Making Connections

6. Consumer products from propylene include antifreeze, cellophane, solvents, perfumes, colouring agents, coolants, hydraulic fluids, preservatives, cleansing creams, pharmaceuticals, brake fluids, detergents, and synthetic lubricants, to name just a few. It is probable that any of these products can be manufactured from other materials — but is also probable that such a substitution would result in a product that was more expensive and/or less effective.

SECTION 12.4 QUESTIONS

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Understanding Concepts

1. The burning of fossil fuels has applications for: producing electricity; heating homes and offices; and for powering automobiles, trucks, ships, and planes.
2. Burning hydrocarbons creates pollution and global warming risks, but is far and away the cheapest current source of energy for society.
3. About 95% of fossil fuel is burned for energy, and about 5% is used for petrochemicals.
4. A majority of all the consumer products used in our society originate with petrochemicals.
5. Plastics make durable, lightweight, and inexpensive consumer products. They also do not biodegrade, in most cases, and so present a long-term disposal problem.

CHAPTER 12 SUMMARY

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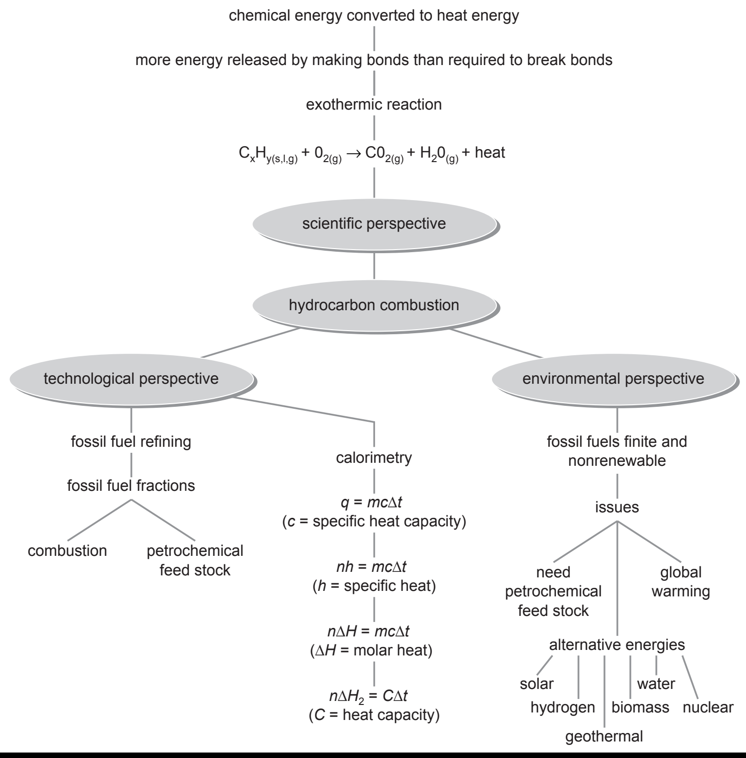

CHAPTER 12 REVIEW

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Understanding Concepts

1. Energy from food digestion keeps us alive; energy from combustion heats our homes and powers our vehicles.

2. Alternative energy sources and resources include solar, hydro (water), wind, nuclear, geothermal, and biomass energy.
3. Temperature is related to the average value of the kinetic energy of the particles in a sample. Heat is related to the change in the total of the kinetic energy of the particles in a sample.
4.

Quantity	Quantity symbol	SI Unit
specific heat capacity	c	J/(g · °C)
heat capacity	C	J/°C
specific heat	h	J/g
temperature change	Δt	°C
heat	q	J
heat of reaction	q_r	J
molar heat of reaction	ΔH_r	J/mol

5. $q = ?$

$m = 2.57$ kg

$c = 4.18$ J/(g · °C)

$\Delta t = |95.0°C - 3.0°C| = 92.0°C$

$$q = mc\Delta t$$
$$= 2.57\ \text{k}\cancel{\text{g}} \times \frac{4.18\ \text{J}}{\cancel{\text{g}} \cdot \cancel{°\text{C}}} \times 92.0\cancel{°\text{C}}$$
$$q = 988\ \text{kJ}$$

The quantity of heat energy entering the water is 988 kJ.

