

Worked Answers:

$$13. \Delta H_{\text{vap (methanol)}} = 32.0 \frac{\text{g}}{\text{mol}} \times 1.18 \frac{\text{kJ}}{\text{g}} = 37.8 \text{ kJ/mol (e)}$$

$$16. \frac{120 \text{ g}}{(2 \text{ mol} \times 39.1 \text{ g/mol})} \times 160 \text{ kJ} = 246 \text{ kJ (c)}$$

CHAPTER 5 REVIEW

(Page 356)

Understanding Concepts

1.

Physical	Chemical	Nuclear
(a) change in state or change in arrangement of atoms in molecules	change in arrangement of atoms in molecules	change in arrangement of nuclei
(b) about 10 kJ/mol	about 10^3 kJ/mol	about 10^{11} kJ/mol
(c) freezing water or melting butter	burning gasoline or cooking food	uranium decay or hydrogen fusion in Sun

$$2. c = \frac{q}{m\Delta T}$$

$$= \frac{16\,000 \text{ J}}{938 \text{ g} \times (35.0^\circ\text{C} - 19.5^\circ\text{C})}$$

$$c = 1.10 \text{ J/g}\cdot^\circ\text{C}$$

The specific heat capacity of the brick is $1.10 \text{ J/g}\cdot^\circ\text{C}$.

3. We assume that no heat is lost to the environment, negligible heat is lost to the calorimeter materials unless specific information is given about the container, and dilute aqueous solutions have density and specific heat capacity of water.

$$4. q_{\text{water}} = mc\Delta T$$

$$= 500 \text{ g} \times 4.18 \text{ J/g}\cdot^\circ\text{C} \times (80^\circ\text{C} - 20^\circ\text{C})$$

$$q_{\text{water}} = 1.25 \times 10^5 \text{ J}$$

$$q_{\text{copper}} = mc\Delta T$$

$$= 2000 \text{ g} \times 0.385 \text{ J/g}\cdot^\circ\text{C} \times (80^\circ\text{C} - 20^\circ\text{C})$$

$$q_{\text{copper}} = 4.6 \times 10^4 \text{ J}$$

$$q_{\text{total}} = q_{\text{water}} + q_{\text{copper}}$$

$$q_{\text{total}} = 1.7 \times 10^5 \text{ J, or } 170 \text{ kJ}$$

170 kJ of heat is required.

$$5. m_{\text{water}} = d \times V$$

$$= 1.00 \text{ g/mL} \times 200\,000 \text{ g}$$

$$m_{\text{water}} = 2.00 \times 10^5 \text{ g}$$

$$q_{\text{water}} = mc\Delta T$$

$$= 2.00 \times 10^5 \text{ g} \times 4.18 \text{ J/g}\cdot^\circ\text{C} \times (65^\circ\text{C} - 20^\circ\text{C})$$

$$q_{\text{water}} = 3.76 \times 10^4 \text{ kJ}$$

$$n = \frac{q_{\text{water}}}{\Delta H_{\text{comb}}} = \frac{3.76 \times 10^4 \text{ kJ}}{2200 \text{ kJ/mol}}$$

$$n = 17.1 \text{ mol}$$

$$M_{\text{C}_3\text{H}_8} = 32.0 \text{ g/mol}$$

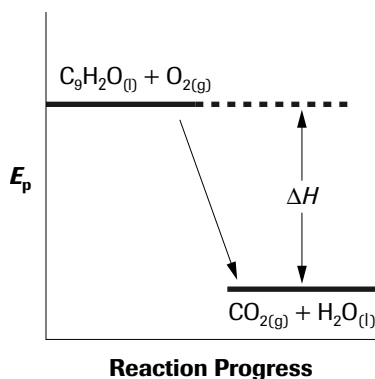
$$m_{\text{C}_3\text{H}_8} = 17.1 \text{ mol} \times 32.0 \text{ g/mol}$$

$$m_{\text{C}_3\text{H}_8} = 547 \text{ g propane}$$

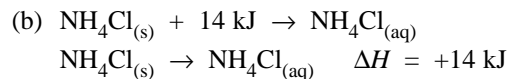
You would have to burn 547 g of propane to heat the water.

