Energy

Kinetic: Mechanical – moving car
Thermal – moving molecules
Electrical – moving charge
Sound – moving waves of gas compression and expansion

Potential: Gravitational – the eraser
Chemical – gasoline
Electrostatic – +..- attraction (static E)

1 cal (calorie) = 4.184 J (joules)

1 Cal (Dietary Calorie) = 1000 cal (calorie)

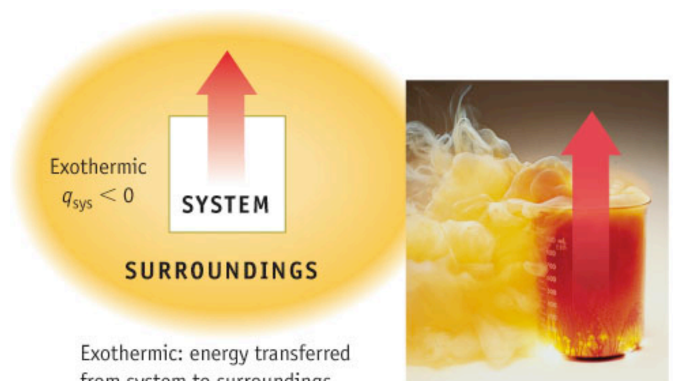
Law of Conservation of Energy

The total energy of the universe is constant

System: define carefully

System + Surroundings = Universe

All nomenclature is from the point of view of the system



Exothermic: energy transferred from system to surroundings

Temperature reflects molecular kinetic energy (thermal)

T = 21°C	T = 55°C

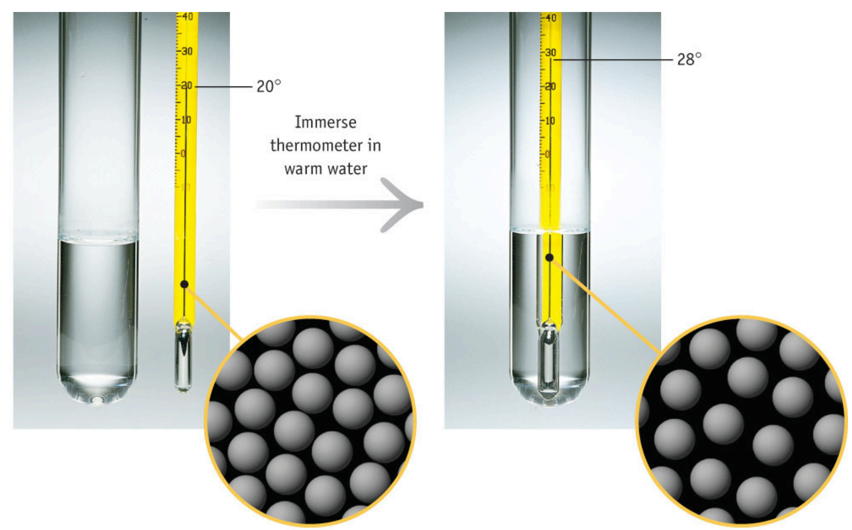


Fig. 5-3, p. 211

Temperature reflects molecular kinetic energy (thermal)

T = 21°C	T = 55°C

Transfer of thermal energy is *spontaneous*

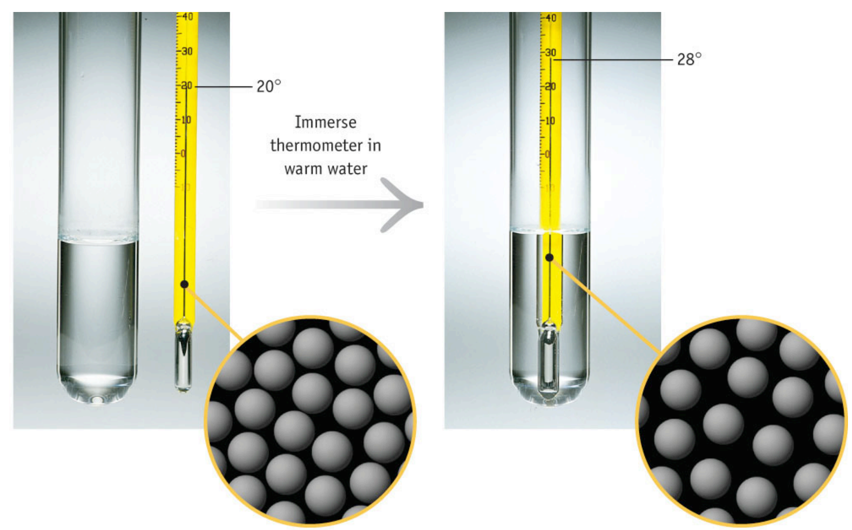


Fig. 5-3, p. 211

Temperature reflects molecular kinetic energy (thermal)

T = 21°C	T = 55°C

T = 38°C	T = 38°C

Thermal Equilibrium

Transfer of thermal energy is *spontaneous*

Continues until the system reaches thermal equilibrium

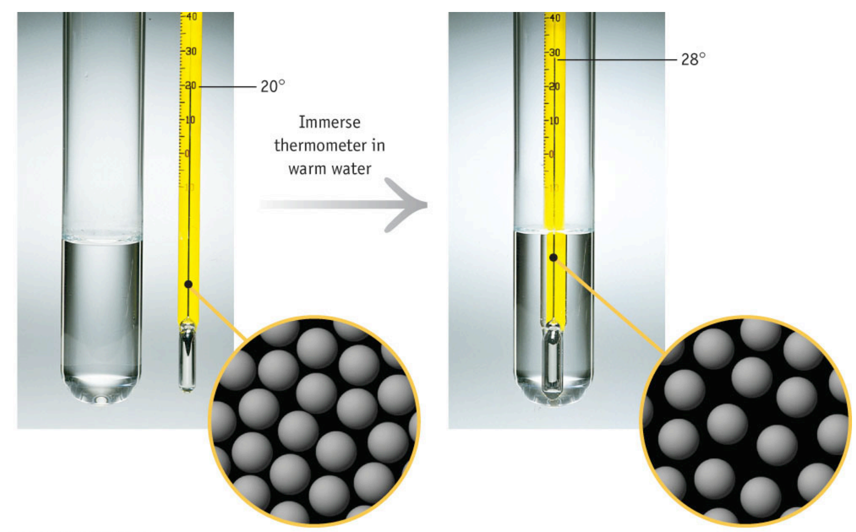
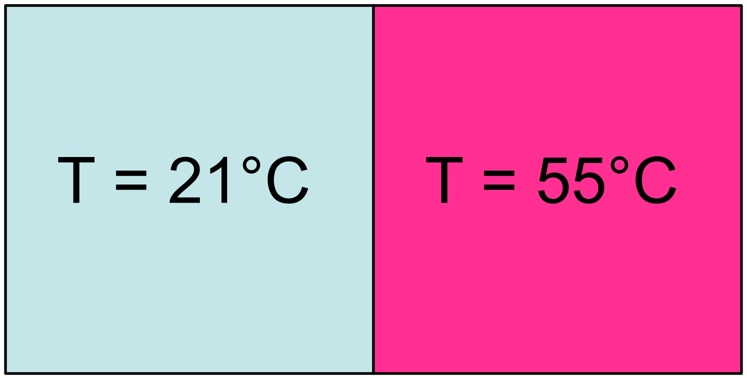
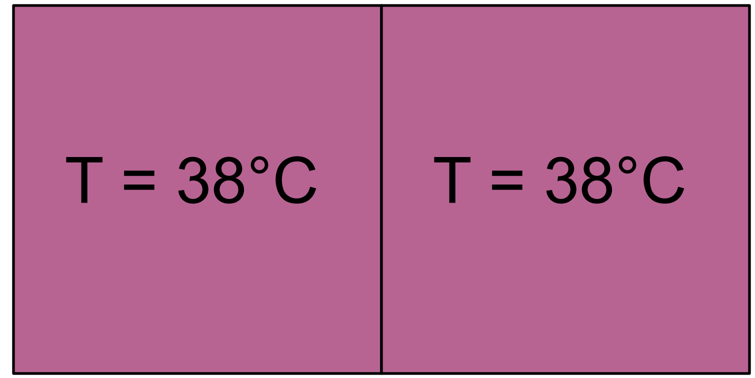


Fig. 5-3, p. 211

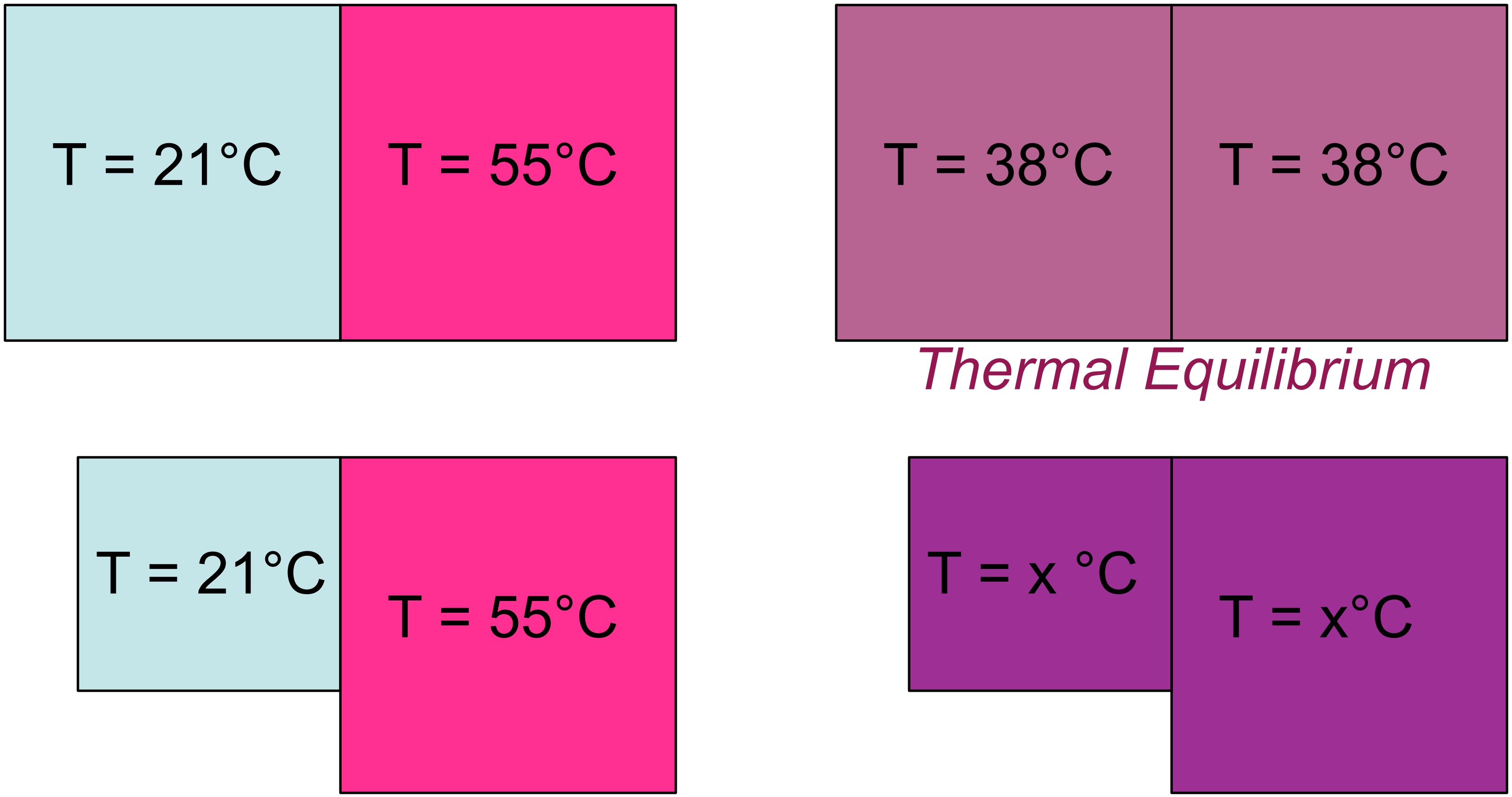
Temperature reflects molecular kinetic energy