6. $q = 1.75$ MJ

$m = 12.5$ kg

$c = 4.18$ J/(g · °C)

$\Delta t = ?$

$$q = mc\Delta t$$
$$\Delta t = \frac{q}{mc}$$
$$\Delta t = \frac{1.75\ \text{M}\cancel{\text{J}}}{12.5\ \text{k}\cancel{\text{g}} \times \frac{4.18\ \cancel{\text{J}}}{\cancel{\text{g}} \cdot °\text{C}}}$$
$$\Delta t = 33.5°\text{C}$$

The temperature increase of the water is 33.5°C, so the final temperature is (5.0 + 33.5)°C = 38.5°C.

7. (a) All calorimeters have a container, a substance to transfer heat to/from, and a thermometer.
   (b) The law of conservation of energy is fundamental to calorimeter calculation.
   (c) The main assumptions made when using a simple lab calorimeter are that the calorimeter materials have negligible heat effect, and that no heat is transferred to/from the environment.
8. The energy change of a reaction can be communicated as a specific heat of reaction or as a molar heat of reaction.
9. Reactant(s) plus energy produces product(s) endothermic
   Reactant(s) produces product(s) plus energy exothermic
10. (a) Burning a mole of butane will release 2657 kJ of thermal energy.
    (b) $C_4H_{10(g)} + 13/2\ O_{2(g)} \rightarrow 4\ CO_{2(g)} + 5\ H_2O_{(g)} + 2657\ \text{kJ}$

    or $2\ C_4H_{10(g)} + 13\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 10\ H_2O_{(g)} + 5314\ \text{kJ}$

11. m_r = ? (reactant — methane)

h_r = 50.0 kJ/g

m = 3.77 $\cancel{L}$ × 1 kg/$\cancel{L}$ = 3.77 kg (water in calorimeter)

c = 4.18 J/(g · ºC)

Δt = $|98.6ºC - 16.8ºC|$ = 81.8ºC

$$\Delta E_r = q$$

$$m_r h_r = mc\Delta t$$

$$m_r = \frac{mc\Delta t}{h_r}$$

$$m_r = \frac{3.77\ \cancel{kg} \times \frac{4.18\ \cancel{J}}{\cancel{g} \cdot º\cancel{C}} \times 81.8º\cancel{C}}{\frac{50.g\ \cancel{kJ}}{g}}$$

$$m_r = 25.8\ g$$

The mass of natural gas required is 25.8 g.

12. m_r = ? (reactant – gasoline)

h_r = 11.4 kJ/g

C = 105 kJ/°C (engine)

c = 4.18 J/(g · ºC)

Δt = $|120ºC - 18ºC|$ = 102ºC

$$\Delta E_r = q$$

$$m_r h_r = C\Delta t$$

$$m_r = \frac{C\Delta t}{h_r}$$

$$m_r = \frac{105\ \frac{\cancel{kJ}}{º\cancel{C}} \times 102\ º\cancel{C}}{11.4\ \frac{\cancel{kJ}}{g}}$$

$$m_r = 939\ g$$

The mass of gasoline required is 939 g.

13. m = 3.00 g

h_c = ? (butter)

C = 9.22 kJ/ºC

Δt = $|31.89ºC - 19.62ºC|$ = 12.27ºC

$$\Delta E_c = q$$

$$mh_c = C\Delta t$$

$$h_c = \frac{C\Delta t}{m}$$

$$= \frac{\frac{9.22\ kJ}{º\cancel{C}} \times 12.27º\cancel{C}}{3.00\ g}$$

$h_c = 37.7 \text{ kJ/g}$

The specific heat of combustion of butter is an exothermic 37.7 kJ/g.

14. $h_c = 46 \text{ kJ/g}$ (propane, $C_3H_{8(g)}$)

$M = 44.11 \text{ g/mol}$

$\Delta H_c = ?$

$$\Delta H_c = \frac{46 \text{ kJ}}{\cancel{\text{g}}} \times \frac{44.11 \cancel{\text{g}}}{1 \text{ mol}}$$

$$\Delta H_c = 2.0 \times 10^3 \text{ kJ/mol} = 2.0 \text{ MJ/mol}$$

The molar heat of combustion of propane is an exothermic 2.0 MJ/mol.

