

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. $\text{kg m}^2 \text{s}^{-2}$
- D. $\text{kg m}^{-1} \text{s}^{-2}$
- E. $\text{kg m}^2 \text{s}^{-1}$

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 ΔH° 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)

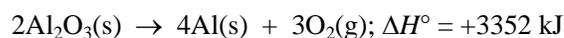
6. The reaction shown below is _____ and therefore heat is _____ by the reaction.



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

Thermochemical Equations

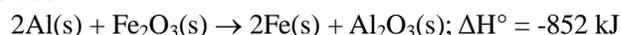
7. When aluminum oxide, Al_2O_3 , is heated to high temperatures, it decomposes to produce aluminum metal by the following thermochemical equation:



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:



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

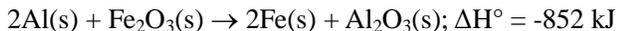
- A. 82.0 g
- B. 2.97×10^4 g
- C. 164 g
- D. 328 g
- E. 9531 g

9. What is the enthalpy change (ΔH°) for the reaction $4\text{NaCl(s)} \rightarrow 4\text{Na(s)} + 2\text{Cl}_2\text{(g)}$, if the reaction



- 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)



- 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 25.00°C to 45.00°C?

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

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 $\text{g}^{-1} \text{ }^\circ\text{C}^{-1}$.

- 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 $\text{g}^{-1} \text{ }^\circ\text{C}^{-1}$. We will ignore the energy absorbed by the calorimeter.)

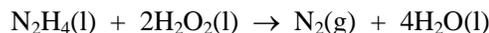
- A. 0.325 J $\text{g}^{-1} \text{ }^\circ\text{C}^{-1}$
- B. 0.225 J $\text{g}^{-1} \text{ }^\circ\text{C}^{-1}$
- C. 0.876 J $\text{g}^{-1} \text{ }^\circ\text{C}^{-1}$
- D. 0.601 J $\text{g}^{-1} \text{ }^\circ\text{C}^{-1}$
- E. 0.476 J $\text{g}^{-1} \text{ }^\circ\text{C}^{-1}$

Hess's Law; Heats of Reaction

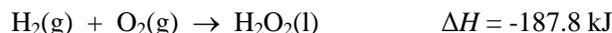
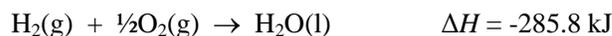
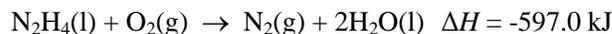
14. Which ONE of the following thermochemical equations has a value of ΔH° that corresponds to the enthalpy of formation, ΔH_f° ?

- A. $6\text{C}(s) + 6\text{H}(g) \rightarrow \text{C}_6\text{H}_6(l)$
- B. $\frac{1}{2}\text{N}_2(g) + \text{O}_2(g) \rightarrow \text{NO}_2(g)$
- C. $\text{N}_2(g) + 3\text{H}_2(g) \rightarrow 2\text{NH}_3(g)$
- D. $\text{H}_2\text{O}(l) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{H}_2\text{O}_2(l)$
- E. $2\text{H}(g) + \text{O}(g) \rightarrow \text{H}_2\text{O}(l)$

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

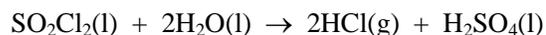


Use the following thermochemical equations:



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

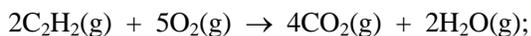
16. Calculate the energy change for the following reaction, using the enthalpies of formation provided.



Substance	ΔH_f° (kJ/mol)
$\text{SO}_2\text{Cl}_2(l)$	-394.1
$\text{H}_2\text{O}(l)$	-285.8
$\text{H}_2\text{O}(g)$	-241.8
$\text{HCl}(g)$	-92.3
$\text{HCl}(aq)$	-167.2
$\text{H}_2\text{SO}_4(l)$	-814.0
$\text{H}_2\text{SO}_4(aq)$	-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:



$$\Delta H^\circ = -2511.6 \text{ kJ}$$

Given that ΔH_f° of $\text{O}_2(\text{g})$ is 0 kJ, ΔH_f° of $\text{CO}_2(\text{g})$ is -393.5 kJ, and ΔH_f° of $\text{H}_2\text{O}(\text{g})$ is -241.8 kJ, what is ΔH_f° of $\text{C}_2\text{H}_2(\text{g})$?

- A. 454 kJ
 - B. 227 kJ
 - C. -454 kJ
 - D. -227 kJ
 - E. none of the above
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18. Which of the following statements are true?

- I. q (heat) is a state function because ΔH is a state function and $q = \Delta H$.
 - 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 $\text{H}_2\text{O} = 1.0 \text{ g/mL}$, the specific heat capacity of $\text{H}_2\text{O} = 4.18 \text{ J/g}^\circ\text{C}$, and the specific heat capacity of aluminum = $0.89 \text{ J/g}^\circ\text{C}$)
 - 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) $2\text{N}_2(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 2\text{N}_2\text{O}_5(\text{g})$, 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.
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