CHAPTER 5 – THERMOCHEMISTRY

Energy Changes

1. The dimensions of the SI unit of energy, the Joule (J), are

A. K
B. kg m s
C. kg m^2 s^{-2}
D. kg m^{-1} s^{-2}
E. kg m^2 s^{-1}

---

2. Natural gas, or methane, is an important fuel. Combustion of one mole of methane releases 802.3 kilojoules of energy. How much energy does that represent in kilocalories?

A. 3.36×10^3 kcal
B. 3.357 kcal
C. 191.8 kcal
D. 0.192 kcal
E. 1.918×10^5 kcal

---

3. What is the change in internal energy, ΔE, (in kJ) of a system that absorbs 100 kJ of heat and does 200 kJ of work on its surroundings?

A. +100 kJ
B. -100 kJ
C. +300 kJ
D. -300 kJ
E. none of the above

---

4. Which ONE of the following statements is NOT true?

A. The change in enthalpy for exothermic chemical reactions is negative.
B. In an exothermic reaction, the reactants are lower in enthalpy than the products.
C. An endothermic reaction is one in which enthalpy is absorbed by the system from the surroundings.
D. If $\Delta H°$ is positive in the forward direction, it will be negative in the reverse direction.
E. If the coefficients in a balanced reaction are multiplied by 2, the enthalpy change for the reaction is multiplied by 2.

---

5. Which one of the following is **NOT** an endothermic process?

A. ice melting
B. boiling soup
C. water evaporating
D. condensation of water vapor
E. dry ice subliming (evaporating without melting)

---

6. The reaction shown below is ________ and therefore heat is ________ by the reaction.

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s);\ \Delta H° = -3351 \text{ kJ}$$

A. endothermic, released
B. exothermic, absorbed
C. endothermic, absorbed
D. exothermic, released
E. none of the above

Thermochemical Equations

7. When aluminum oxide, Al_2O_3, is heated to high temperatures, it decomposes to produce aluminum metal by the following thermochemical equation:

$$2Al_2O_3(s) \rightarrow 4Al(s) + 3O_2(g);\ \Delta H° = +3352 \text{ kJ}$$

In order to produce 75.0 g of aluminum, how much heat energy will be required?

A. 9320 kJ
B. 2330 kJ
C. 1210 kJ
D. 37300 kJ
E. none of the above

---

8. In the *thermite reaction*, powdered aluminum reacts with iron(III) oxide to produce iron metal and aluminum oxide:

$$2Al(s) + Fe_2O_3(s) \rightarrow 2Fe(s) + Al_2O_3(s);\ \Delta H° = -852 \text{ kJ}$$

When this reaction is carried out, 1250. kJ of heat energy are released. How many grams of iron are also formed?

A. 82.0 g
B. 2.97×10^4 g
C. 164 g
D. 328 g
E. 9531 g

---

9. What is the enthalpy change ($\Delta H°$) for the reaction $4NaCl(s) \rightarrow 4Na(s) + 2Cl_2(g)$, if the reaction $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$ has $\Delta H° = -821.8$ kJ?

A. +1644 kJ
B. +410.9 kJ
C. -1644 kJ
D. -410.9 kJ
E. -205.5 kJ

---

10. What is the maximum amount of heat that could be generated from the following reaction, starting from 10.0 g of Al and 45.0 g of Fe_2O_3? (MM Al = 26.98 g/mol, MM Fe_2O_3 = 159.69 g/mol)

$$2Al(s) + Fe_2O_3(s) \rightarrow 2Fe(s) + Al_2O_3(s);\ \Delta H° = -852\ kJ$$

A. 158 kJ
B. 240. kJ
C. 398 kJ
D. 316 kJ
E. none of the above

Hint: This is a limiting-reactant calculation.

Specific Heat Capacity and Calorimetry

11. What is the specific heat capacity of a sample of a metal weighing 100.0 g that absorbs 10.00 kJ of heat energy when the temperature changes from 25.00ºC to 45.00ºC?

A. 0.00500 J g^{-1} $°C^{-1}$
B. 5.00 J g^{-1} $°C^{-1}$
C. 0.500 J g^{-1} $°C^{-1}$
D. 200.0 J g^{-1} $°C^{-1}$
E. 20.0 J g^{-1} $°C^{-1}$

---

12. If 10.0 kJ of heat energy is added to 45.0 g of water initially at 25.0°C, what will be the final temperature of the water? The specific heat of water is 4.18 J g^{-1} $°C^{-1}$.

