: Medium Section: 6.5

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
    Ans: D Category: Medium Section: 6.5

14. A glass containing 200. g of H_2O at 20°C was placed in a refrigerator. The water loses 11.7 kJ as it cools to a constant temperature. What is its new temperature? The specific heat of water is 4.184 J/g·°C.
    A) 0.013°C B) 4°C C) 6°C D) 14°C E) 34°C
    Ans: C Category: Medium Section: 6.5

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
    Ans: A Category: Easy Section: 6.5

16. The specific heat of gold is 0.129 J/g·°C. What is the molar heat capacity of gold?
    A) 0.039 J/mol·°C
    B) 0.129 J/mol·°C
    C) 25.4 J/mol·°C
    D) 39.0 kJ/mol·°C
    E) 197 J/mol·°C
    Ans: C Category: Easy Section: 6.5

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.
    Ans: B Category: Medium Section: 6.5

18. When 0.7521 g of benzoic acid was burned in a calorimeter containing 1,000. g of water, a temperature rise of 3.60°C was observed. What is the heat capacity of the bomb calorimeter, excluding the water? The heat of combustion of benzoic acid is –26.42 kJ/g.
    A) 15.87 kJ/°C
    B) 4.18 kJ/°C
    C) 5.52 kJ/°C
    D) 1.34 kJ/°C
    E) 752.1 kJ/°C
    Ans: D Category: Medium Section: 6.5

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
    Ans: C Category: Medium Section: 6.5

20. Which of the following processes is *endothermic*?
    A) $O_2(g) + 2H_2(g) \rightarrow 2H_2O(g)$
    B) $H_2O(g) \rightarrow H_2O(l)$
    C) $3O_2(g) + 2CH_3OH(g) \rightarrow 2CO_2(g) + 2H_2O(g)$
    D) $H_2O(s) \rightarrow H_2O(l)$
    Ans: D Category: Medium Section: 6.4

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
Ans: E Category: Difficult Section: 6.5

22. A 0.1326 g sample of magnesium was burned in an oxygen bomb calorimeter. The total heat capacity of the calorimeter plus water was 5,760 J/°C. If the temperature rise of the calorimeter with water was 0.570°C, calculate the enthalpy of combustion of magnesium.
$Mg(s) + 1/2O_2(g) \rightarrow MgO(s)$
A) –3280 kJ/mol
B) –24.8 kJ/mol
C) 435 kJ/mol
D) 106 kJ/mol
E) –602 kJ/mol
Ans: E Category: Difficult Section: 6.5

23. To which one of the following reactions occurring at 25°C does the symbol $\Delta H°_f[H_2SO_4(l)]$ 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) $H_2(g) + S(s) + 2O_2(g) \rightarrow H_2SO_4(l)$
Ans: E Category: Medium Section: 6.6

24. To which one of the following reactions occurring at 25°C does the symbol $\Delta H°_f[HNO_3(l)]$ refer?
A) $H(g) + N(g) + O_3(g) \rightarrow HNO_3(l)$
B) $(1/2)H_2(g) + (1/2)N_2(g) + (3/2)O_2(g) \rightarrow HNO_3(l)$
C) $HNO_3(l) \rightarrow (1/2)H_2(g) + (1/2)N_2(g) + (3/2)O_2(g)$
D) $HNO_3(l) \rightarrow H(g) + N(g) + 3O(g)$
E) $H_2(g) + N_2(g) + O_3(g) \rightarrow HNO_3(l)$
Ans: B Category: Medium Section: 6.6

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
Ans: E Category: Medium Section: 6.6

26. When 18.5 g of HgO(s) is decomposed to form Hg(l) and $O_2(g)$, 7.75 kJ of heat is absorbed at standard-state conditions. What is the standard enthalpy of formation ($\Delta H°_f$) of HgO(s)?
A) –90.7 kJ/mol
B) –7.75 kJ/mol
C) 0.419 kJ/mol
D) 27.9 kJ/mol
E) 143 kJ/mol
Ans: A Category: Medium Section: 6.6

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
Ans: C Category: Difficult Section: 6.6