6.

Potential Energy Diagram of the Combustion of Nonane

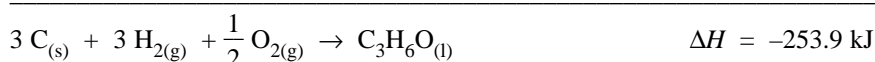
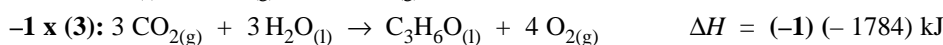
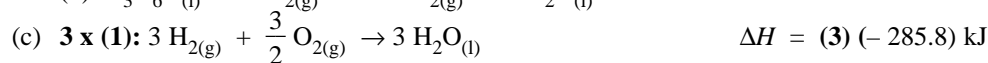
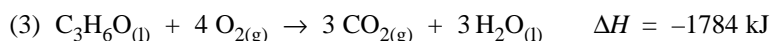
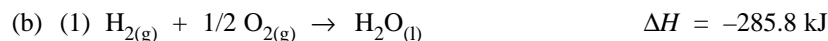
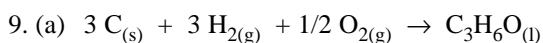
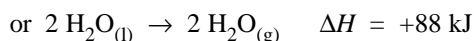
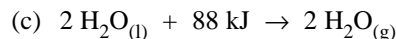
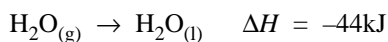
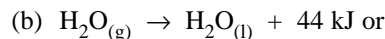
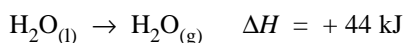


7. (a) The enthalpy changes for a reaction may be represented as an energy term in the equation, a ΔH value, the molar enthalpy, or a potential energy diagram.

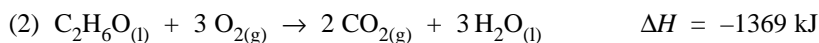
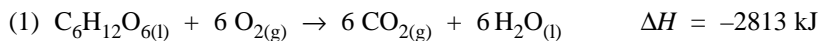


$$\Delta H_{\text{sol}}(\text{NH}_4\text{Cl}) = +14 \text{ kJ/mol}$$

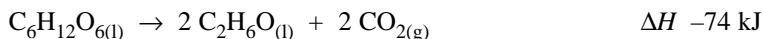
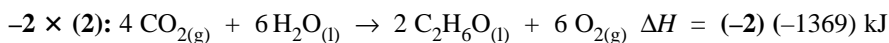
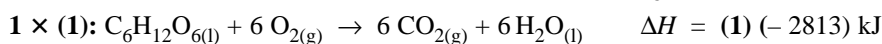
Since the reaction is endothermic, the potential energy diagram will resemble Figure 6(b) on p. 318. Reactant is ammonium chloride solid; product is aqueous ammonium chloride.



10. The known equations are:



The target equation is $\text{C}_6\text{H}_{12}\text{O}_{6(l)} \rightarrow 2 \text{C}_2\text{H}_6\text{O}_{(l)} + 2 \text{CO}_{2(g)}$



or $\Delta H_{\text{ferm}} = -74 \text{ kJ/mol glucose}$

molar mass of glucose, $M = 180 \text{ g/mol}$

$$n_{\text{glucose}} = 500 \text{ g} \times \frac{1 \text{ mol}}{180 \text{ g}}$$

$$n_{\text{glucose}} = 2.78 \text{ mol}$$

$$\Delta H = n\Delta H_{\text{ferm}}$$

$$= 2.78 \text{ mol} \times -74 \text{ kJ/mol}$$

$$\Delta H = -206 \text{ kJ}$$

The enthalpy change would be -206 kJ .