$C_3H_{8(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)} + 2.0 \text{ MJ}$

15. (a) $\Delta H_r = \frac{746 \text{ kJ}}{2 \text{ mol}}$ (2 is an exact value ...)

$\Delta H_r = 373 \text{ kJ/mol}$ (nitrogen monoxide)

The molar heat of reaction of nitrogen monoxide is an exothermic 373 kJ/mol.

(b) $m = 500 \text{ g}$ (nitrogen monoxide, $NO_{(g)}$)

$M = 30.01 \text{ g/mol}$

$\Delta H_r = 373 \text{ kJ/mol}$

$q = ?$

$$n_{NO} = 500 \cancel{\text{g}} \times \frac{1 \text{ mol}}{30.01 \cancel{\text{g}}}$$

$$n_{NO} = 16.7 \text{ mol}$$

$$q = 16.7 \cancel{\text{mol}} \times \frac{373 \text{ kJ}}{1 \cancel{\text{mol}}}$$

$$q = 6.21 \times 10^3 \text{ kJ} = 6.21 \text{ MJ}$$

The heat released to the surroundings by the reaction of 500 g of nitrogen monoxide is 6.21 MJ.

16. (a) H—H and O—O covalent bonds break, and H—O covalent bonds form. Bond formation involves more energy (exothermic).

(b) H—H and I—I covalent bonds break, and H—I covalent bonds form. Bond breaking involves more energy (endothermic).

(c) Ca—Cl ionic bonds break, and dipole–dipole and hydrogen bonds form. Bond formation involves more energy (exothermic).

Applying Inquiry Skills

17. **Analysis**

(a) **Trial 1**

$m = 1.035 \text{ g}$

$C = 9.68 \text{ kJ/°C}$

$h_c = ?$ (combustion of decane, $C_{10}H_{22(l)}$)

$\Delta t = |28.92°C - 23.85°C| = 5.07°C$

$$\Delta E_c = q$$

$$mh_c = C\Delta t$$

$$h_c = \frac{C\Delta t}{m}$$

$$= \frac{\frac{9.68\ \text{kJ}}{°\cancel{\text{C}}} \times 5.07°\cancel{\text{C}}}{1.035\ \text{g}}$$

$$h_c = 47.4\ \text{kJ/g}$$

Trial 2

$m = 1.054$ g

$C = 9.68$ kJ/°C

$h_c = ?$ (combustion of decane, $C_{10}H_{22(l)}$)

$\Delta th = |30.06°C - 24.91°C| = 5.15°C$

$$\Delta E_c = q$$

$$mh_c = C\Delta t$$

$$h_c = \frac{C\Delta t}{m}$$

$$h_c = \frac{\frac{9.68\ \text{kJ}}{°\cancel{\text{C}}} \times 5.15°\cancel{\text{C}}}{1.054\ \text{g}}$$

$$h_c = 47.3\ \text{kJ/g}$$

Trial 3

$m = 1.046$ g

$C = 9.68$ kJ/°C

$h_c = ?$ (combustion of decane, $C_{10}H_{22(l)}$)

$\Delta t = |30.10°C - 24.99°C| = 5.11°C$

$$\Delta E_c = q$$

$$mh_c = C\Delta t$$

$$h_c = \frac{C\Delta t}{m}$$

$$h_c = \frac{\frac{9.68\ \text{kJ}}{°\cancel{\text{C}}} \times 5.11°\cancel{\text{C}}}{1.046\ \text{g}}$$

$$h_c = 47.3\ \text{kJ/g}$$

Average of 3 trials: (47.4 + 47.3 + 47.3)/3 kJ/g = 47.3 kJ/g

The exothermic specific heat of combustion of decane is 47.3 kJ/g.

(b) The reaction is exothermic because heat is transferred to the surroundings, increasing the temperature in the calorimeter.