28. Find the standard enthalpy of formation of ethylene, $C_2H_4(g)$, given the following data: heat of combustion of $C_2H_4(g) = –1411$ kJ/mol; $\Delta H°_f[CO_2(g)] = –393.5$ kJ/mol; $\Delta H°_f[H_2O(l)] = –285.8$ kJ/mol.
A) 52 kJ/mol
B) 87 kJ/mol
C) 731 kJ/mol
D) 1.41×10^3 kJ/mol
E) 2.77×10^3 kJ/mol
Ans: A Category: Difficult Section: 6.6

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
Ans: A Category: Medium Section: 6.6

30. Glycine, $C_2H_5O_2N$, is important for biological energy. The combustion reaction of glycine is given by the equation
$4C_2H_5O_2N(s) + 9O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l) + 2N_2(g) \quad \Delta H°_{rxn} = –3857$ 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 enthalpy of formation of glycine.
A) –537.2 kJ/mol
B) –268.2 kJ/mol
C) 2,149 kJ/mol
D) –3,178 kJ/mol
E) –964 kJ/mol
Ans: A Category: Medium Section: 6.6

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

Ans: E Category: Difficult Section: 6.6

32. Given $2Al(s) + (3/2)O_2(g) \rightarrow Al_2O_3(s)$, $\Delta H°_f = –1{,}670$ kJ/mol for Al_2O_3 (s). Determine $\Delta H°$ for the reaction $2Al_2O_3(s) \rightarrow 4Al(s) + 3O_2(g)$.

A) 3,340 kJ/mol
B) 1,670 kJ/mol
C) –3,340 kJ/mol
D) –1,670 kJ/mol
E) –835 kJ/mol

Ans: A Category: Easy Section: 6.6

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

Ans: B Category: Difficult Section: 6.6

34. Calculate the standard enthalpy change for the reaction
$2C_8H_{18}(l) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(l)$.
Given:
$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$ $\Delta H° = –11{,}020$ kJ/mol
$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ $\Delta H° = –566.0$ kJ/mol

A) 10,450 kJ/mol
B) 6,492 kJ/mol
C) 15,550 kJ/mol
D) –6,492 kJ/mol
E) –10.450 kJ/mol

Ans: D Category: Medium Section: 6.6

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
Ans: A Category: Medium Section: 6.6

36. Calculate the standard enthalpy change for the reaction
$2C_8H_{18}(l) + 21O_2(g) \rightarrow 8CO(g) + 8CO_2(g) + 18H_2O(l)$.
Given:
$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$ $\Delta H° = -11{,}020$ kJ/mol
$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ $\Delta H° = -566.0$ kJ/mol
A) 1.0454×10^4 kJ/mol
B) –8,756 kJ/mol
C) 1.1586×10^4 kJ/mol
D) –6,492 kJ/mol
E) -1.0454×10^4 kJ/mol
Ans: B Category: Medium Section: 6.6

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
Ans: C Category: Medium Section: 6.6

38. Given $H_2(g) + (1/2)O_2(g) \rightarrow H_2O(l)$, $\Delta H° = -286$ kJ/mol, determine the standard enthalpy change for the reaction $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$.
A) $\Delta H° = -286$ kJ/mol
B) $\Delta H° = +286$ kJ/mol
C) $\Delta H° = -572$ kJ/mol
D) $\Delta H° = +572$ kJ/mol
E) $\Delta H° = -143$ kJ/mol
Ans: D Category: Easy Section: 6.6

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
Ans: B Category: Difficult Section: 6.6

40. For the reaction
$C(graphite) + O_2(g) \rightarrow CO_2(g)$ $\Delta H° = –393$ kJ/mol
how many grams of C(graphite) must be burned to release 275 kJ of heat?
A) 22.3 g B) 0.70 g C) 12.0 g D) 17.1 g E) 8.40 g
Ans: E Category: Medium Section: 6.4

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
Ans: B Category: Medium Section: 6.4

42. The combustion of octane produces heat according to the equation
$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$ $\Delta H°_{rxn} = –11{,}020$ kJ/mol
What is the heat of combustion per gram of octane?
A) –5,510 kJ/g
B) –96.5 kJ/g
C) –48.2 kJ/g
D) –193 kJ/g
E) $–6.292 \times 10^5$ kJ/g
Ans: C Category: Medium Section: 6.4