$$11. q_{\text{water}} = mc\Delta T$$

$$= 3770 \text{ g} \times 4.18 \text{ J/g}\cdot^\circ\text{C} \times (98.6 - 16.8)^\circ\text{C}$$

$$q_{\text{water}} = 1.29 \times 10^3 \text{ kJ}$$

$$n\Delta H_{\text{comb}} = q_{\text{water}}$$

$$n = \frac{q_{\text{water}}}{\Delta H_{\text{comb}}}$$

$$= \frac{1.29 \times 10^3 \text{ kJ}}{802 \text{ kJ/mol}}$$

$$n = 1.61 \text{ mol}$$

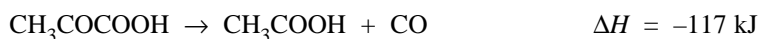
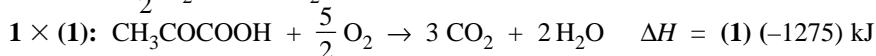
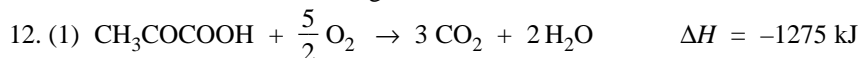
$$M_{\text{CH}_4} = 16.0 \text{ g/mol}$$

$$m = nM$$

$$= 1.61 \text{ mol} \times 16.0 \text{ g/mol}$$

$$m = 25.7 \text{ g}$$

The minimum mass of natural gas that must be burned to heat 3.77 L of water from 16.8°C to 98.6°C is 25.7 g .



13. (a) $\text{N}_{2(\text{g})} + 3 \text{H}_2\text{O}_{(\text{l})} \rightarrow 2 \text{NH}_{3(\text{g})} + 3/2 \text{O}_{2(\text{g})}$
- $$\Delta H = 2 \Delta H^\circ_{\text{f}(\text{NH}_{3(\text{g})})} + \frac{3}{2} \Delta H^\circ_{\text{f}(\text{O}_{2(\text{g})})} - 1 \Delta H^\circ_{\text{f}(\text{N}_{2(\text{g})})} - 3 \Delta H^\circ_{\text{f}(\text{H}_2\text{O}_{(\text{l})})}$$
- $$= 2(-45.9) + \frac{3}{2}(0) - 1(0) - 3(-285.8)$$
- $$\Delta H = 765.6 \text{ kJ}$$
- $$\Delta H_{\text{r}} = 765.6 \text{ kJ}/2 \text{ mol NH}_3$$
- $$\Delta H_{\text{r}} = 382.8 \text{ kJ/mol NH}_3$$
- (b) $n_{\text{ammonia}} = \frac{m}{M}$
- $$= \frac{1000 \text{ g}}{17.0 \text{ g/mol}}$$
- $$n_{\text{ammonia}} = 58.8 \text{ mol}$$
- $$\Delta H = n\Delta H_{\text{r}}$$
- $$= 58.8 \text{ mol NH}_3 \times 382.8 \text{ kJ/mol NH}_3$$
- $$\Delta H = 2.25 \times 10^4 \text{ kJ}$$
- $2.25 \times 10^4 \text{ kJ}$ of solar energy is needed to produce 1.00 kg of ammonia.

(c) area, $a = \frac{2.25 \times 10^4 \text{ kJ}}{(3.60 \times 10^3 \text{ kJ/m}^2)}$

$$a = 6.25 \text{ m}^2$$

An area of 6.25 m^2 would be needed to produce 1.00 kg of ammonia in one day.

- (d) The assumption is made that all of the solar energy will go into the reaction and none will be lost to the surroundings.

14. $2 \text{NaHCO}_{3(\text{s})} \rightarrow \text{Na}_2\text{CO}_{3(\text{s})} + \text{H}_2\text{O}_{(\text{g})} + 2 \text{CO}_{2(\text{g})} \quad \Delta H = -74 \text{ kJ}$
- $$\Delta H = 2 \Delta H^\circ_{\text{f}(\text{CO}_{2(\text{g})})} + 1 \Delta H^\circ_{\text{f}(\text{H}_2\text{O}_{(\text{g})})} + 1 \Delta H^\circ_{\text{f}(\text{Na}_2\text{CO}_{3(\text{s})})} - 2 \Delta H^\circ_{\text{f}(\text{NaHCO}_{3(\text{s})})}$$
- $$= 2(-393.5) + 1(-241.6) + 1(-1131) - 2(-947.7)$$
- $$\Delta H = -264 \text{ kJ}$$

The enthalpy change for the reaction is -264 kJ .