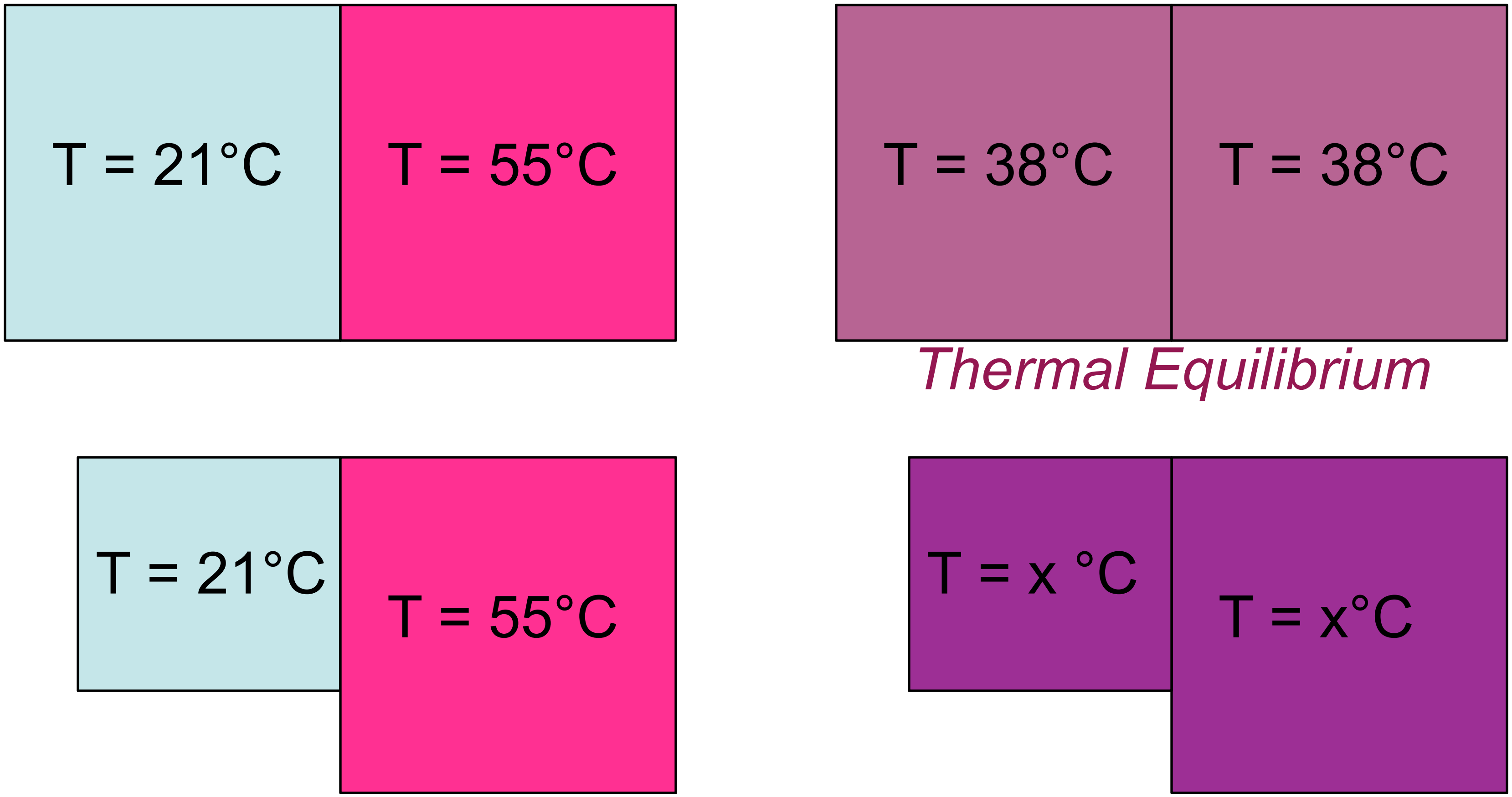


Thermal Equilibrium

Temperature reflects molecular kinetic energy



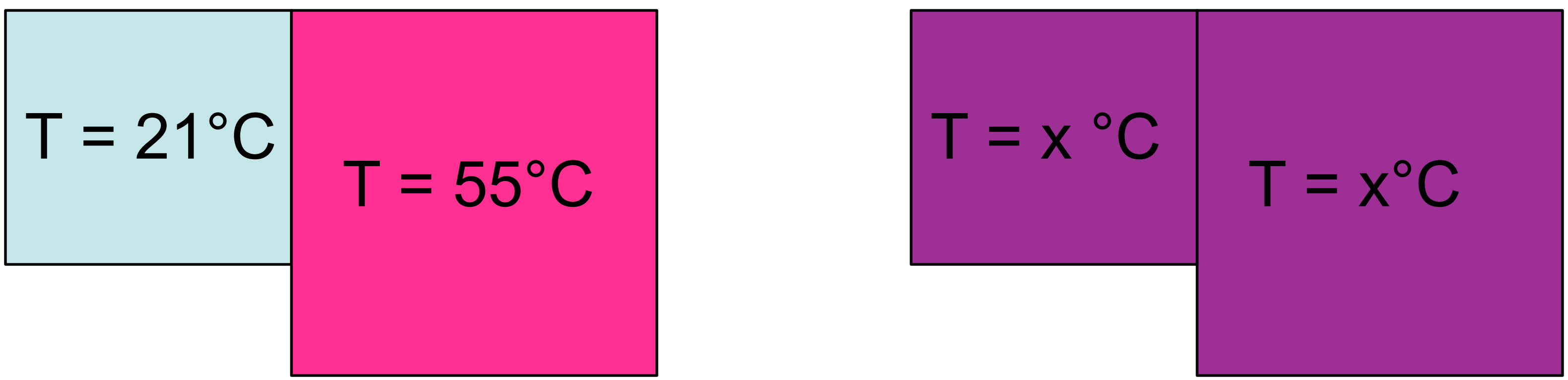
Temperature reflects molecular kinetic energy



Is x **(1) less** than 38°C or **(2) greater** than 38°C?

Temperature reflects molecular kinetic energy

Mass matters

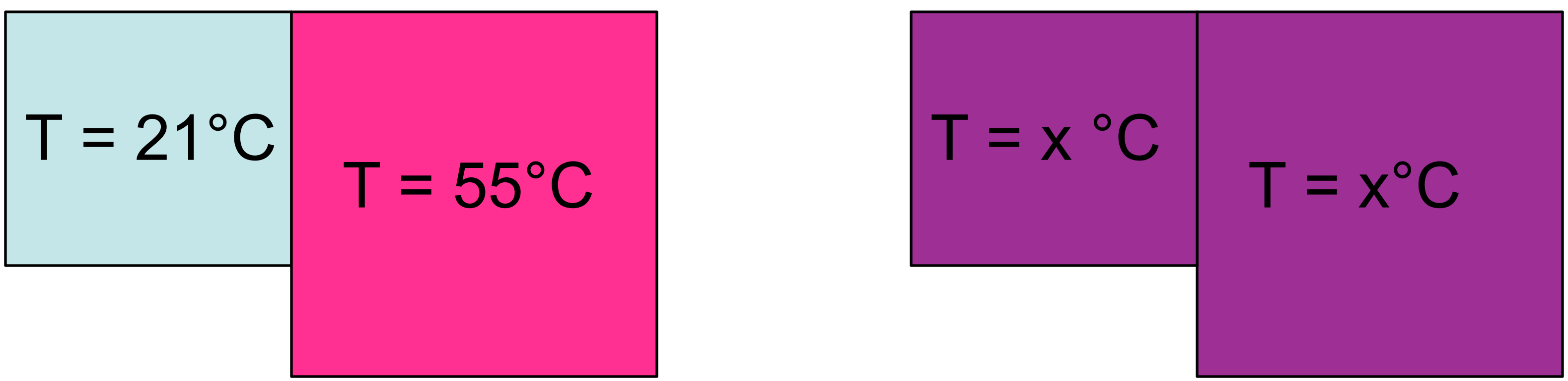


Is x **(1) less** than 38°C or **(2) greater** than 38°C?

Temperature reflects molecular kinetic energy

Mass matters

Heat Capacity matters



Is x **(1) less** than 38°C or **(2) greater** than 38°C?

$$q = Cm\Delta T$$

Energy (q) required to change the temperature (ΔT) of a given mass (m) of a substance with a specific heat capacity (C)

p. 216

$$q = Cm\Delta T$$

Energy (q) required to change the temperature (ΔT) of a given mass (m) of a substance with a specific heat capacity (C)

$$q = \left(0.385\ \frac{\mathrm{J}}{\mathrm{g \cdot K}}\right)(10.0\ \mathrm{g})(\underset{\substack{\uparrow \\ T_{\mathrm{final}} \\ \text{Final temp.}}}{598\ \mathrm{K}} - \underset{\substack{\uparrow \\ T_{\mathrm{initial}} \\ \text{Initial temp.}}}{298\ \mathrm{K}}) = +1160\ \mathrm{J}$$

$$q = Cm\Delta T$$

Energy (q) required to change the temperature (ΔT) of a given mass (m) of a substance with a specific heat capacity (C)

$$q = \underbrace{\left(0.385\ \frac{\text{J}}{\text{g} \cdot \text{K}}\right)}_{\text{C}}(10.0\ \text{g})(\underbrace{598\ \text{K}}_{\substack{T_{\text{final}} \\ \text{Final temp.}}} - \underbrace{298\ \text{K}}_{\substack{T_{\text{initial}} \\ \text{Initial temp.}}}) = +1160\ \text{J}$$

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$$q = Cm\Delta T$$

Energy (q) required to change the temperature (ΔT) of a given mass (m) of a substance with a specific heat capacity (C)

$$q = \underbrace{\left(0.385\ \frac{\mathrm{J}}{\mathrm{g \cdot K}}\right)}_{C} \underbrace{(10.0\ \mathrm{g})}_{m} \underbrace{(598\ \mathrm{K} - 298\ \mathrm{K})}_{\Delta T} = +1160\ \mathrm{J}$$

598 K: T_{final} Final temp.

298 K: T_{initial} Initial temp.

$$q = Cm\Delta T$$

Energy (q) required to change the temperature (ΔT) of a given mass (m) of a substance with a specific heat capacity (C)

$$q = \underbrace{\left(0.385\ \frac{\text{J}}{\cancel{\text{g}} \cdot \text{K}}\right)}_{\text{C}} \underbrace{(10.0\ \cancel{\text{g}})}_{\text{m}} \underbrace{(\underset{\substack{\uparrow \\ T_{\text{final}} \\ \text{Final temp.}}}{598\ \text{K}} - \underset{\substack{\uparrow \\ T_{\text{initial}} \\ \text{Initial temp.}}}{298\ \text{K}})}_{\Delta\text{T}} = +1160\ \text{J}$$

$$q = Cm\Delta T$$

Energy (q) required to change the temperature (ΔT) of a given mass (m) of a substance with a specific heat capacity (C)

$$q = \underbrace{\left(0.385 \frac{\text{J}}{\cancel{\text{g}} \cdot \cancel{\text{K}}}\right)}_{C} \underbrace{(10.0\ \cancel{\text{g}})}_{m} \underbrace{(\underset{\substack{\uparrow \\ T_{\text{final}} \\ \text{Final temp.}}}{598\ \cancel{\text{K}}} - \underset{\substack{\uparrow \\ T_{\text{initial}} \\ \text{Initial temp.}}}{298\ \cancel{\text{K}}})}_{\Delta T} = +1160\ \text{J}$$

$$q = Cm\Delta T$$

$$q = \overbrace{\left(0.385\ \frac{\text{J}}{\text{g}\cdot\text{K}}\right)}^{\text{C}}\overbrace{(10.0\ \text{g})}^{\text{m}}\overbrace{(\underbrace{598\ \text{K}}_{\substack{T_{\text{final}}\\ \text{Final temp.}}} - \underbrace{298\ \text{K}}_{\substack{T_{\text{initial}}\\ \text{Initial temp.}}})}^{\Delta\text{T}} = +1160\ \text{J}$$

$$q = Cm\Delta T$$

Specific heat capacity
(per gram)

$$q = \underbrace{\left(0.385 \frac{\text{J}}{\text{g}\cdot\text{K}}\right)}_{C}\underbrace{(10.0\text{ g})}_{m}\underbrace{(598\text{ K} - 298\text{ K})}_{\Delta T} = +1160\text{ J}$$

T_{final} Final temp.