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
Ans: E Category: Medium Section: 6.4

44. 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 CO_2 are produced per 1.00×10^4 kJ of heat released?
A) 23.4 g B) 44.0 g C) 82.3 g D) 187 g E) 662 g
Ans: E Category: Medium Section: 6.4

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
Ans: C Category: Medium Section: 6.4

46. The combustion of pentane produces heat according to the equation
$C_5H_{12}(l) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(l)$ $\Delta H°_{rxn} = -3{,}510$ kJ/mol
How many grams of CO_2 are produced per 2.50×10^3 kJ of heat released?
A) 0.0809 g B) 3.56 g C) 31.3 g D) 157 g E) 309 g
Ans: D Category: Medium Section: 6.4

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
Ans: B Category: Medium Section: 6.4

48. Given the thermochemical equation $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$, $\Delta H°_{rxn} = -198$ kJ/mol, how much heat is evolved when 600. g of SO_2 is burned?
A) 5.46×10^{-2} kJ
B) 928 kJ
C) 1.85×10^3 kJ
D) 59,400 kJ
E) 3.71×10^3 kJ
Ans: B Category: Medium Section: 6.4

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
Ans: C Category: Medium Section: 6.4

50. Find the heat absorbed from the surroundings when 15 g of O_2 reacts according to the equation $O + O_2 \rightarrow O_3$, $\Delta H°_{rxn} = -103$ kJ/mol.
A) 4.6×10^{-3} kJ B) 48 kJ C) 96 kJ D) 32 kJ E) 110 kJ
Ans: B Category: Medium Section: 6.4

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
Ans: E Category: Medium Section: 6.4

52. Methanol (CH_3OH) burns according to the equation
$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$, $\Delta H°_{rxn} = -1454$ kJ/mol.
How much heat, in kilojoules, is given off when 75.0 g of methanol is burned?
A) 727 kJ
B) 3.22×10^3 kJ
C) 1.45×10^3 kJ
D) 1.70×10^{-3} kJ
E) 3.41×10^3 kJ
Ans: D Category: Medium Section: 6.4

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
Ans: B Category: Medium Section: 6.4

54. Solid sodium peroxide (Na_2O_2) reacts with liquid water yielding aqueous sodium hydroxide and oxygen gas. How much heat is released when 250.0 L of oxygen gas is produced from the reaction of sodium peroxide and water if the reaction is carried out in an open container at 1.000 atm pressure and 25°C?
(Given: $\Delta H°_f[Na_2O_2(s)] = -510.9$ kJ/mol; $\Delta H°_f[NaOH(aq)] = -469.2$ kJ/mol; $\Delta H°_f[H_2O(l)] = -285.8$ kJ/mol)
A) 35,400 kJ B) 1740 kJ C) 141.7 kJ D) 3330 kJ E) 2900 kJ
Ans: E Category: Difficult Section: 6.6

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 $\Delta H°$ 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
Ans: D Category: Medium Section: 6.6

56. At 25°C, the standard enthalpy of formation of anhydrous sodium carbonate is –1130.9 kJ/mol, whereas the standard enthalpy of formation of sodium carbonate monohydrate is –1430.1 kJ/mol. Determine $\Delta H°$ at 25°C for the reaction
$Na_2CO_3(s) + H_2O(l) \rightarrow Na_2CO_3 \cdot H_2O(s)$.
(Given: $\Delta H°_f[H_2O(l)] = -285.8$ kJ/mol)
A) –13.4 kJ/mol
B) –285.8 kJ/mol
C) –585.0 kJ/mol
D) –299.2 kJ/mol
E) –156.3 kJ/mol
Ans: A Category: Medium Section: 6.6

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.
    Ans: A Category: Easy Section: 6.3

58. The heat of solution of KCl is 17.2 kJ/mol and the lattice energy of KCl(s) is 701.2 kJ/mol. Calculate the total heat of hydration of 1 mol of gas phase K^+ ions and Cl^- ions.
    A) 718 kJ B) 684 kJ C) –684 kJ D) –718 kJ E) None of these.
    Ans: C Category: Medium Section: 6.7

