

## CHAPTER 5 THERMOCHEMISTRY

### Reflect on Your Learning

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1. Absorbing energy: ice melting, water evaporating, photosynthesis.  
Releasing energy: water vapour condensing, respiration, combustion of gasoline.
2. Nuclear power plants, fossil fuel-burning power plants, hydroelectric power (largely from Niagara), solar power.
3. Both technologies drive turbines to generate electricity, but one uses falling water to drive the turbine and the other uses nuclear energy to create pressurized steam to drive the turbine.

### Try This Activity: Burning Food

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- (a) Use  $q = mc\Delta T$  with student data.
- (b) The heat released equalled the difference in potential energy of the reactants and products.
- (c) Divide the heat by the mass of the nut.
- (d) The reactants would be the same but the nut might not be completely digested, so there would be products other than carbon dioxide and water. The energy might be stored rather than released to the surroundings as heat. The process would be more efficient in terms of production of energy in useful forms, rather than heat.
- (e) Much heat is lost to the surroundings, apart from the water in the can. Insulating the apparatus would improve results.

## 5.1 CHANGES IN MATTER AND ENERGY

### PRACTICE

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#### Understanding Concepts

1. (a) chemical (new products: water and carbon dioxide)  
(b) physical (no new products)  
(c) chemical (new products: water and carbon dioxide)  
(d) physical (no new products)  
(e) chemical (new products: hydrogen gas and zinc chloride)  
(f) physical (no new products)
- 2.

System	Surroundings
(a) gas and oxygen	air and metal parts
(b) ice	hand
(c) gas and oxygen	air and metal parts
(d) wax	stove
(e) zinc and acid	beaker and water solvent
(f) ice	body part

3. All of these systems may be regarded as open because energy and/or matter may escape from the system, often in the form of gases. However, (a) may be considered a closed system for the instant at which the air–fuel mixture ignites.
4. The thimbleful has greater average thermal energy per molecule, but the pool has greater total thermal energy.
5. (a) exothermic  
(b) exothermic  
(c) endothermic

## Making Connections

6. (a) Answers could include biological examples such as:
- cellular respiration (chemical, exothermic, open);
  - combustion of fuel examples such as burning gasoline (chemical, exothermic, open);
  - change of state examples such as boiling water (physical, endothermic, open) or condensation (physical, exothermic, open);
  - household processes such as the use of drain cleaner (physical, exothermic, open).
- (b) Exothermic reactions are more common.
7. (a) 1 calorie = 4.18 J; 1 Calorie = 1000 calories = 4.18 kJ.
- (b) The reaction is controlled oxidation of food: a “slow burn” that releases energy.
- (c) Bomb calorimetry is used.

## PRACTICE

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### Understanding Concepts

8. Aluminum has the lowest specific heat capacity, which implies that it requires the least amount of heat to change temperature, and will undergo the greatest temperature change.

9.  $q = mc\Delta T$

$$= 1.50 \text{ kg} \times 4.18 \text{ kJ}/(\text{kg}\cdot^{\circ}\text{C}) \times (98.7 - 18.0)^{\circ}\text{C}$$

$$q = 506 \text{ kJ}$$

10.  $m = \frac{q}{(c\Delta T)}$

$$= 80\,000 \text{ J}/(4.18 \text{ kJ}/(\text{kg}\cdot^{\circ}\text{C}) \times 50^{\circ}\text{C})$$

$$m = 383 \text{ g}$$

11.  $\Delta T = \frac{q}{(mc)}$

$$= 250\,000 \text{ J}/(4000 \text{ g} \times 3.5 \text{ J}/(\text{g}\cdot^{\circ}\text{C}))$$

$$\Delta T = 18^{\circ}\text{C}$$

12. (a)  $q = mc\Delta T$

$$= 100 \text{ kg} \times 4.18 \text{ kJ}/(\text{kg}\cdot^{\circ}\text{C}) \times (45 - 10)^{\circ}\text{C}$$

$$q = 1.5 \times 10^4 \text{ kJ, or } 15 \text{ MJ}$$

(b) money saved =  $14.6 \text{ MJ} \times 0.351\text{¢}/\text{MJ} \times 1500$

$$= 7.7 \times 10^3\text{¢, or } \$77$$

13. (a)  $q = mc\Delta T$

$$= 100 \text{ kg} \times 4.18 \text{ kJ}/(\text{kg}\cdot^{\circ}\text{C}) \times (75 - 45)^{\circ}\text{C}$$

$$q = 1.0 \times 10^4 \text{ kJ, or } 10 \text{ MJ}$$

(b) money saved =  $10 \text{ MJ} \times 0.351\text{¢}/\text{MJ} \times 1500$

$$= 5.5 \times 10^3\text{¢, or } \$55$$

## PRACTICE

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### Understanding Concepts

14. When a change occurs in a system, the potential energy change ( $\Delta H$ ) of the system is numerically equal to the change in thermal kinetic energy ( $q$ ) of the surroundings.
15. Chemical changes have generally greater enthalpy changes than physical changes; nuclear changes have much greater enthalpy changes than chemical changes.

## 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

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### 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 10<sup>1</sup>, 10<sup>3</sup>, and 10<sup>11</sup> 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

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### Understanding Concepts

1. amount of water,  $n = 100.0 \text{ g} \times \frac{1 \text{ mol}}{18.0 \text{ g}}$   
 $n = 5.56 \text{ mol}$   
 $\Delta H = n\Delta H_{\text{vap}}$   
 $= 5.56 \text{ mol} \times \frac{40.8 \text{ kJ}}{1 \text{ mol}}$   
 $\Delta H = 227 \text{ kJ}$