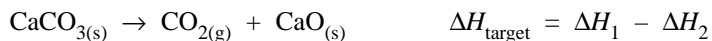
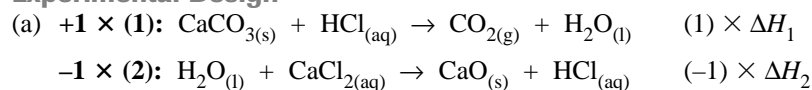
15. $\text{C}_6\text{H}_5\text{COOH}_{(\text{s})} + \frac{15}{2} \text{O}_{2(\text{g})} \rightarrow 7 \text{CO}_{2(\text{g})} + 3 \text{H}_2\text{O}_{(\text{l})}$
- $$\Delta H = 7 \Delta H^\circ_{\text{f}(\text{CO}_{2(\text{g})})} + 3 \Delta H^\circ_{\text{f}(\text{H}_2\text{O}_{(\text{l})})} - 1 \Delta H^\circ_{\text{f}(\text{acid}_{(\text{s})})} - \frac{15}{2} \Delta H^\circ_{\text{f}(\text{O}_{2(\text{g})})}$$
- $$-3223.6 = 7(-393.5) + 3(-285.8) - 1(\Delta H^\circ_{\text{f}(\text{acid}_{(\text{s})})}) - \frac{15}{2}(0)$$
- $$1(\Delta H^\circ_{\text{f}(\text{acid}_{(\text{s})})}) = 7(-393.5) + 3(-285.8) + 3223.6 \text{ kJ}$$
- $$\Delta H^\circ_{\text{f}(\text{acid}_{(\text{s})})} = -388.3 \text{ kJ/mol}$$

The molar enthalpy of formation of benzoic acid is -388.3 kJ/mol .

Applying Inquiry Skills

16. (1) $\text{CaCO}_{3(\text{s})} + 2 \text{HCl}_{(\text{aq})} \rightarrow \text{CO}_{2(\text{g})} + \text{H}_2\text{O}_{(\text{l})} + \text{CaCl}_{2(\text{aq})} \quad \Delta H_1 = ? \text{ kJ}$
- (2) $\text{CaO}_{(\text{s})} + 2 \text{HCl}_{(\text{aq})} \rightarrow \text{H}_2\text{O}_{(\text{l})} + \text{CaCl}_{2(\text{aq})} \quad \Delta H_2 = ? \text{ kJ}$
- The target equation is
- $$\text{CaCO}_{3(\text{s})} \rightarrow \text{CO}_{2(\text{g})} + \text{CaO}_{(\text{s})} \quad \Delta H = ? \text{ kJ}$$

Experimental Design



Procedure

- (b) • Find the mass of a Styrofoam cup, add about 170 mL of dilute acid, and find the mass of the cup again.
• Find the mass accurately of about 4 g of CaCO_3 solid.
• Measure the initial temperature of the acid solution.
• Add the solid to the acid and stir until a maximum temperature is reached. Record this temperature.
• Repeat the previous steps for a new cup, sample of acid, and mass of calcium oxide solid.

Analysis

- (c) In all three experiments, assume that the acid solution has the same density as water: 1 g/mL.

Experiment 1:

mass of acid solution, $m = 173.2 \text{ g} - 3.0 \text{ g}$

$$m = 170.2 \text{ g}$$

$$q_{\text{water}} = mc\Delta T$$

$$= 170.2 \text{ g} \times 4.18 \text{ J/g}\cdot^\circ\text{C} \times (31.0 - 29.0)^\circ\text{C}$$

$$q_{\text{water}} = 1.4(2) \text{ kJ}$$

$$n\Delta H_1 = q_{\text{water}}$$

$$n\Delta H_1 = 1.4(2) \text{ kJ}$$

$$n_{\text{CaCO}_3} = \frac{m}{M}$$

$$= 4.2 \text{ g CaCO}_3 \times \frac{1 \text{ mol}}{100.1 \text{ g CaCO}_3}$$

$$n_{\text{CaCO}_3} = 0.042 \text{ mol}$$

$$\Delta H_1 = \frac{q_{\text{water}}}{n_{\text{CaCO}_3}}$$

$$\Delta H_1 = \frac{1.4(2) \text{ kJ}}{0.042 \text{ mol}}$$

$$\Delta H_1 = 34 \text{ kJ/mol CaCO}_3$$

Because the reaction is exothermic and is written for one mole of CaCO_3 , $\Delta H_1 = -34 \text{ kJ}$.

