Applying Inquiry Skills

16. **Experimental Design**
    - A measured mass of the metal is added to a measured mass of dilute acid, and the temperature change in the solution is determined.
    - The heat gained by the solution is calculated using $q = mc\Delta T$.
    - The heat released per gram is calculated by dividing the heat by the mass of metal, and the result is compared to the three accepted values.

SECTION 5.1 QUESTIONS

(Page 305)

Understanding Concepts

1. Changes of state from solid to liquid, liquid to gas, and solid to gas are endothermic; changes of state from gas to liquid, liquid to solid, and gas to solid are exothermic.
2. mass, temperature change, specific heat capacity
3. (a) chemical (new products; rearrangement of atoms to new molecules)
   (b) physical (no new product; same molecules)
   (c) nuclear (uranium decays to form new atoms)
4.

System	Surroundings
(a) gasoline and oxygen	engine block and air
(b) water	air and remaining water
(c) uranium fuel	concrete

5. (a) open
   (b) open (because there is no container keeping the water vapour in contact with the liquid water)
   (c) isolated (although open if one considers the waste heat produced)
6. Energies per mol for physical, chemical, and nuclear changes are on the order of 101, 103, and 1011 kJ/mol, respectively.

Making Connections

7. See the Nelson *Chemistry 12* web site for possible useful sources of information. Bomb calorimeters are used to determine the energy content of foods, fuels, and even organisms in ecological food chains.
8. See the Nelson *Chemistry 12* web site for possible useful sources of information. Cold packs typically contain ammonium salts which, when mixed with water, absorb energy. Some hot packs contain iron filings which slowly oxidize in air and produce heat.

5.2 MOLAR ENTHALPIES

PRACTICE

(Page 308)

Understanding Concepts

1. amount of water, $n = 100.0\ \cancel{\text{g}} \times \dfrac{1\ \text{mol}}{18.0\ \cancel{\text{g}}}$

$$n = 5.56\ \text{mol}$$

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

$$= 5.56\ \cancel{\text{mol}} \times \frac{40.8\ \text{kJ}}{1\ \cancel{\text{mol}}}$$

$$\Delta H = 227\ \text{kJ}$$

2. molar mass of Freon, $M = 120.9$ g/mol

$$n_{Freon} = 500 \cancel{g} \times \frac{1 \text{ mol}}{120.9 \cancel{g}}$$

$$n_{Freon} = 4.14 \text{ mol}$$

$$\Delta H = n\Delta H_{vap}$$

$$= 4.14 \text{ mol} \times 34.99 \text{ kJ/mol}$$

$$\Delta H = 145 \text{ kJ}$$

3. amount of water, $n = 1.00 \times 10^6 \cancel{g} \times \dfrac{1 \text{ mol}}{18.0 \cancel{g}}$

$$n = 5.56 \times 10^4 \text{ mol}$$

$$\Delta H = n\Delta H_{vap}$$

$$= 5.56 \times 10^4 \text{ mol} \times 6.03 \text{ kJ/mol}$$

$$\Delta H = 3.35 \times 10^5 \text{ kJ}$$

PRACTICE

(Page 310)

Understanding Concepts

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

$$= 150 \text{ g} \times 4.18 \text{ J/g•°C} \times (20.4 - 16.7)\text{°C}$$

$$q_{water} = 2320 \text{ J, or } 2.32 \text{ kJ}$$

molar mass of urea, $M = 60.0$ g/mol

$$n_{urea} = 10.0 \cancel{g} \times \frac{1 \text{ mol}}{60 \cancel{g}}$$

$$n_{urea} = 0.167 \text{ mol}$$

$$n\Delta H_{solution} = q_{water}$$

$$\Delta H_{solution} = \frac{q_{water}}{n_{urea}}$$

$$= \frac{2.32 \text{ kJ}}{0.167 \text{ mol}}$$

$$\Delta H_{solution} = 13.9 \text{ kJ/mol}$$

Because the reaction is endothermic, $\Delta H_{solution}$ is +13.9 kJ/mol.