T_{initial} Initial temp.

$$q = Cm\Delta T$$

Specific heat capacity
(per gram)

mass

$$\underbrace{\quad C \quad}\ \underbrace{\quad m \quad}\ \underbrace{\quad \Delta T \quad}$$

$$q = \left(0.385\ \frac{\mathrm{J}}{\mathrm{g \cdot K}}\right)(10.0\ \mathrm{g})(\underset{\substack{T_{\mathrm{final}} \\ \text{Final temp.}}}{598\ \mathrm{K}} - \underset{\substack{T_{\mathrm{initial}} \\ \text{Initial temp.}}}{298\ \mathrm{K}}) = +1160\ \mathrm{J}$$

$$q = Cm\Delta T$$

Specific heat capacity
(per gram)

Temperature
(in Kelvin)

mass

$$\underbrace{\left(0.385\ \frac{\text{J}}{\text{g}\cdot\text{K}}\right)}_{C}\ \underbrace{(10.0\ \text{g})}_{m}\ \underbrace{(598\ \text{K} - 298\ \text{K})}_{\Delta T}$$

$$q = \left(0.385\ \frac{\text{J}}{\text{g}\cdot\text{K}}\right)(10.0\ \text{g})(598\ \text{K} - 298\ \text{K}) = +1160\ \text{J}$$

T_{final}
Final temp.

$T_{initial}$
Initial temp.

$$q = Cm\Delta T$$

Specific heat capacity (per gram)

mass

Temperature (in Kelvin)

C	m	ΔT

$$q = \left(0.385\ \frac{\mathrm{J}}{\mathrm{g \cdot K}}\right)(10.0\ \mathrm{g})(\underset{\substack{\uparrow \\ T_{\mathrm{final}} \\ \text{Final temp.}}}{598\ \mathrm{K}} - \underset{\substack{\uparrow \\ T_{\mathrm{initial}} \\ \text{Initial temp.}}}{298\ \mathrm{K}}) = +1160\ \mathrm{J}$$

It takes 1,160 J energy to heat 10g of Cu from 298K to 598K

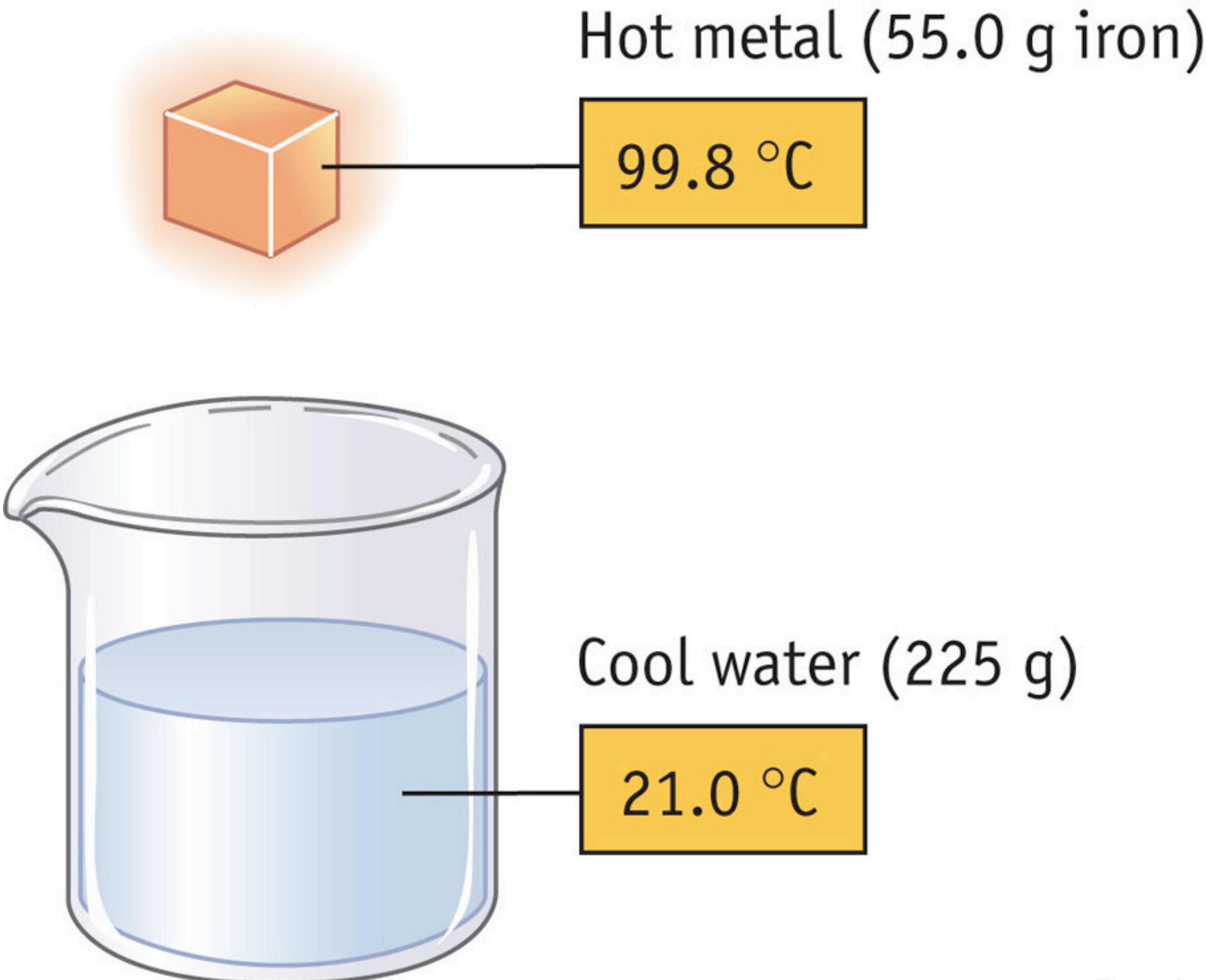
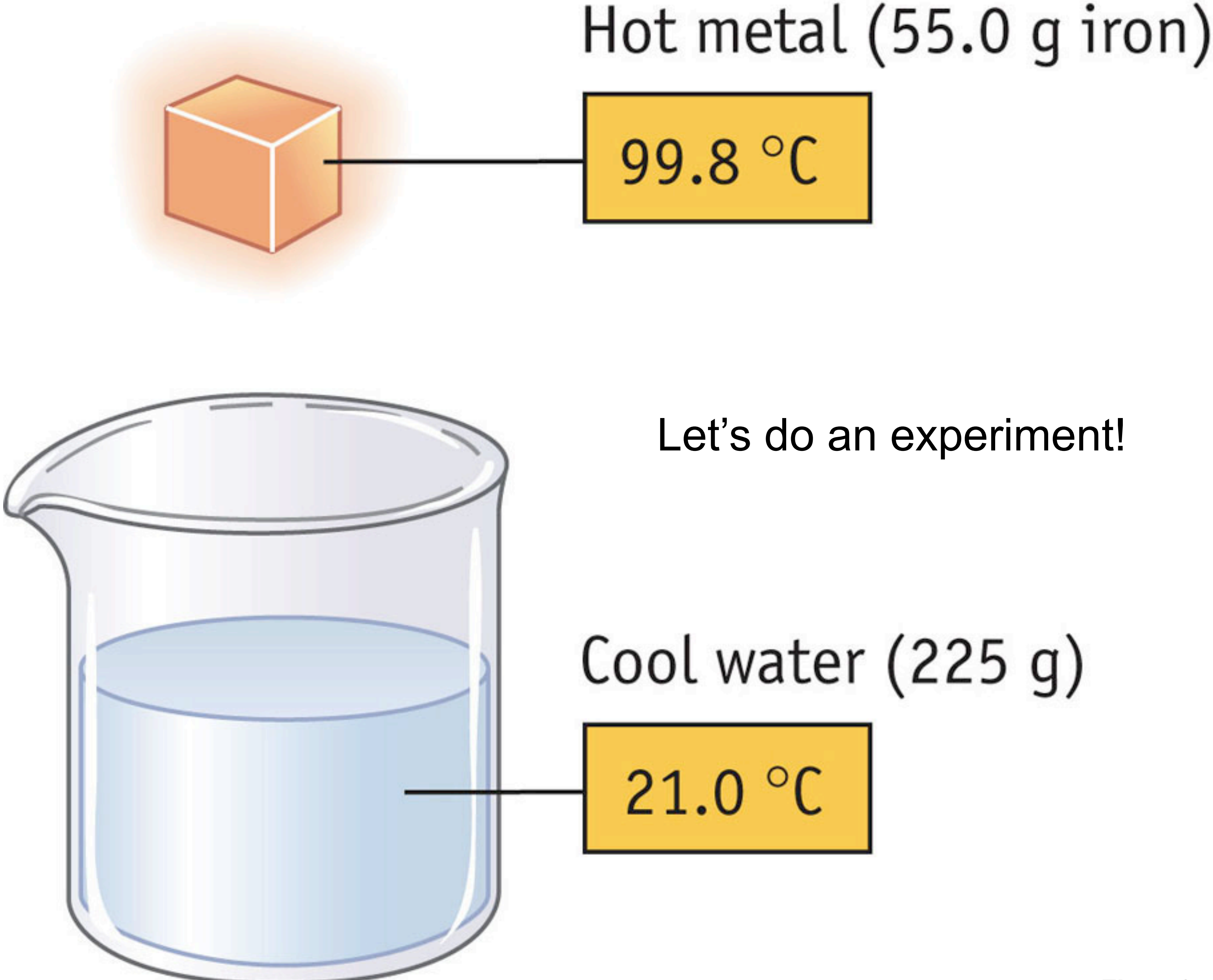


Fig. 5-8, p. 217



Let’s do an experiment!