Experiment 2:

mass of acid solution, $m = 158.6 \text{ g} - 3.1 \text{ g}$

$$m = 155.5 \text{ g}$$

$$q_{\text{water}} = mc\Delta T$$

$$= 155.5 \text{ g} \times 4.18 \text{ J/g}\cdot^\circ\text{C} \times (36.0 - 29.0)^\circ\text{C}$$

$$q_{\text{water}} = 4.5(5) \text{ kJ}$$

$$n\Delta H_2 = q_{\text{water}}$$

$$n\Delta H_2 = 4.5(5) \text{ kJ}$$

$$n_{\text{CaO}} = \frac{m}{M}$$

$$= 4.6 \text{ g CaO} \times \frac{1 \text{ mol}}{56.1 \text{ g CaO}}$$

$$n_{\text{CaO}} = 0.0820 \text{ mol}$$

$$\Delta H_2 = \frac{q_{\text{water}}}{n_{\text{CaO}}}$$

$$= \frac{4.5(5) \text{ kJ}}{0.0820 \text{ mol}}$$

$$\Delta H_2 = 55 \text{ kJ/mol CaO}$$

Because the reaction is exothermic and is written for one mole of CaO, $\Delta H_2 = -55 \text{ kJ}$.

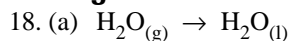
$$(d) \Delta H_{\text{target}} = \Delta H_1 - \Delta H_2$$

$$= -34 \text{ kJ} - (-55 \text{ kJ})$$

$$\Delta H_{\text{target}} = +19 \text{ kJ}$$

- (e) (i) Less solid would react, so the observed temperature change, calculated q , and ΔH would be smaller than expected.
(ii) Less heat would go into the water, so the observed temperature change, calculated q , and ΔH would be smaller than expected.
17. (a) One possibility is to burn a mass of the alcohol in a bomb calorimeter and determine its heat of combustion, which could be compared to a tabulated value. Another is to dissolve a known mass in water and determine its heat of solution, which could be compared to a tabulated value.
(b) The boiling point of the liquid could be determined. Various diagnostic organic tests could be used to confirm its identity as an alcohol. Derivatives could be made of the alcohol (for example, esters) whose melting and boiling points could be compared to tabulated values.

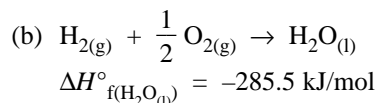
Making Connections



$$\Delta H = \Delta H^\circ_{\text{f}(\text{H}_2\text{O}_{(\text{l})})} - \Delta H^\circ_{\text{f}(\text{H}_2\text{O}_{(\text{g})})}$$

$$= (-285.8) - (-241.8)$$

$$\Delta H = -44 \text{ kJ}$$



(c) $\Delta H_{\text{fusion}} = -1.7 \times 10^9 \text{ kJ}$

(d) $\Delta H_{\text{condensation}}$ would be about $44/100 \text{ cm}$, or 0.4 cm .

$$\Delta H^\circ_{\text{f}(\text{H}_2\text{O}_{(\text{l})})}$$
 would be about $285.5/100 \text{ cm}$, or 3 cm .

$$\Delta H_{\text{fusion}}$$
 would be about $-1.7 \times 10^9/100 \text{ cm}$, or 10^8 cm , or 1000 km .

- (e) (Answers will vary.) 0.4 g is about the mass of a fingernail; 3 g is about the mass of a teaspoon of sugar; 1000 kg is about the mass of a small car.

19. Answers will vary, but could include the special demands of geography (Canada is a large country requiring transportation over great distances), temperature (Canada is a cool country requiring heating of homes and businesses), and the economy (Canada is an economically strong country with heavy industry that demands power). Furthermore, Canadians enjoy and expect a high standard of living, with many consumer goods.