5. $q_{water} = mc\Delta T$

$$= 50.0 \text{ g} \times 4.18 \text{ J/g•°C} \times (27.8 - 24.0)\text{°C}$$

$$q_{water} = 794 \text{ J}$$

molar mass of gallium, $M = 69.72$ g/mol

$$n_{gallium} = 10.0 \text{ g} \times 1 \text{ mol/ } 69.72 \text{ g}$$

$$n_{gallium} = 0.143 \text{ mol}$$

$$n\Delta H_{solution} = q_{water}$$

$$\Delta H_{solution} = \frac{q_{water}}{n_{gallium}}$$

$$= \frac{794 \text{ J}}{0.143 \text{ mol}}$$

$$\Delta H_{solution} = 5.54 \times 10^3 \text{ J/mol or } 5.54 \text{ kJ/mol}$$

Because the reaction is exothermic, $\Delta H_{solution}$ is − 5.54 kJ/mol.

PRACTICE

(Page 311)

Understanding Concepts

6. No heat is transferred to the outside environment; negligible heat is transferred to calorimeter materials; dilute aqueous solutions have the same specific heat capacity as water.
7. (a) $\Delta H_{\text{vaporization}}$

   (b) $\Delta H_{\text{sublimation}}$

   (c) $\Delta H_{\text{solution}}$

   (d) $\Delta H_{\text{combustion}}$

   (e) $\Delta H_{\text{neutralization}}$

Applying Inquiry Skills

8. Certainty is limited by the balance used to measure masses of reactants and solutions, graduated cylinders or other containers used to measure volumes of water and solutions, and thermometers used to measure temperature.
9. (a) $q_{\text{water}} = mc\Delta T$

   $= 500 \text{ g} \times 4.18 \text{ J/g}\bullet°\text{C} \times (21.8 - 19.2)°\text{C}$

   $q_{\text{water}} = 5434 \text{ J, or } 5.43 \text{ kJ}$

   amount of $HCl_{(aq)}$, $n = MV$

   $= 11.6 \text{ mol/L} \times 0.0431 \text{ L}$

   $n = 0.500 \text{ mol}$

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

   $\Delta H_{\text{dilution}} = \dfrac{q_{\text{water}}}{n}$

   $= \dfrac{5.43 \text{ kJ}}{0.500 \text{ mol}}$

   $\Delta H_{\text{dilution}} = 10.9 \text{ kJ/mol}$

   Because the reaction is exothermic, $\Delta H_{\text{dilution}}$ is -10.9 kJ/mol.

   (b) The observed temperature increase would be too small, making the calculated ΔH too small.

   (c) The large amount of heat can cause the water to boil rapidly and spatter the acid solution about.

10. **Analysis**

    Assume 2.0 L of solution is 2000 g water.

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

    $= 2000 \text{ g} \times 4.18 \text{ J/g}\bullet°\text{C} \times (29.1 - 26.0)°\text{C}$

    $q_{\text{water}} = 25.9 \text{ kJ}$

    amount of $Ba(NO_3)_{2(aq)}$, $n = 261 \text{ g} \times \dfrac{1 \text{ mol}}{261.3 \text{ g}}$

    $n = 1.00 \text{ mol}$

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

    $\Delta H_{\text{reaction}} = \dfrac{q_{\text{water}}}{n}$

    $= \dfrac{25.9 \text{ kJ}}{1.00 \text{ mol}}$

    $\Delta H_{\text{reaction}} = 25.9 \text{ kJ/mol } Ba(NO_3)_{2(aq)}$

    Because the reaction is exothermic, $\Delta H_{\text{reaction}}$ is -26 kJ/mol.