Fig. 5-8, p. 217

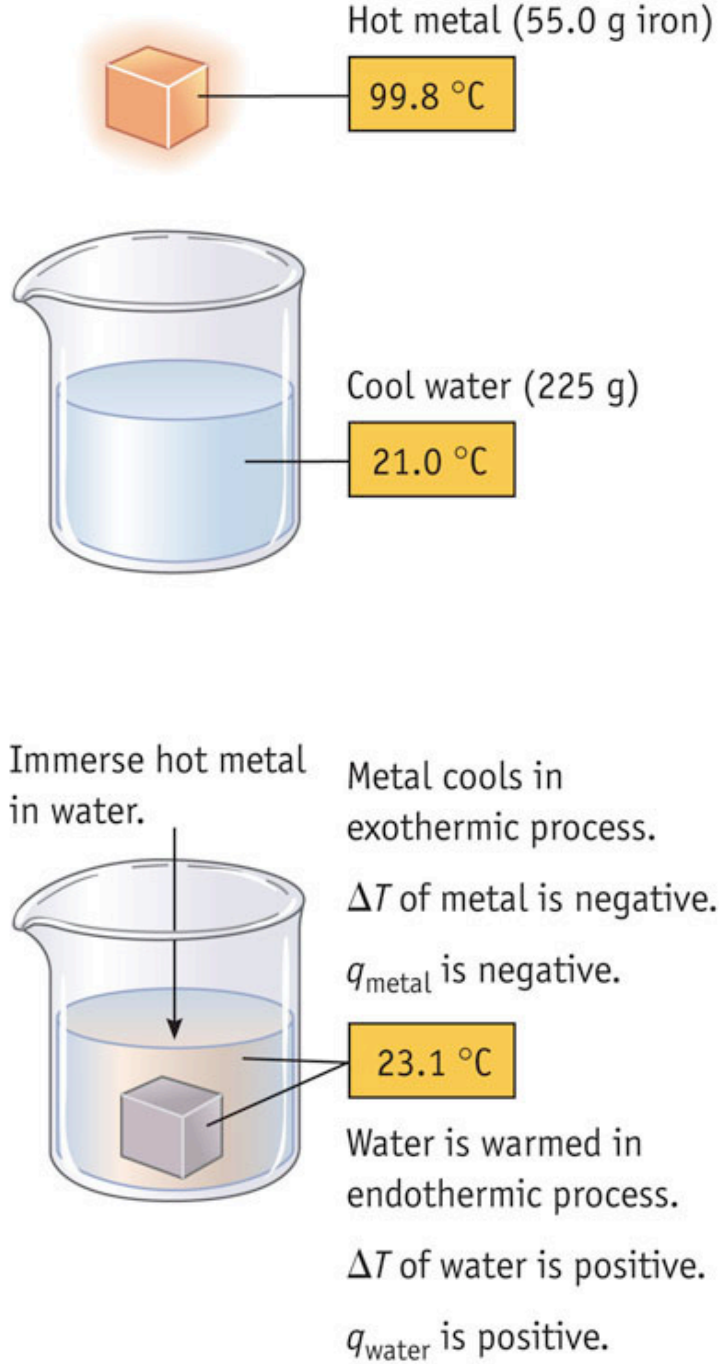

Hot metal (55.0 g iron)
99.8 °C
Cool water (225 g)
21.0 °C
Immerse hot metal in water.
Metal cools in exothermic process.
ΔT of metal is negative.
q_{metal} is negative.
23.1 °C
Water is warmed in endothermic process.
ΔT of water is positive.
q_{water} is positive.

Fig. 5-8, p. 217

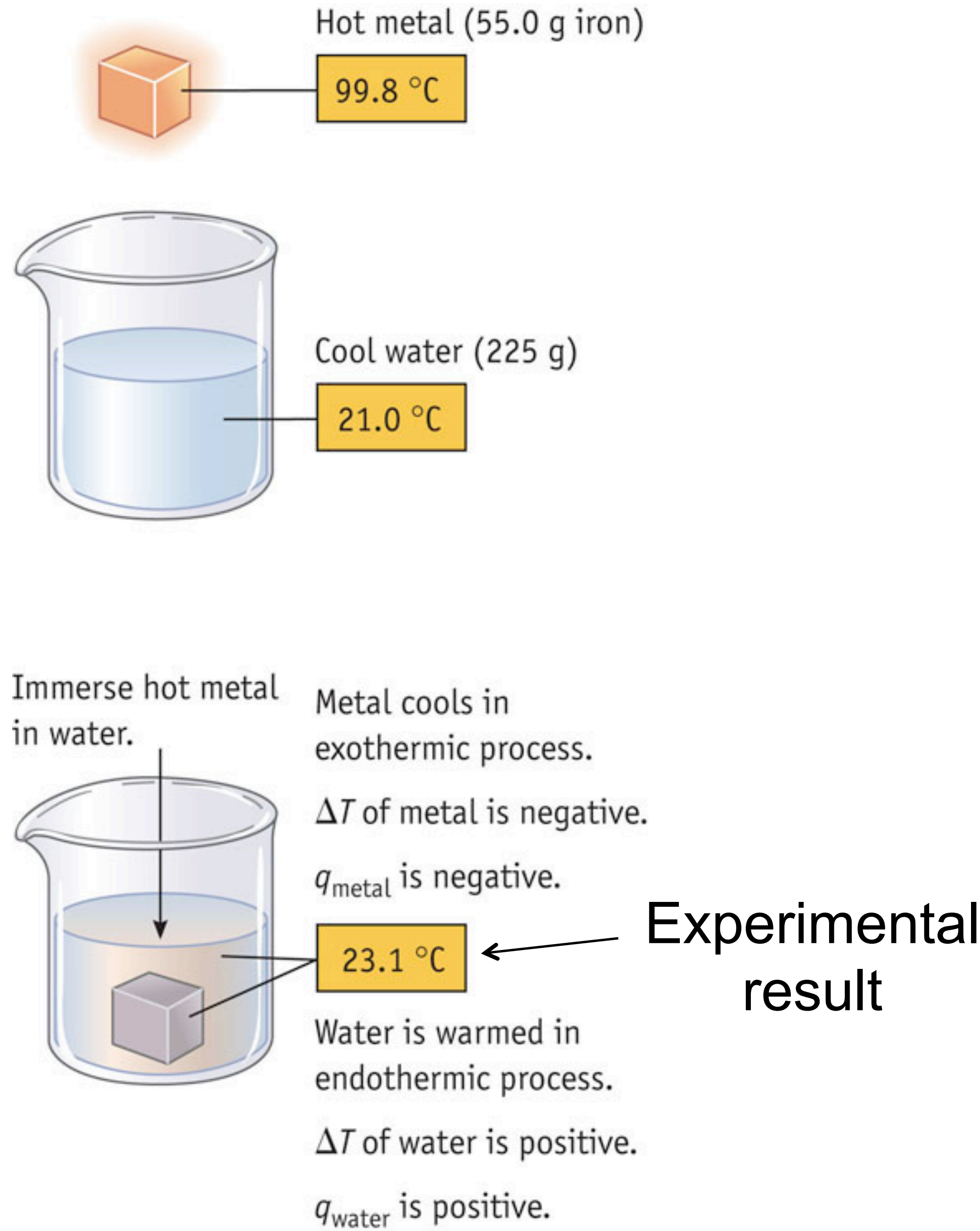
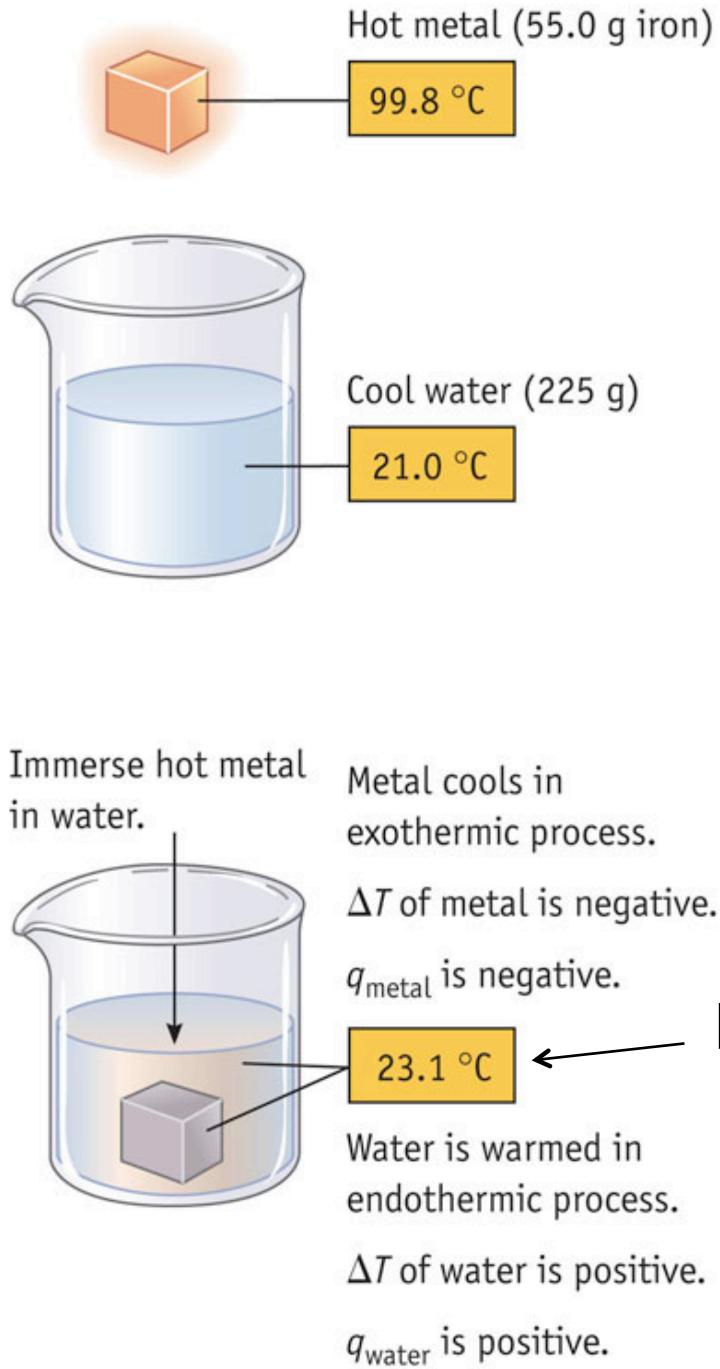

Hot metal (55.0 g iron)
99.8 °C
Cool water (225 g)
21.0 °C
Immerse hot metal in water.
Metal cools in exothermic process.
ΔT of metal is negative.
q_{metal} is negative.
23.1 °C
Experimental result
Water is warmed in endothermic process.
ΔT of water is positive.
q_{water} is positive.

Fig. 5-8, p. 217

Facts:

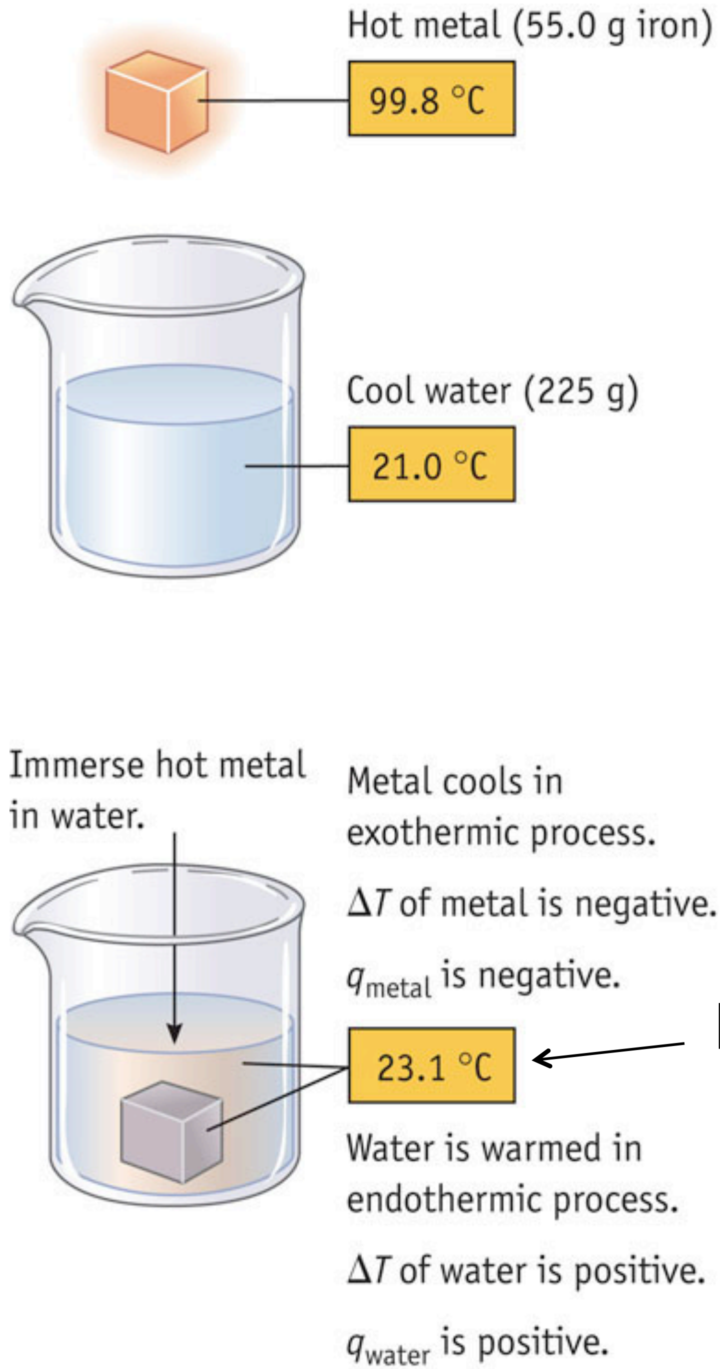


Experimental result

Fig. 5-8, p. 217

Facts:

55g Fe at 99.8°C



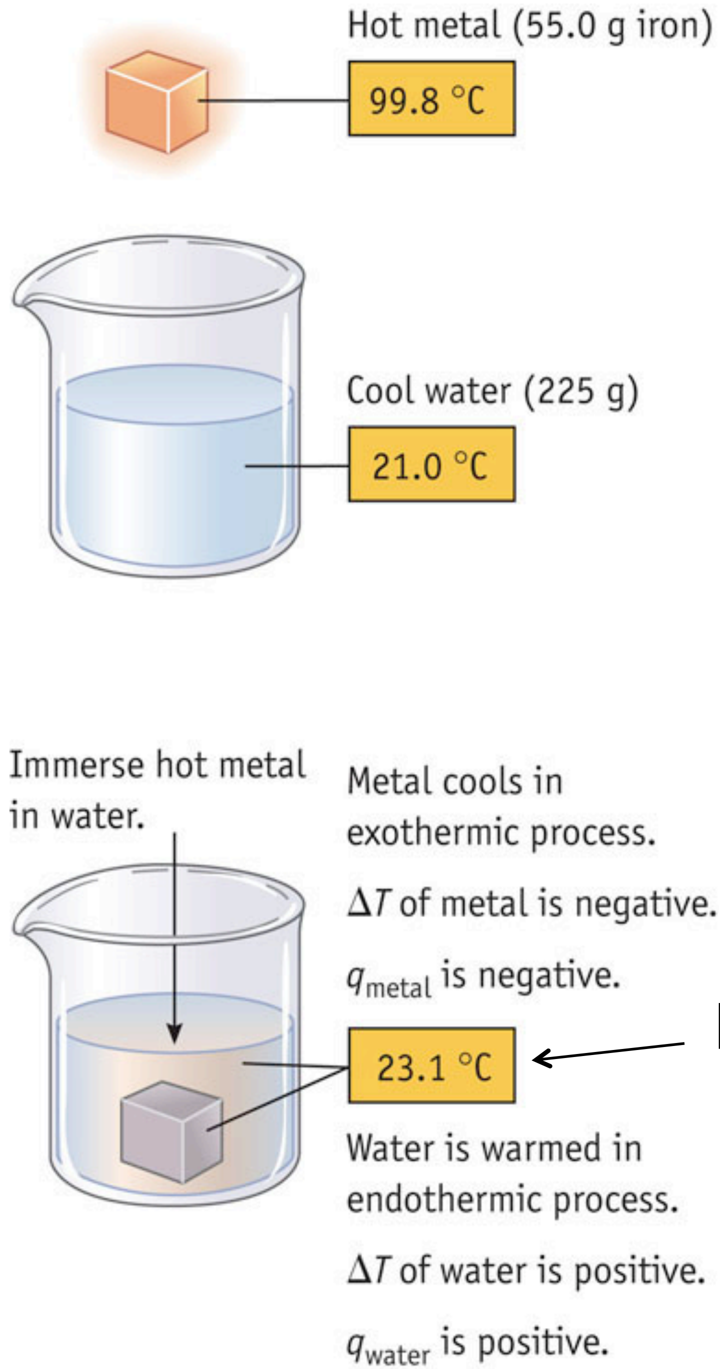
Experimental result

Fig. 5-8, p. 217

Facts:

55g Fe at 99.8°C

225g H_2O at 21.0°C



Experimental result

Fig. 5-8, p. 217

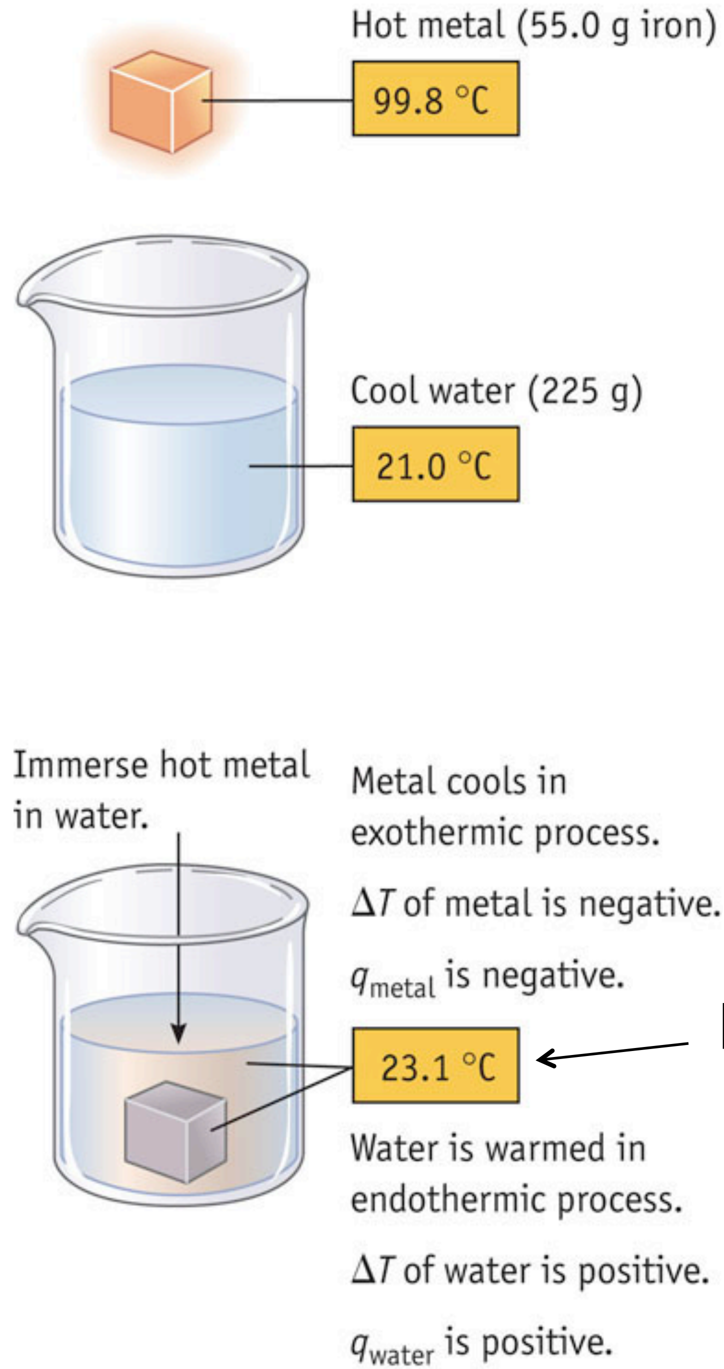
Facts:

55g Fe at 99.8°C

225g H_2O at 21.0°C

55g Fe at 23.1°C

225g H_2O at 23.1°C



Experimental result

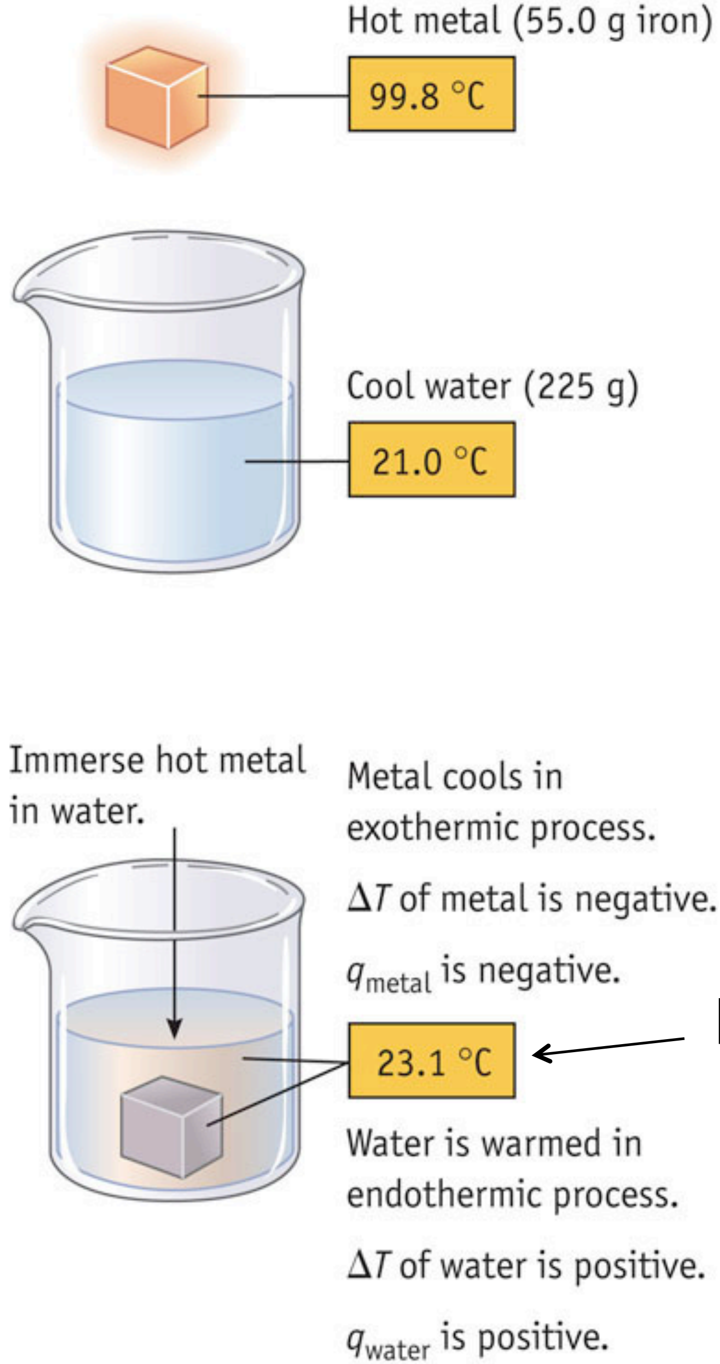
Fig. 5-8, p. 217

Facts:

Initial State

55g Fe at 99.8°C

225g H_2O at 21.0°C



55g Fe at 23.1°C

225g H_2O at 23.1°C

Experimental result

Fig. 5-8, p. 217

Facts:

Initial State

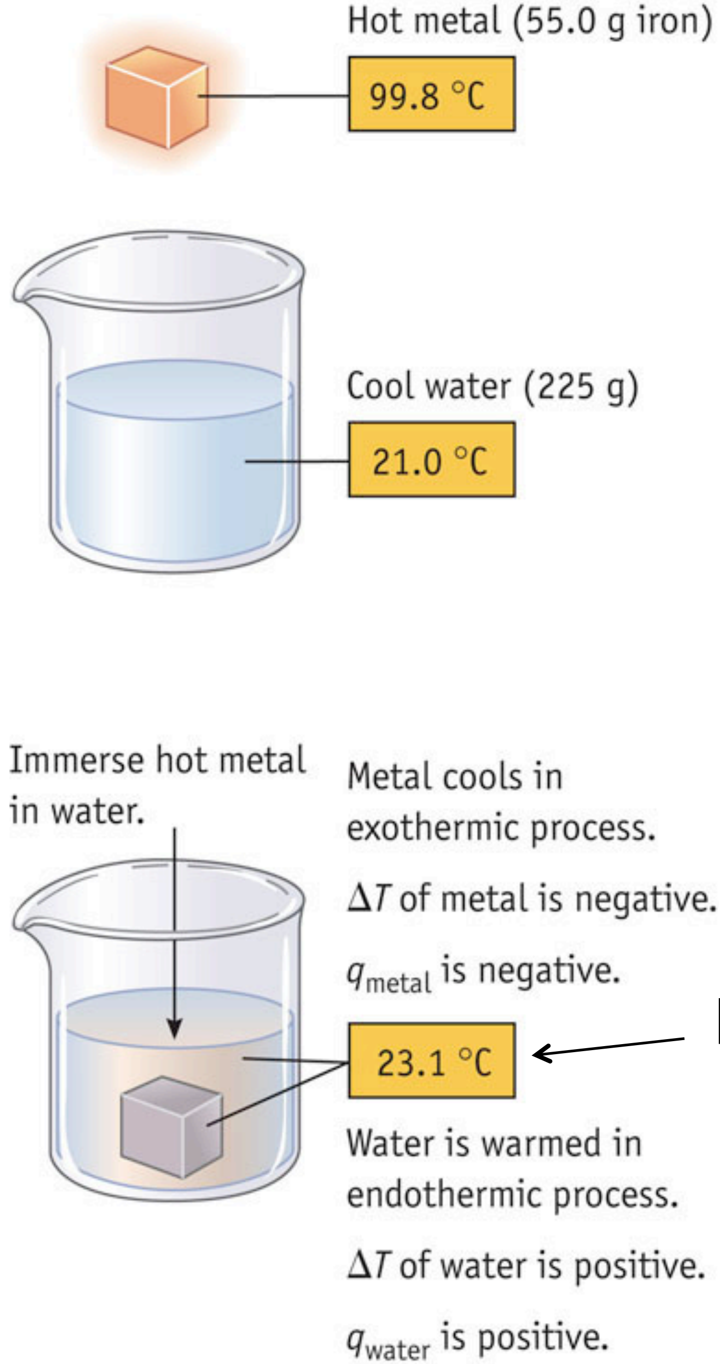
55g Fe at 99.8°C

225g H_2O at 21.0°C

Final State

55g Fe at 23.1°C

225g H_2O at 23.1°C



Experimental result

Fig. 5-8, p. 217

Facts:

Initial State

55g Fe at 99.8°C

225g H_2O at 21.0°C

Final State

55g Fe at 23.1°C

225g H_2O at 23.1°C

Fig. 5-8, p. 217

Facts:

Initial State

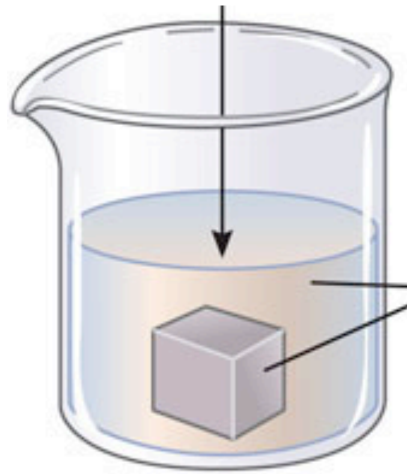
55g Fe at 99.8°C

225g H_2O at 21.0°C

Final State

55g Fe at 23.1°C

225g H_2O at 23.1°C



System

Fig. 5-8, p. 217

Facts:

Initial State

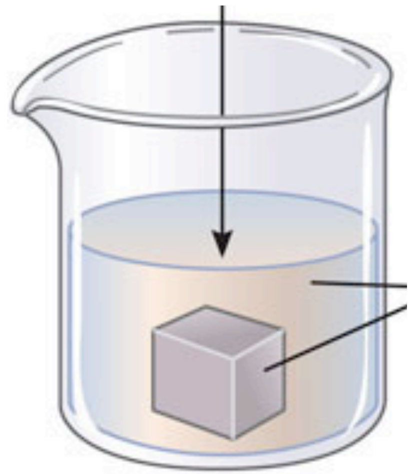
55g Fe at 99.8°C

225g H_2O at 21.0°C

Final State

55g Fe at 23.1°C

225g H_2O at 23.1°C



System

$$q_{system} = q_{water} + q_{Fe} = 0$$

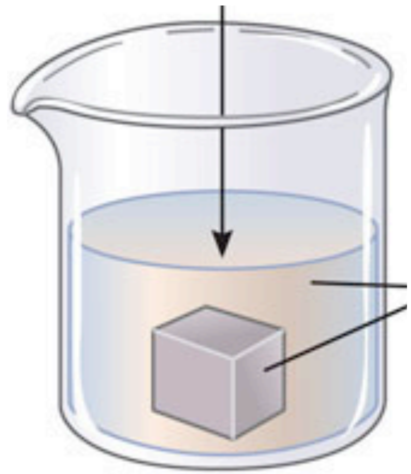
Fig. 5-8, p. 217

Facts:

Initial State

55g Fe at 99.8°C

225g H_2O at 21.0°C



System

Final State

55g Fe at 23.1°C

225g H_2O at 23.1°C

$$q_{system} = q_{water} + q_{Fe} = 0$$

$$\left[C_{water} \cdot m_{water} \cdot \left(T_{final}^{water} - T_{initial}^{water}\right)\right] + \left[C_{Fe} \cdot m_{Fe} \cdot \left(T_{final}^{Fe} - T_{initial}^{Fe}\right)\right] = 0$$

Fig. 5-8, p. 217

Facts:

Initial State

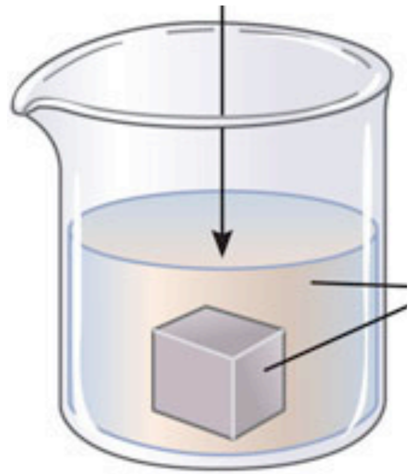
55g Fe at 99.8°C

225g H_2O at 21.0°C

Final State

55g Fe at 23.1°C

225g H_2O at 23.1°C



System

$$C_{water} = 4.184 J \cdot g^{-1} \cdot K^{-1}$$

$$C_{Fe} = unknown$$

$$q_{system} = q_{water} + q_{Fe} = 0$$

$$\left[C_{water} \cdot m_{water} \cdot \left(T_{final}^{water} - T_{initial}^{water}\right)\right] + \left[C_{Fe} \cdot m_{Fe} \cdot \left(T_{final}^{Fe} - T_{initial}^{Fe}\right)\right] = 0$$

Fig. 5-8, p. 217

Facts:

Initial State

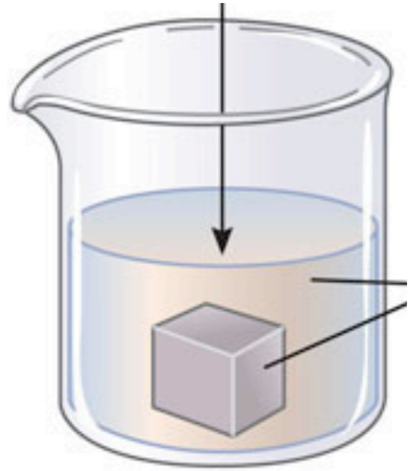
55g Fe at 99.8°C

225g H_2O at 21.0°C

Final State

55g Fe at 23.1°C

225g H_2O at 23.1°C



System

$$C_{water} = 4.184 J \cdot g^{-1} \cdot K^{-1}$$

$$C_{Fe} = unknown$$

$$q_{system} = q_{water} + q_{Fe} = 0$$

$$\left[C_{water} \cdot m_{water} \cdot \left(T_{final}^{water} - T_{initial}^{water}\right)\right] + \left[C_{Fe} \cdot m_{Fe} \cdot \left(T_{final}^{Fe} - T_{initial}^{Fe}\right)\right] = 0$$

Fig. 5-8, p. 217

Facts:

Initial State

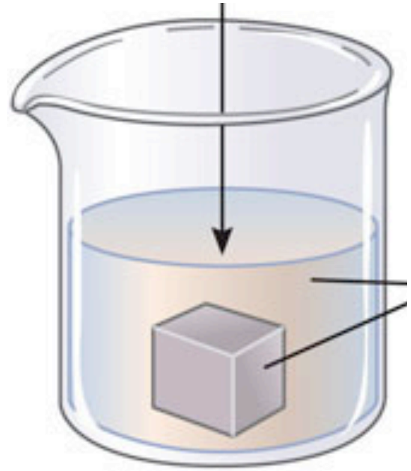
55g Fe at 99.8°C

225g H_2O at 21.0°C

Final State

55g Fe at 23.1°C

225g H_2O at 23.1°C



System

$$C_{water} = 4.184 J \cdot g^{-1} \cdot K^{-1}$$

$$C_{Fe} = unknown$$

$$q_{system} = q_{water} + q_{Fe} = 0$$

$$\left[C_{water} \cdot m_{water} \cdot \left(T^{water}_{final} - T^{water}_{initial}\right)\right] + \left[C_{Fe} \cdot m_{Fe} \cdot \left(T^{Fe}_{final} - T^{Fe}_{initial}\right)\right] = 0$$

$$\left[\left(4.184 J \cdot g^{-1} \cdot K^{-1}\right) \cdot (225 g) \cdot (23.1 - 21.0)°C\right] + \left[C_{Fe} \cdot (55 g) \cdot (23.1 - 99.8)°C\right] = 0$$

Fig. 5-8, p. 217

Facts:

Initial State

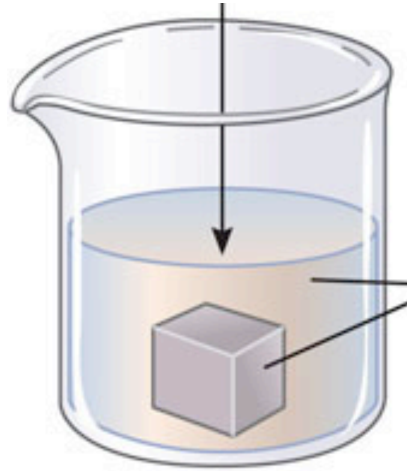
55g Fe at 99.8°C

225g H_2O at 21.0°C

Final State

55g Fe at 23.1°C

225g H_2O at 23.1°C



System

$$C_{water} = 4.184 J \cdot g^{-1} \cdot K^{-1}$$

$$C_{Fe} = unknown$$

$$q_{system} = q_{water} + q_{Fe} = 0$$

$$\left[\underline{C_{water}} \cdot \underline{m_{water}} \cdot \underline{\left(T^{water}_{final} - T^{water}_{initial}\right)}\right] + \left[C_{Fe} \cdot m_{Fe} \cdot \left(T^{Fe}_{final} - T^{Fe}_{initial}\right)\right] = 0$$

$$\left[\underline{\left(4.184 J \cdot g^{-1} \cdot K^{-1}\right)} \cdot \underline{(225 g)} \cdot \underline{(23.1 - 21.0)}{}^{\circ}C\right] + \left[C_{Fe} \cdot (55 g) \cdot (23.1 - 99.8)^{\circ}C\right] = 0$$

Fig. 5-8, p. 217

Facts:

Initial State

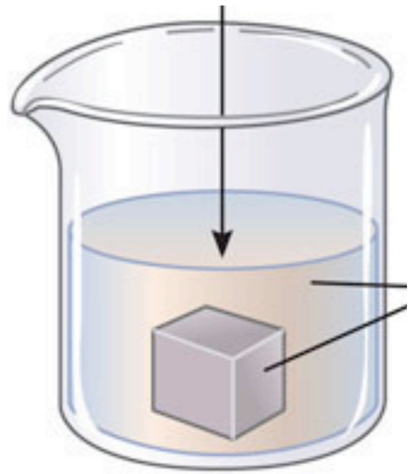
55g Fe at 99.8°C

225g H_2O at 21.0°C

Final State

55g Fe at 23.1°C

225g H_2O at 23.1°C



System

$$C_{water} = 4.184 J \cdot g^{-1} \cdot K^{-1}$$

$$C_{Fe} = unknown$$

$$q_{system} = q_{water} + q_{Fe} = 0$$

$$\left[C_{water} \cdot m_{water} \cdot \left(T_{final}^{water} - T_{initial}^{water}\right)\right] + \left[C_{Fe} \cdot m_{Fe} \cdot \left(T_{final}^{Fe} - T_{initial}^{Fe}\right)\right] = 0$$

$$\left[\left(4.184 J \cdot g^{-1} \cdot K^{-1}\right) \cdot (225 g) \cdot (23.1 - 21.0)°C\right] + \left[C_{Fe} \cdot (55 g) \cdot (23.1 - 99.8)°C\right] = 0$$

$$[1976.94 J] + \left[C_{Fe} \cdot (-4218.5) \cdot g \cdot °C\right] = 0$$

Fig. 5-8, p. 217

Facts:

Initial State

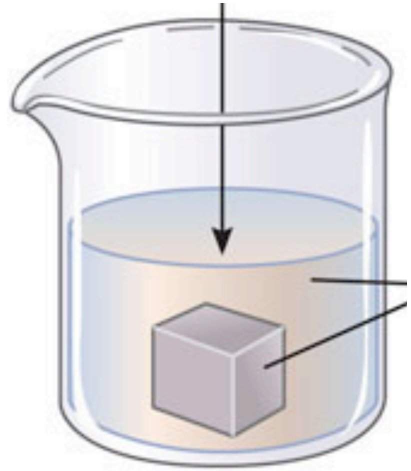
55g Fe at 99.8°C

225g H_2O at 21.0°C

Final State

55g Fe at 23.1°C

225g H_2O at 23.1°C



System

$$C_{water} = 4.184 J \cdot g^{-1} \cdot K^{-1}$$

$$C_{Fe} = unknown$$

$$q_{system} = q_{water} + q_{Fe} = 0$$

$$\left[C_{water} \cdot m_{water} \cdot \left(T_{final}^{water} - T_{initial}^{water}\right)\right] + \left[C_{Fe} \cdot m_{Fe} \cdot \left(T_{final}^{Fe} - T_{initial}^{Fe}\right)\right] = 0$$

$$\left[\left(4.184 J \cdot g^{-1} \cdot K^{-1}\right) \cdot (225 g) \cdot (23.1 - 21.0)°C\right] + \left[C_{Fe} \cdot (55 g) \cdot (23.1 - 99.8)°C\right] = 0$$

$$[1976.94 J] + \left[C_{Fe} \cdot (-4218.5) \cdot g \cdot °C\right] = 0 \qquad C_{Fe} = \frac{1976.94 J}{(4218.5) \cdot g \cdot °C} = 0.469 \cdot \mathrm{J} \cdot \mathrm{g}^{-1} \cdot K^{-1}$$

Fig. 5-8, p. 217

State

State

Examples?

State

Examples?

Solid

State

Examples?

Solid

Liquid

State

Examples?

Solid

Liquid

Gas

State

Examples?

Solid

Liquid

Gas

Aqueous (solvated)

State

Examples?

Solid

ΔH_{fusion}

Liquid

Gas

Aqueous (solvated)

State

Examples?

Solid

Liquid

Gas

ΔH_{fusion}

$\Delta H_{vaporization}$

Aqueous (solvated)

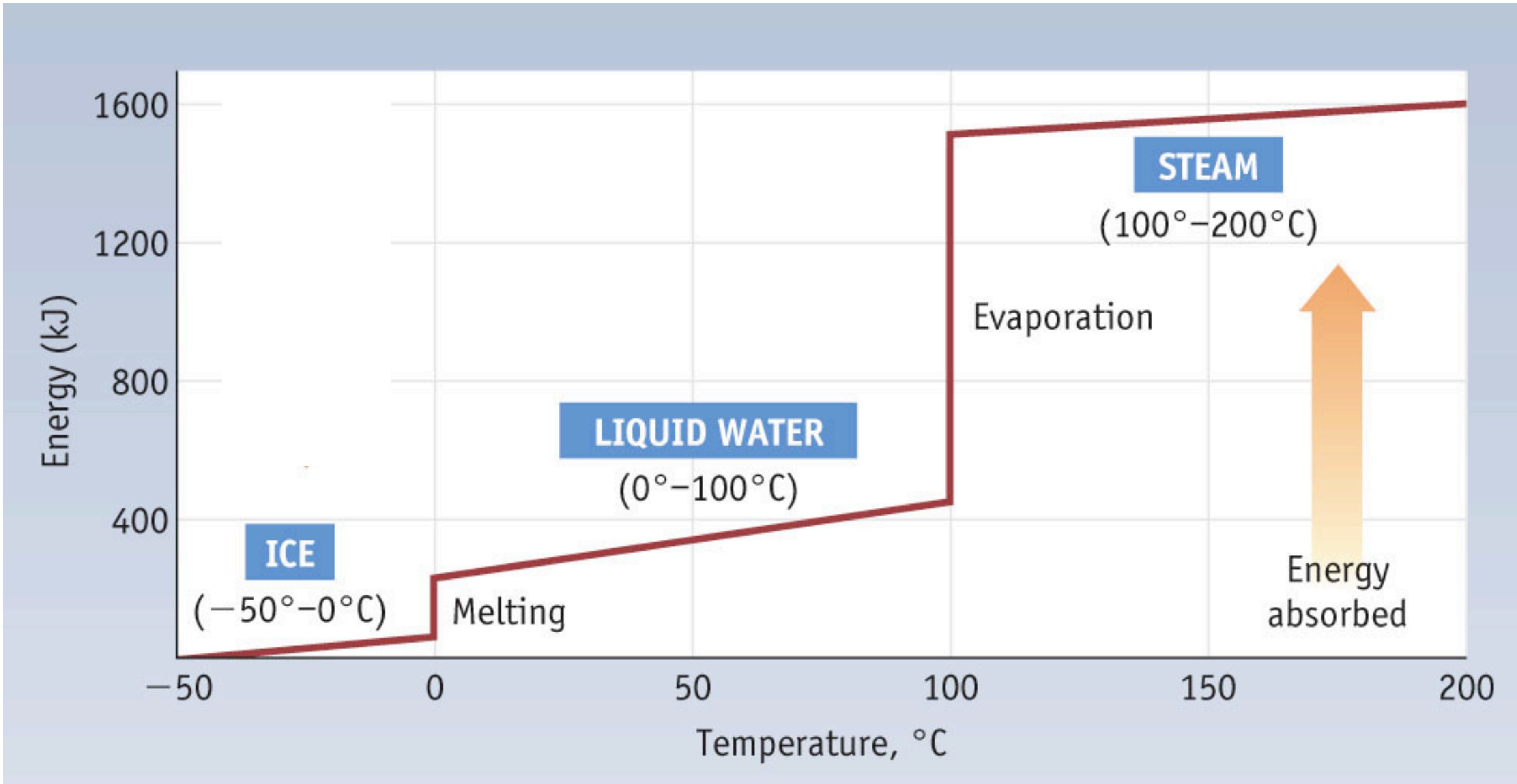
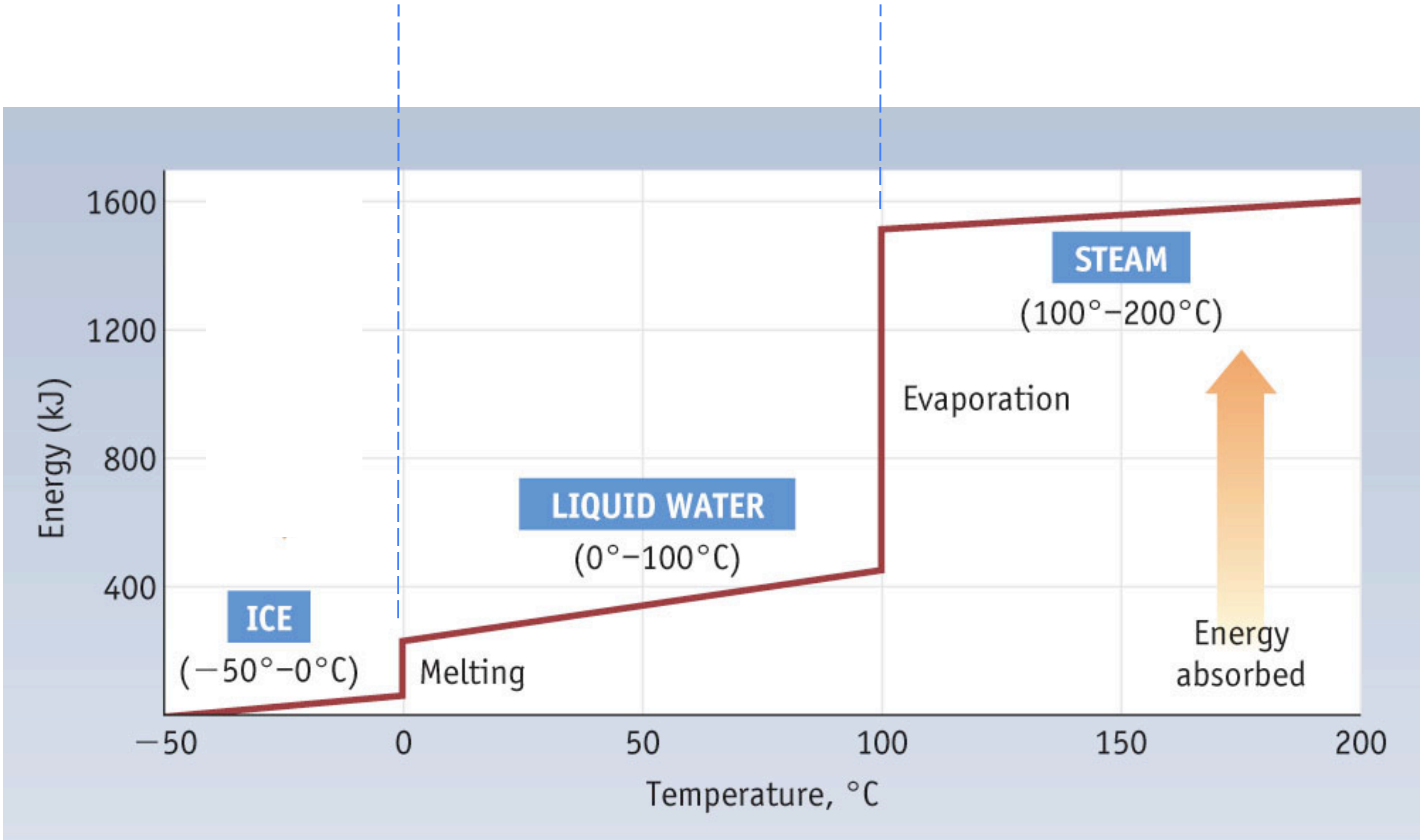

1600
1200
800
400
Energy (kJ)
ICE
(−50°–0°C)
Melting
LIQUID WATER
(0°–100°C)
Evaporation
STEAM
(100°–200°C)
Energy
absorbed
−50
0
50
100
150
200
Temperature, °C

Fig. 5-9, p. 219


1600
1200
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Energy (kJ)
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Evaporation
STEAM
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Energy absorbed
−50
0
50
100
150
200
Temperature, °C

