Chapter 3: Thermochemistry

1. Which is a unit of energy?
    a. pascal
    b. newton
    c. joule
    d. watt
    e. ampere

2. For a chemical reaction, where the internal energy is given the symbol *E*, the correct statement is:
    a. E_{final} signifies the internal energy of the reactants.
    b. $E_{initial}$ signifies the internal energy of the products.
    c. $\Delta E = E_{products} - E_{reactants}$
    d. ΔE is positive if energy is released to the surroundings.
    e. ΔE is positive if energy is released by the chemical reaction.

3. A 500.0 gram sample of aluminum is initially at 25.0 $^{\circ}$C. It absorbs 32.60 kJ of heat from its surroundings. What is its final temperature, in $^{\circ}$C? (specific heat = 0.9930 J $g^{-1}\ {}^{\circ}C^{-1}$ for aluminum)
    a. 40.4 $^{\circ}$C
    b. 64.7 $^{\circ}$C
    c. 65.7 $^{\circ}$C
    d. 89.7 $^{\circ}$C
    e. 90.7 $^{\circ}$C

4. A 113.25 gram sample of gold is initially at 100.0 $^{\circ}$C. It loses 20.00 J of heat to its surroundings. What is its final temperature? (specific heat of gold = 0.129 J $g^{-1}\ {}^{\circ}C^{-1}$)
    a. 98.6 $^{\circ}$C
    b. -98.6 $^{\circ}$C
    c. 94.6 $^{\circ}$C
    d. -94.6 $^{\circ}$C
    e. 96.6 $^{\circ}$C

5. During an ***endothermic*** chemical reaction,
    a. a system becomes warmer, and the chemical substances undergo an increase in potential energy.
    b. a system becomes warmer, and the chemical substances undergo a decrease in potential energy.
    c. a system becomes cooler, and the chemical substances undergo an increase in potential energy.

d. a system becomes cooler, and the chemical substances undergo a decrease in potential energy.

e. a system becomes warmer, and additional heat is gained from the surroundings.

6. A bomb calorimeter consists of metal parts with a heat capacity of 925.0 J $^{\circ}C^{-1}$ and 1.100×10^3 grams of oil with a specific heat of 2.814 J g^{-1} $^{\circ}C^{-1}$. What is the heat capacity, in joules per degree, of the ***entire*** calorimeter?
   a. 1321 J $^{\circ}C^{-1}$
   b. 2028 J $^{\circ}C^{-1}$
   c. 3703 J $^{\circ}C^{-1}$
   d. 4020 J $^{\circ}C^{-1}$
   e. 5698 J $^{\circ}C^{-1}$

7. A closed, uninsulated system was fitted with a movable piston. Introduction of 483 J of heat caused the system to expand, doing 320 J of work in the process against a constant pressure of 101 kPa (kilopascals). What is the value of ΔE for this process?
   a. (483 + 320) joules
   b. (483 - 320) joules
   c. (320 - 483) joules
   d. 483 joules
   e. (-320 - 483) joules

8. When nitrogen gas reacts with hydrogen gas to form ammonia, 92.38 kJ of heat are given off for each mole of nitrogen gas consumed, under constant pressure and standard conditions. What is the correct value for the standard enthalpy of reaction in the thermochemical equation below when 0.750 mol of hydrogen reacts?

$$\mathbf{N_2(g) + 3H_2(\mathit{s}) \rightarrow 2\,NH_3(g)}$$

   a. +34.5 kJ
   b. -98.3 kJ
   c. +59.2 kJ
   d. -59.2 kJ
   e. -23.1 kJ

9. The thermochemical equation which is associated with ΔH_f^o, the standard enthalpy of formation for HCl(*g*), is
   a. $H(g) + Cl(g) \rightarrow HCl(g)$
   b. $H_2(g) + Cl_2(g) \rightarrow 2\,HCl(g)$
   c. $\frac{1}{2}\,H_2(g) + \frac{1}{2}\,Cl_2(g) \rightarrow HCl(g)$
   d. $H_2(g) + Cl_2(l) \rightarrow 2\,HCl(g)$
   e. $\frac{1}{2}\,H_2(g) + \frac{1}{2}\,Cl_2(l) \rightarrow HCl(g)$