(c) $h_c = 47.3$ kJ/g (combustion of decane, $C_{10}H_{22(l)}$)

$M = 142.32$ g/mol

$\Delta H_c = ?$

$$\Delta H_c = \frac{47.3\ \text{kJ}}{\cancel{\text{g}}} \times \frac{142.32\ \cancel{\text{g}}}{1\ \text{mol}}$$

$$\Delta H_c = 6.74 \times 10^3\ \text{kJ/mol} = 6.74\ \text{MJ/mol}$$

18. **Analysis**

(a) **Trial 1** — ammonium chloride, $NH_4Cl_{(s)}$

$m = 10.37\ \text{g}$

$h_s = ?$ (of solution)

$m_w = 250\ \cancel{\text{mL}} \times 1\ \text{g}/\cancel{\text{mL}} = 250\ \text{g}$ (calorimeter water)

$c = 4.18\ \text{J/(g} \cdot \text{°C)}$

$t = |20.41\text{°C} - 23.15\text{°C}| = 2.74\text{°C}$

$$\Delta E_s = q$$

$$mh_s = m_w c \Delta t$$

$$h_s = \frac{m_w c \Delta t}{m}$$

$$h_s = \frac{250\ \cancel{\text{g}} \times \dfrac{4.18\ \text{J}}{\cancel{\text{g}} \cdot \cancel{\text{°C}}} \times 2.74\cancel{\text{°C}}}{10.37\ \text{g}}$$

$$h_s = 276\ \text{J/g}$$

The endothermic specific heat of solution of ammonium chloride, $NH_4Cl_{(s)}$, is 276 J/g.

Trial 2 — ammonium bromide, $NH_4Br_{(s)}$

$m = 9.97\ \text{g}$

$h_s = ?$ (of solution)

$m_w = 250\ \cancel{\text{mL}} \times 1\ \text{g}/\cancel{\text{mL}} = 250\ \text{g}$ (calorimeter water)

$c = 4.18\ \text{J/(g} \cdot \text{°C)}$

$\Delta t = |21.74\text{°C} - 23.37\text{°C}| = 1.63\text{°C}$

$$\Delta E_s = q$$

$$mh_s = m_w c \Delta t$$

$$h_s = \frac{m_w c \Delta t}{m}$$

$$h_s = \frac{250\ \cancel{\text{g}} \times \dfrac{4.18\ \text{J}}{\cancel{\text{g}} \cdot \cancel{\text{°C}}} \times 1.63\cancel{\text{°C}}}{9.97\ \text{g}}$$

$$h_s = 171\ \text{J/g}$$

The endothermic specific heat of solution of ammonium bromide, $NH_4Br_{(s)}$, is 171 J/g.

Trial 3 – ammonium iodide, $NH_4I_{(s)}$

$m = 10.00\ \text{g}$

$h_s = ?$ (of solution)

$m_w = 250\ \cancel{\text{mL}} \times 1\ \text{g}/\cancel{\text{mL}} = 250\ \text{g}$ (calorimeter water)

$c = 4.18\ \text{J/(g} \cdot \text{°C)}$

Δt = $|21.99°C - 22.90°C|$ = 0.91°C

$$\Delta E_s = q$$

$$mh_s = m_w c\Delta t$$

$$h_s = \frac{m_w c\Delta t}{m}$$

$$h_s = \frac{250\ \cancel{g} \times \frac{4.18\ J}{\cancel{g} \cdot \cancel{°C}} \times 0.91\cancel{°C}}{10.00\ g}$$

$$h_s = 95\ J/g$$

The endothermic specific heat of solution of ammonium iodide, $NH_4I_{(s)}$, is 95 J/g.

(b) The greatest endothermic specific heat of solution is for the ammonium chloride, $NH_4Cl_{(s)}$, at 276 J/g.

19. **Analysis**

(a) m = 1.05 g

C = 8.35 kJ/°C

h_c = ? (combustion of palmitic acid, $HC_{16}H_{31}O_{2(s)}$)

Δt = $|28.05°C - 23.15°C|$ = 4.90°C

$$\Delta E_c = q$$

$$mh_c = C\Delta t$$

$$h_c = \frac{C\Delta t}{m}$$

$$h_c = \frac{\frac{8.35\ kJ}{\cancel{°C}} \times 4.90\cancel{°C}}{1.05\ g}$$

$$h_c = 39.0\ kJ/g$$

The exothermic specific heat of combustion of the palmitic acid is 39.0 kJ/g.

Evaluation

(b) A single measurement does not give acceptable certainty for a laboratory investigation.

(c) The experiment should involve at least three trials, with variables kept as similar as possible.