A. 95.2°C
B. 45.2°C
C. 53.2°C
D. 78.2°C
E. 62.2°C

---

13. Mithril is a tough, lightweight metal mined by the dwarves in the mines of Moria. A 25.00 g sample of mithril is heated in a test tube to 100.00°C in boiling water and carefully added to a coffee-cup calorimeter containing 50.00 g of water. The water temperature increased from 25.50°C to 30.50°C. What is the specific heat capacity of mithril? (The specific heat capacity of water is 4.18 J g^{-1} $°C^{-1}$. We will ignore the energy absorbed by the calorimeter.)

A. 0.325 J g^{-1} $°C^{-1}$
B. 0.225 J g^{-1} $°C^{-1}$
C. 0.876 J g^{-1} $°C^{-1}$
D. 0.601 J g^{-1} $°C^{-1}$
E. 0.476 J g^{-1} $°C^{-1}$

Hess's Law; Heats of Reaction

14. Which ONE of the following thermochemical equations has a value of $\Delta H°$ that corresponds to the enthalpy of formation, $\Delta H_f°$?

A. $6C(s) + 6H(g) \rightarrow C_6H_6(l)$
B. $½N_2(g) + O_2(g) \rightarrow NO_2(g)$
C. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
D. $H_2O(l) + ½O_2(g) \rightarrow H_2O_2(l)$
E. $2H(g) + O(g) \rightarrow H_2O(l)$

---

15. Use Hess's law to derive the enthalpy of the following reaction:

$$N_2H_4(l) + 2H_2O_2(l) \rightarrow N_2(g) + 4H_2O(l)$$

Use the following thermochemical equations:

$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(l)$ $\Delta H = -597.0$ kJ

$H_2(g) + ½O_2(g) \rightarrow H_2O(l)$ $\Delta H = -285.8$ kJ

$H_2(g) + O_2(g) \rightarrow H_2O_2(l)$ $\Delta H = -187.8$ kJ

A. -1070.6 kJ
B. -123.4 kJ
C. -1364 kJ
D. -793.0 kJ
E. -489.8 kJ

---

16. Calculate the energy change for the following reaction, using the enthalpies of formation provided.

$$SO_2Cl_2(l) + 2H_2O(l) \rightarrow 2HCl(g) + H_2SO_4(l)$$

Substance	**$\Delta H_f°$ (kJ/mol)**
$SO_2Cl_2(l)$	-394.1
$H_2O(l)$	-285.8
$H_2O(g)$	-241.8
$HCl(g)$	-92.3
$HCl(aq)$	-167.2
$H_2SO_4(l)$	-814.0
$H_2SO_4(aq)$	-909.3

A. -105.2 kJ
B. -32.9 kJ
C. -1176.1 kJ
D. +613.4 kJ
E. -1586.2 kJ

17. Acetylene burns in air according to the following equation:

$$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(g);$$

$$\Delta H° = -2511.6 \text{ kJ}$$

Given that $\Delta H_f°$ of $O_2(g)$ is 0 kJ, $\Delta H_f°$ of $CO_2(g)$ is -393.5 kJ, and $\Delta H_f°$ of $H_2O(g)$ is -241.8 kJ, what is $\Delta H_f°$ of $C_2H_2(g)$?

A. 454 kJ
B. 227 kJ
C. -454 kJ
D. -227 kJ
E. none of the above

---

18. Which of the following statements are true?

I. q (heat) is a state function because ΔH is a state function and q = ΔH.

II. When 50.0 g of aluminum at 20.0°C is placed in 50.0 mL of water at 30.0°C, the H_2O will undergo a smaller temperature change than the aluminum. (The density of H_2O = 1.0 g/mL, the specific heat capacity of H_2O = 4.18 J/g°C, and the specific heat capacity of aluminum = 0.89 J/g°C)

III. When a gas is compressed, the work is negative since the surroundings are doing work on the system and energy flows out of the system.

IV. For the reaction (at constant pressure) $2N_2(g) + 5O_2(g) \rightarrow 2N_2O_5(g)$, the change in enthalpy is the same whether the reaction takes place in one step or in a series of steps.

A. I, II, IV
B. II, III
C. II, III, IV
D. II, IV
E. All of the above statements are true.