10. Consider the following thermochemical equation:

$$2NO(g) + O_2(g) \rightarrow 2\ NO_2(g) \qquad \Delta H^o = -113.2\ kJ$$

Calculate ΔH^o for the reaction below:

$$4\ NO_2(g) \rightarrow 4NO(g) + 2O_2(g) \quad \Delta H^o = ??$$

a. +334.5 kJ
b. -146.19 kJ
c. +226.4 kJ
d. -509.2 kJ
e. +192.38 kJ

11. Determine the enthalpy change, ΔH, for the reaction, **$N_2(g) + 2H_2(g) \rightarrow N_2H_4(l)$,** given the following thermochemical equations:

$N_2H_4(l) + O_2(g) \rightarrow 2H_2O(l) + N_2(g)$ $\qquad \Delta H = -622.0\ kJ$

$H_2(g) + ½\ O_2(g) \rightarrow H_2O(l)$ $\qquad \Delta H = -285.9\ kJ$

a. -151.7 kJ
b. -236.2 kJ
c. +106.1 kJ
d. +50.2 kJ
e. +567.4 kJ

12. Determine the enthalpy change, ΔH, for the reaction, **$W(s) + C(s) \rightarrow WC(s)$,** given the following thermochemical equations:

$2W(s) + 3O_2(g) \rightarrow 2WO_3(s)$ $\qquad \Delta H = -1680.8\ kJ$

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

$2WC(s) + 5O_2(g) \rightarrow 2WO_3(s) + 2CO_2(g)$ $\qquad \Delta H = -2391.4\ kJ$

a. +33.3 kJ
b. -38.2 kJ
c. +106.1 kJ
d. -52.9 kJ
e. +177.4 kJ

13. The mathematical equation which expresses the first law of thermodynamics is

a. $\Delta H = \Delta E + p\Delta V$
b. $\Delta H = \Delta E - p\Delta V$
c. $\Delta H = q + w$
d. $\Delta E = q + w$
e. $\Delta H = q + \Delta E$

14. The thermochemical equation for the reaction between dinitrogen monoxide and oxygen to produce nitrogen dioxide is shown below. Write the thermochemical equation for the reaction when 1.00 mole of nitrogen dioxide is formed.

$$\mathbf{2\,N_2O(g) + 3O_2(g) \rightarrow 4NO_2(g) \qquad \Delta H^o = -28.0\ kJ}$$

a. $N_2O(g) + 3O_2(g) \rightarrow NO_2(g)$ $\Delta H^o = -28.0$ kJ
b. $N_2O(g) + O_2(g) \rightarrow NO_2(g)$ $\Delta H^o = -28.0$ kJ
c. $2\,N_2O(g) + 3O_2(g) \rightarrow 4NO_2(g)$ $\Delta H^o = -56.0$ kJ
d. $\frac{1}{2}\,N_2O(g) + \frac{3}{4}\,O_2(g) \rightarrow NO_2(g)$ $\Delta H^o = -7.00$ kJ
e. $\frac{1}{2}\,N_2O(g) + O_2(g) \rightarrow NO_2(g)$ $\Delta H^o = -14.0$ kJ

15. Given the equation for a hypothetical reaction, **3A + 4B → 4C + 7D**, and the following standard enthalpies of formation, ΔH_f^o:
A: +15.7 kJ mol^{-1} B: -86.4 kJ mol^{-1} C: -52.7 kJ mol^{-1} D: -71.6 kJ mol^{-1}
calculate the standard enthalpy of reaction, in kJ, for the reaction shown.

a. -53.6 kJ
b. -413.5 kJ
c. -515.6 kJ
d. -853.6 kJ
e. -908.4 kJ

16. The standard enthalpy of combustion for xylene, $C_8H_{10}(l)$, is -3908 kJ mol^{-1}. Using this information and the standard enthalpies of formation of the following, ΔH_f^o: $H_2O(l)$ = -285.9 kJ mol^{-1}; $CO_2(g)$ = -393.5 kJ mol^{-1}, calculate the standard enthalpy of formation of $C_8H_{10}(l)$, in kJ mol^{-1}.

a. -669.5 kJ
b. +3228.6 kJ
c. -3228.6 kJ
d. +4587.4 kJ
e. +8485.5 kJ

17. The standard enthalpy of reaction, ΔH°_{rxn} for

$$\mathbf{C_2H_2(\mathit{g}) + 2\,H_2(\mathit{g}) \rightarrow C_2H_6(\mathit{g})}$$

is -311.5 kJ mol^{-1}. Determine the value of ΔE°_{rxn} for this reaction.

a. -306.5 kJ mol^{-1}
b. -309.0 kJ mol^{-1}
c. -314.0 kJ mol^{-1}
d. -316.46 kJ mol^{-1}
e. +4646 kJ mol^{-1}