20. A specific heat of reaction value would be more useful in a situation where the quantity of substance is measured by mass. A molar heat of reaction value would be more useful in a situation where the quantity of substance is measured by amount, for example, when working with a balanced equation, which is read in moles.

Making Connections

21. (a) q = ?

v = $(10.00 \times 11.00 \times 2.40)\ m^3 = 264\ m^3$

c = $1.2\ kJ/(m^3 \cdot °C)$ (air)

Δt = $|22.5°C - (-15.0)°C|$ = 37.5°C

$$q = mc\Delta t$$

$$= 264\ \cancel{m^3} \times \frac{1.2\ kJ}{\cancel{m^3} \cdot \cancel{°C}} \times 37.5\cancel{°C}$$

$$q = 1.2 \times 10^4\ kJ = 12\ MJ$$

The quantity of heat entering the air is 12 MJ.

(b) The simple, inexpensive ways to conserve home heating energy are to reduce water heater temperature, set the thermostat down when away or asleep, and to caulk and/or weatherstrip air-leak locations.

(c) Students normally find that doors, windows, and electrical outlets are areas of air leakage.

22. Diesel fuel is used for some automobiles. Diesel engines are more efficient and very durable, but diesel fuel is more polluting than gasoline.

    Propane is also used for some automobiles. Propane is less expensive and very clean-burning, but provides less power than gasoline, must be stored in a tank under high pressure, and creates a severe explosion hazard if it leaks.

    Other alternatives under consideration for automobile fuel are methanol and hydrogen and electricity. Methanol can be produced from renewable biomass, but is very toxic and does not provide good power. Hydrogen burns with no pollution at all, producing only water vapour, but is very difficult to produce, liquify, and transport. Electric cars are simple and nonpolluting, but batteries are very heavy and expensive, and don't provide much power.

UNIT 5 REVIEW

(Page 600)

Understanding Concepts

1. Organic chemistry deals with all of the many compounds of carbon, except for carbon oxides and ions containing carbon.
2. Baking soda (b), and dry ice (e), are not organic compounds.
3. (a) The major source of hydrocarbons is petroleum.
   (b) The term fossil fuel refers to compounds formed over geologic time by heat and pressure on sediments of living materials deep in the Earth.
4. Crude oil is heated until most of it vaporizes, and is then gradually cooled in a tall tower. As compounds in the vapour stream liquify, they are separated into liquid fractions of the original oil.
5. (a) Cracking, which breaks larger molecules into smaller ones, and reforming, which produces larger molecules from smaller ones, can both be used to produce molecules of the desired sizes for gasoline.
   (b) Catalysts are used in reactions to make them occur much faster, producing more product in less time.
6. (a) cracking $C_{15}H_{32(l)} \rightarrow C_7H_{14(l)} + C_8H_{18(l)}$
   (b) combustion $C_4H_{10(g)} + 13/2\ O_{2(g)} \rightarrow 4\ CO_{2(g)} + 5\ H_2O_{(g)}$
   (c) reforming $C_4H_{10(g)} + C_3H_{6(g)} \rightarrow C_7H_{16(l)}$
   (d) combustion $C_5H_{12(g)} + 8\ O_{2(g)} \rightarrow 5\ CO_{2(g)} + 6\ H_2O_{(g)}$
   (e) cracking $C_{16}H_{34(l)} \rightarrow C_8H_{18(l)} + C_8H_{16(l)}$
7. Breaking bonds requires energy transfer to a chemical system, while forming new bonds transfers energy from the system. A reaction is endothermic or exothermic depending on which process involves the greater amount of energy. A net loss of energy by the system is an exothermic change, and a net gain of energy by the system is an endothermic change.
8. Compounds (c) and (e) could be aliphatic alkanes. Compounds (a) and (d) could be cycloalkanes.
9. (a) The great number of known compounds of carbon is explained by chemists as resulting from the combination of these atomic properties:
   (i) Carbon is a small atom that can form four bonds, more than atoms of most other elements.
   (ii) Carbon atoms have the special property of being able to bond together repeatedly to form chains, rings, spheres, sheets, and tubes.
   (iii) Carbon can form multiple combinations of single, double, and triple covalent bonds with itself and with atoms of other elements.

(b) $CH_3—CH_2—CH_2—CH_3$ butane