59. The heat of solution of LiCl is –37.1 kJ/mol, and the lattice energy of LiCl(s) is 828 kJ/mol. Calculate the total heat of hydration of 1 mol of gas phase Li^+ ions and Cl^- ions.
    A) 791 kJ B) 865 kJ C) –865 kJ D) –791 kJ E) None of these.
    Ans: C Category: Medium Section: 6.7

60. The total heat of hydration of 1 mol of gas phase Li^+ ions and Cl^- ions is –865 kJ. The lattice energy of LiCl(s) is 828 kJ/mol. Calculate the heat of solution of LiCl.
    A) 37 kJ/mol
    B) 1,693 kJ/mol
    C) –1,693 kJ/mol
    D) –37 kJ/mol
    E) None of these.
    Ans: D Category: Medium Section: 6.7

61. 10.1 g CaO is dropped into a styrofoam coffee cup containing 157 g H_2O at 18.0°C. If the following reaction occurs, then what temperature will the water reach, assuming that the cup is a perfect insulator and that the cup absorbs only a negligible amount of heat? (the specific heat of water = 4.18 J/g·°C)
    $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s) \quad \Delta H°_{rxn} = -64.8$ kJ/mol
    A) 18.02°C B) 35.8°C C) 311°C D) 42.2°C E) 117°C
    Ans: B Category: Medium Section: 6.5

62. 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 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
    Ans: A Category: Difficult Section: 6.5

63. The enthalpy change when a strong acid is neutralized by strong base is –56.1 kJ/mol. If 12.0 mL of 6.00 M HBr at 21.30°C is mixed with 300. mL of 0.250 M NaOH, also at 21.30°C, what will 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) 18.20°C B) 24.53°C C) 101.8°C D) 24.40°C E) 34.25°C
Ans: D Category: Difficult Section: 6.5

64. 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
Ans: B Category: Medium Section: 6.3

65. A gas is compressed in a cylinder from a volume of 20.0 L to 2.0 L by a constant pressure of 10.0 atm. Calculate the amount of work done on the system.
A) 1.01×10^4 J B) –180 J C) 1.81×10^4 J D) -1.81×10^4 J E) 180 J
Ans: C Category: Medium Section: 6.3

66. 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
Ans: E Category: Medium Section: 6.3

67. A gas is allowed to expand, at constant temperature, from a volume of 1.0 L to 10.1 L against an external pressure of 0.50 atm. If the gas absorbs 250 J of heat from the surroundings, what are the values of q, w, and ΔE?

	q	w	ΔE
A.	250 J	–460 J	–210 J
B.	–250 J	–460 J	–710 J
C.	250 J	460 J	710 J
D.	–250 J	460 J	210 J
E.	250 J	–4.55 J	245 J

Ans: A
Category: Medium Section: 6.3

68. 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.
    Ans: D Category: Medium Section: 6.3

69. For which of these reactions will the difference between $\Delta H°$ and $\Delta E°$ be the greatest?
    A) $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$
    B) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
    C) $NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$
    D) $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$
    E) $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$
    Ans: D Category: Medium Section: 6.4

70. For which of these reactions will the difference between $\Delta H°$ and $\Delta E°$ 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) $P_4(s) + 10Cl_2(g) \rightarrow 4PCl_5(s)$
    Ans: C Category: Medium Section: 6.4

71. At 25°C, the following heats of reaction are known:
    $2ClF(g) + O_2(g) \rightarrow Cl_2O(g) + F_2O(g)$ $\Delta H°_{rxn} = 167.4$ kJ/mol
    $2ClF_3(g) + 2O_2(g) \rightarrow Cl_2O(g) + 3F_2O(g)$ $\Delta H°_{rxn} = 341.4$ kJ/mol
    $2F_2(g) + O_2(g) \rightarrow 2F_2O(g)$ $\Delta H°_{rxn} = -43.4$ kJ/mol

At the same temperature, use Hess's law to calculate $\Delta H°_{rxn}$ for the reaction:

$ClF(g) + F_2(g) \rightarrow ClF_3(g)$

    A) –217.5 kJ/mol
    B) –130.2 kJ/mol
    C) 217.5 kJ/mol
    D) –108.7 kJ/mol
    E) 465.4 kJ/mol
    Ans: D Category: Medium Section: 6.6

72. 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
Ans: A Category: Medium Section: 6.6

73. The heat of solution of ammonium nitrate is 26.2 kJ/mol. If a 5.368 g sample of NH_4NO_3 is added to 40.0 mL of water in a calorimeter at 23.5°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 = 650. J/°C.)
A) 14.3°C B) 20.8°C C) –7.7°C D) 25.6°C E) 21.4°C
Ans: E Category: Difficult Section: 6.5

74. 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
Ans: D Category: Difficult Section: 6.5

75. Aluminum oxide can be reduced to aluminum metal using carbon, the other reaction product being carbon monoxide. Determine the enthalpy change when 12.5 g of aluminum is produced by this method. [$\Delta H°_f$(carbon monoxide) = –110.5 kJ/mol; $\Delta H°_f$(aluminum oxide) = –1669.8 kJ/mol]
A) 725 kJ B) 697 kJ C) 310 kJ D) 361 kJ E) 1504 kJ
Ans: C Category: Difficult Section: 6.6

76. 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
Ans: A Category: Difficult Section: 6.6

77. Define *specific heat*.
Ans: The amount of heat required to raise the temperature of one gram of a substance by one degree Celsius.
Category: Easy Section: 6.5

78. How many grams of ethylene (C_2H_4) would have to be burned to produce 450 kJ of heat?
$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$ $\Delta H°_{rxn} = -1411$ kJ/mol
Ans: 8.95 g
Category: Medium Section: 6.4

79. Calculate the enthalpy of reaction for $H_2(g) + C_2H_4(g) \rightarrow C_2H_6(g)$.
[$\Delta H°_f(C_2H_4(g)) = 52.3$ kJ/mol; $\Delta H°_f(C_2H_6(g)) = -84.7$ kJ/mol]
Ans: –137 kJ/mol
Category: Medium Section: 6.6

80. The enthalpy of combustion of acetylene C_2H_2 is described by
$C_2H_2(g) + (5/2)O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$ $\Delta H°_{rxn} = -1299$ kJ/mol
Calculate the enthalpy of formation of acetylene, given the following enthalpies of formation
$\Delta H°_f[CO_2(g)] = -393.5$ kJ/mol
$\Delta H°_f[H_2O(l)] = -285.8$ kJ/mol
Ans: 226 kJ/mol
Category: Medium Section: 6.6

81. Given the following $\Delta H°$ values,
$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l)$ $\Delta H°_f = -285.8$ kJ/mol
$H_2O_2(l) \rightarrow H_2(g) + O_2(g)$ $\Delta H°_{rxn} = 187.6$ kJ/mol
calculate $\Delta H°_{rxn}$ for the reaction $H_2O_2(l) \rightarrow H_2O(l) + \frac{1}{2} O_2(g)$,
Ans: –98.2 kJ/mol
Category: Medium Section: 6.6

82. The heat of solution of calcium chloride $CaCl_2$ is –82.8 kJ/mol, and the combined heats of hydration of 1 mole of gaseous calcium ions and 2 mole of gaseous chloride ions is –2327 kJ. What is the lattice energy of calcium chloride?
Ans: 2,244 kJ/mol
Category: Medium Section: 6.7

83. The heat of solution of NH_4NO_3 is 26.2 kJ/mol. Is heat evolved or absorbed when a solution of NH_4NO_3 is diluted by addition of more water?
Ans: Absorbed
Category: Easy Section: 6.7

84. A 26.2 g piece of copper metal is heated from 21.5°C to 201.6°C. Calculate the amount of heat absorbed by the metal. The specific heat of Cu is 0.385 J/g·°C.
Ans: 1,820 J
Category: Medium Section: 6.5