SECTION 5.2 QUESTIONS

(Page 312)

Understanding Concepts

1. (a) $q = n\Delta H_{comb}$

$= 5.0 \text{ mol} \times 1.56 \text{ MJ/mol}$

$q = 7.8 \text{ MJ}$

(b) molar mass of ethane, (C_2H_6) = 30.0 g/mol

$q = n\Delta H°_{comb}$

$= 40.0 \text{ g} \times (1 \text{ mol/ } 30.0 \text{ g}) \times (1.56 \text{ MJ/mol})$

$q = 2.08 \text{ MJ}$

2. $q_{water} = n\Delta H°_{solution}$

$= 40.0 \text{ g } NH_4Cl \times 1 \text{ mol/}53.5 \text{ g} \times 14.8 \text{ kJ/mol}$

$q_{water} = 11.1 \text{ kJ}$

$$\Delta T = \frac{q}{mc}$$

$$= \frac{11\,100}{(200.0 \times 4.18)}$$

$\Delta T = 13.2°C$

Since the dissolving is endothermic, the temperature of the water will fall.

$T_f = T_i - \Delta T$

$= 25 - 13$

$T_f = 12°C$

3. $q_{water} = mc\Delta T$

$= 500.0 \text{ g} \times 4.18 \text{ J/g•°C} \times (55.0 - 20.0)°C$

$q_{water} = 71\,750 \text{ J} = 0.0718 \text{ MJ}$

molar mass of decane, $M = 142 \text{ g}$

$n\Delta H_{combustion} = q_{water}$

amount of decane, $n = \dfrac{q}{\Delta H_{combustion}}$

$$= \frac{0.0718 \text{ MJ}}{6.78 \text{ MJ/mol}}$$

$n = 0.0106 \text{ mol}$

mass decane, $m = 0.0106 \text{ mol} \times 142 \text{ g/mol}$

$m = 1.50 \text{ g}$

4. molar mass of salt, $M = 322.1 \text{ g/mol}$

amount of salt, $n = 1000 \text{ g} \times (1 \text{ mol/}322.1 \text{ g})$

$n = 3.10 \text{ mol}$

$\Delta H = n\Delta H_{solid}$

$= 3.10 \text{ mol} \times 78.0 \text{ kJ/1 mol}$

$\Delta H = 242 \text{ kJ}$

Applying Inquiry Skills

5. Assume that 200 mL of solution is 200 g water.

$q_{water} = mc\Delta T$

$= 200\text{ g} \times 4.18\text{ J/g•°C} \times (28.1 - 21.0)\text{°C}$

$q_{water} = 5.94\text{ kJ}$

amount of KOH $= n$

$= 5.2\text{ g} \times 1\text{ mol}/56.1\text{ g}$

$n = 0.0927\text{ mol}$

$n\Delta H_{reaction} = q_{water}$

$$\Delta H_{reaction} = \frac{q_{water}}{n}$$

$$= \frac{5.94\text{ kJ}}{0.0927\text{ mol}}$$

$\Delta H_{reaction} = 64\text{ kJ/mol } Ba(NO_3)_2$

Because the reaction is exothermic, $\Delta H_{reaction}$ is -64 kJ/mol.

6. Answers will vary, but the student could use a polystyrene (Styrofoam) coffee cup calorimeter and thermometer to investigate temperature changes that occurred when the dextrose tablets were added to water. A mortar and pestle might be used to simulate the grinding process that occurs in chewing. Ambitious students might even investigate whether there was any effect of amylase (found in saliva) on the process.

Making Connections

7. See the Nelson *Chemistry 12* web site for possible useful sources of information. In general, the propane is used to vaporize and separate the components of an aqueous ammonia mixture. The ammonia gas then goes through cycles of condensation (outside the compartment, releasing heat to the air) and evaporation inside the compartment (absorbing heat from food).

5.3 REPRESENTING ENTHALPY CHANGES

PRACTICE

(Page 319)

Understanding Concepts

1. (a) $2\ C_{(s)} + H_{2(g)} + 228\text{ kJ} \rightarrow C_2H_{2(g)}$

$2\ C_{(s)} + H_{2(g)} \rightarrow C_2H_{2(g)} \quad \Delta H = +228\text{ kJ}$

$\Delta H°_f = +228$ kJ/mol acetylene