85. A 0.1946 g piece of magnesium metal is burned in a constant-volume calorimeter that has a heat capacity of 1349 J/°C. The calorimeter contains 500. g of water and the temperature rise is 1.40°C. Calculate the heat of combustion of magnesium metal in kJ/g, given that the specific heat of water = 4.184 J/g·°C.
Ans: 24.8 kJ/g
Category: Medium Section: 6.5

86. A 0.3423 g sample of pentane, C_5H_{12}, was burned in a bomb calorimeter. The temperature of the calorimeter and the 1.000 kg of water contained therein rose from 20.22°C to 22.82°C. The heat capacity of the calorimeter is 2.21 kJ/°C. The heat capacity of water = 4.184 J/g·°C. How much heat was given off during combustion of the sample of pentane?
Ans: 16.6 kJ
Category: Medium Section: 6.5

87. A 0.3423 g sample of pentane, C_5H_{12}, was burned in a bomb calorimeter. The temperature of the calorimeter and the 1.000 kg of water contained therein rose from 20.22°C to 22.82°C. The heat capacity of the calorimeter is 2.21 kJ/°C. The heat capacity of water = 4.184 J/g·°C. What is the heat of combustion, in kilojoules, per gram of pentane?
Ans: 48.6 kJ/g
Category: Medium Section: 6.5

88. A 0.3423 g sample of pentane, C_5H_{12}, was burned in a bomb calorimeter. The temperature of the calorimeter and the 1.000 kg of water contained therein rose from 20.22°C to 22.82°C. The heat capacity of the calorimeter is 2.21 kJ/°C. The heat capacity of water = 4.184 J/g·°C. What is the heat of combustion, in megajoules (MJ), per mole of pentane?
Ans: 3.50 MJ/mol
Category: Medium Section: 6.5

89. The heat of combustion of propane, C_3H_8, 2220 kJ/mol. The specific heat of copper is 0.385 J/g·°C. How many grams of propane must be burned to raise the temperature of a 10.0 kg block of copper from 25.0°C to 65.0°C, assuming none of the heat is lost to the surroundings
Ans: 3.06 g
Category: Medium Section: 6.5

90. The residential rate for natural gas is about $15 per thousand cubic foot. Burning one cubic foot of natural gas releases about 1080 kJ of heat. How much would it cost to heat the water in a 25,000 gallon swimming pool from 52°F to 78°F, assuming all of the heat from burning the natural gas went towards warming the water? (1 gal = 3.785 L; the specific heat of water = 4.184 J/g·°C)
Ans: $79
Category: Difficult Section: 6.5

91. The heat of neutralization of HCl by NaOH is $\Delta H°_{rxn}$ = –56.2 kJ/mol. How much heat is released when 125 mL of 1.750 M HCl is mixed with 195 mL of 0.667 M NaOH?
Ans: 7.31 kJ
Category: Difficult Section: 6.5

92. The heat released when one mole of water is formed from the elements is 1,198 kJ. An experiment was conducted that permitted water to form in this manner, and the heat was contained in 2.0 liters of water. The water temperature before the reaction was 34.5°C, and after the reaction it had risen to 52.0°C. How many moles of water were formed? (The specific heat of water is 4.184 J/g·°C.)
Ans: 0.12 mole
Category: Medium Section: 6.5

93. When an automobile engine starts, the metal parts immediately begin to absorb heat released during the combustion of gasoline. How much heat will be absorbed by a 165 kg iron engine block as the temperature rises from 15.7°C to 95.7°C? (The specific heat of iron is 0.489 J/g·°C.)
Ans: 6,450 kJ
Category: Medium Section: 6.5

94. The value of $\Delta H°_{rxn}$ for the following reaction is –6535 kJ/mol.
$2C_6H_6(l) + 15O_2(g) \rightarrow 12CO_2(g) + 6H_2O(g)$
How many kilojoules of heat will be evolved during the combustion of 16.0 g of $C_6H_6(l)$?
Ans: 669 kJ
Category: Medium Section: 6.4

95. What would be the standard enthalpy change for the reaction of one mole of $H_2(g)$ with one mole of $Cl_2(g)$ to produce two moles of HCl(g) at standard state conditions? [$\Delta H°_f$ (HCl(g))= –92.3 kJ/mol]
Ans: –185 kJ
Category: Medium Section: 6.6

96. What is the standard enthalpy of formation of $H_2(g)$ at 25°C?
Ans: 0 kJ/mol
Category: Easy Section: 6.6

97. Find $\Delta H°_{rxn}$ for the reaction
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$.
[$\Delta H°_f$ ($CH_4(g)$) = –74.8 kJ/mol; $\Delta H°_f$ ($CO_2(g)$) = –393.5 kJ/mol; $\Delta H°_f$ ($H_2O(l)$) = –285.5 kJ/mol]
Ans: -889.7 kJ/mol
Category: Medium Section: 6.6

98. Find $\Delta H°_{rxn}$ for the reaction
$2Ag_2S(s) + 2H_2O(l) \rightarrow 4Ag(s) + 2H_2S(g) + O_2(g)$.
[$\Delta H°_f$ ($Ag_2S(s)$) = –32.6 kJ/mol; $\Delta H°_f$ ($H_2S(g)$) = –20.5 kJ/mol; $\Delta H°_f$ ($H_2O(l)$) = –285.5 kJ/mol]
Ans: 595.2 kJ/mol
Category: Medium Section: 6.6

99. Find $\Delta H°_{rxn}$ for the reaction
$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + 2H_2(g)$.
[$\Delta H°_f$ ($NaOH(aq)$) = –426.8 kJ/mol; $\Delta H°_f$ ($H_2O(l)$) = –285.5 kJ/mol]
Ans: –282.6 kJ
Category: Medium Section: 6.6

100. The specific heat of silver is 0.235 J/g·°C. How many joules of heat are required to heat a 75 g silver spoon from 20°C to 35°C?
Ans: 260 J
Category: Easy Section: 6.5

101. At body temperature 2,404 joules of energy are required to evaporate 1.00 g of water. After vigorous exercise, a person feels chilly because the body is giving up heat to evaporate the perspiration. A typical person perspires 25 mL of water after 20. minutes of exercise. How much body heat is this person using to evaporate this water?
Ans: 6.0×10^4 J
Category: Easy Section: 6.4

102. The combustion of one mole of benzene, C_6H_6, in oxygen liberates 3268 kJ of heat. The products of the reaction are carbon dioxide and water. How much heat is given off when 183 g of oxygen are reacted with excess benzene?
Ans: 2490 kJ
Category: Difficult Section: 6.4

103. A feverish student weighing 75 kilograms was immersed in 400. kg of water at 4.0°C to try to reduce the fever. The student's body temperature dropped from 40.0°C to 37.0°C. Assuming the specific heat of the student to be 3.77 J/g·°C, what was the final temperature of the water?
Ans: 4.5°C
Category: Difficult Section: 6.5

104. The specific heats of water and iron are 4.184 and 0.444 J/g°C, respectively. When equal masses of water and iron both absorb the same amount of heat, the temperature increase of the water will be 5.42 times greater than that of the iron.
Ans: True Category: Medium Section: 6.5

105. Chemical reactions in a bomb calorimeter occur at constant pressure.
Ans: True Category: Easy Section: 6.5

106. If $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$, $\Delta H° = –1203.6$ kJ/mol.
For $Mg(s) + (1/2)O_2(g) \rightarrow MgO(s)$, the enthalpy change is $\Delta H = –601.8$ kJ/mol.
Ans: True Category: Easy Section: 6.6

107. The heat capacity of 20.0 g of water is 83.7 J/°C.
Ans: True Category: Medium Section: 6.5

108. The work done on the surroundings by the expansion of a gas is $w = –P\Delta V$.
Ans: True Category: Easy Section: 6.3

109. The heat absorbed by a system at constant pressure is equal to $\Delta E + P\Delta V$.
Ans: True Category: Easy Section: 6.4

110. In an endothermic process, heat is absorbed by the system.
Ans: True Category: Easy Section: 6.2

111. A home aquarium is an example of an open system.
Ans: True Category: Easy Section: 6.2

112. The heat of hydration (ΔH_{hydr}) of ions is always endothermic.
Ans: False Category: Medium Section: 6.7