Fig. 5-9, p. 219

$$q = C_{ice} m \Delta T$$

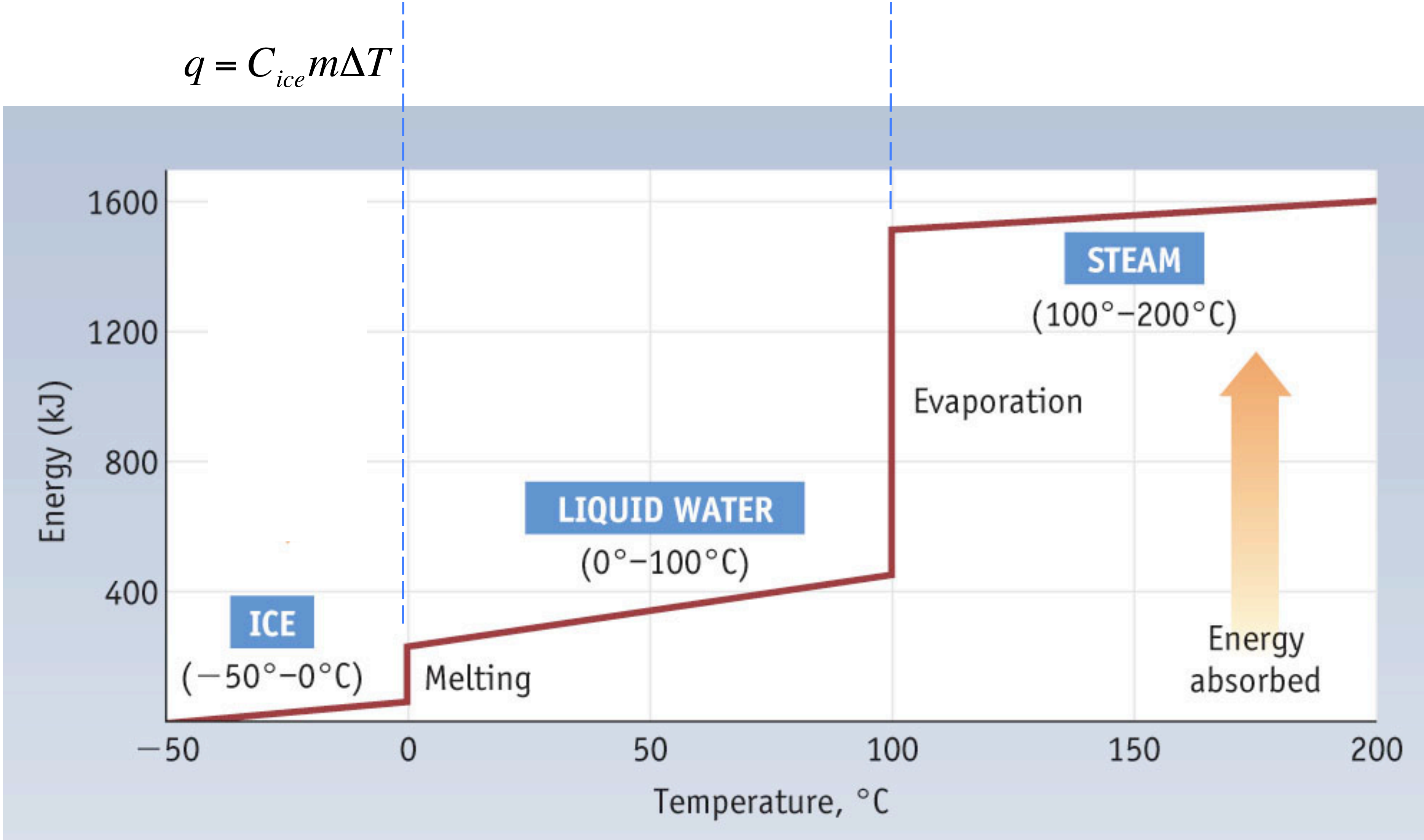


Fig. 5-9, p. 219

$q = C_{ice} m \Delta T$ $q = C_{water} m \Delta T$

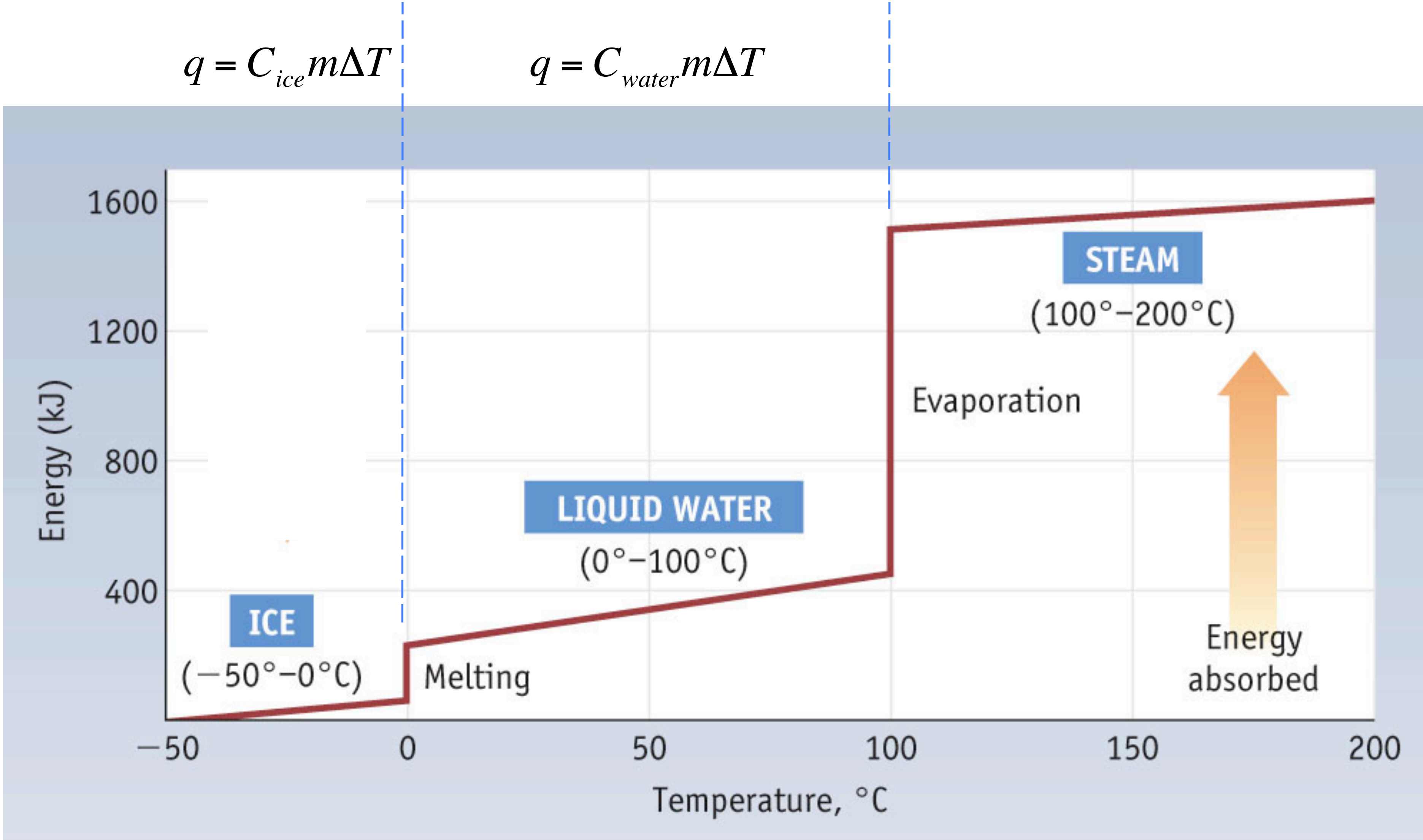


Fig. 5-9, p. 219

$q = C_{ice} m \Delta T$ $\quad$ $q = C_{water} m \Delta T$ $\quad$ $q = C_{steam} m \Delta T$

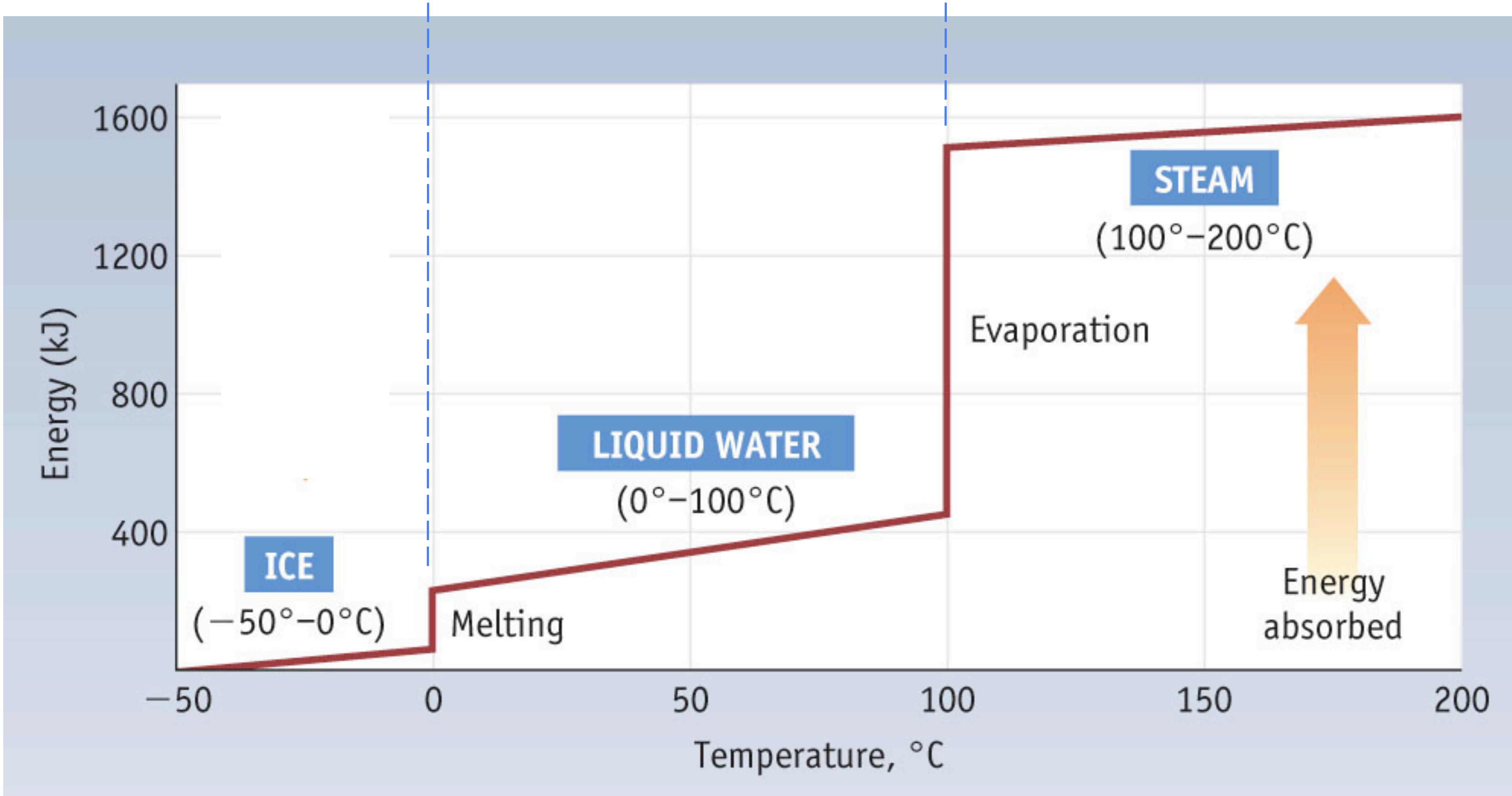


Fig. 5-9, p. 219

ΔH_{fusion}

$q = C_{ice} m \Delta T$ $q = C_{water} m \Delta T$ $q = C_{steam} m \Delta T$

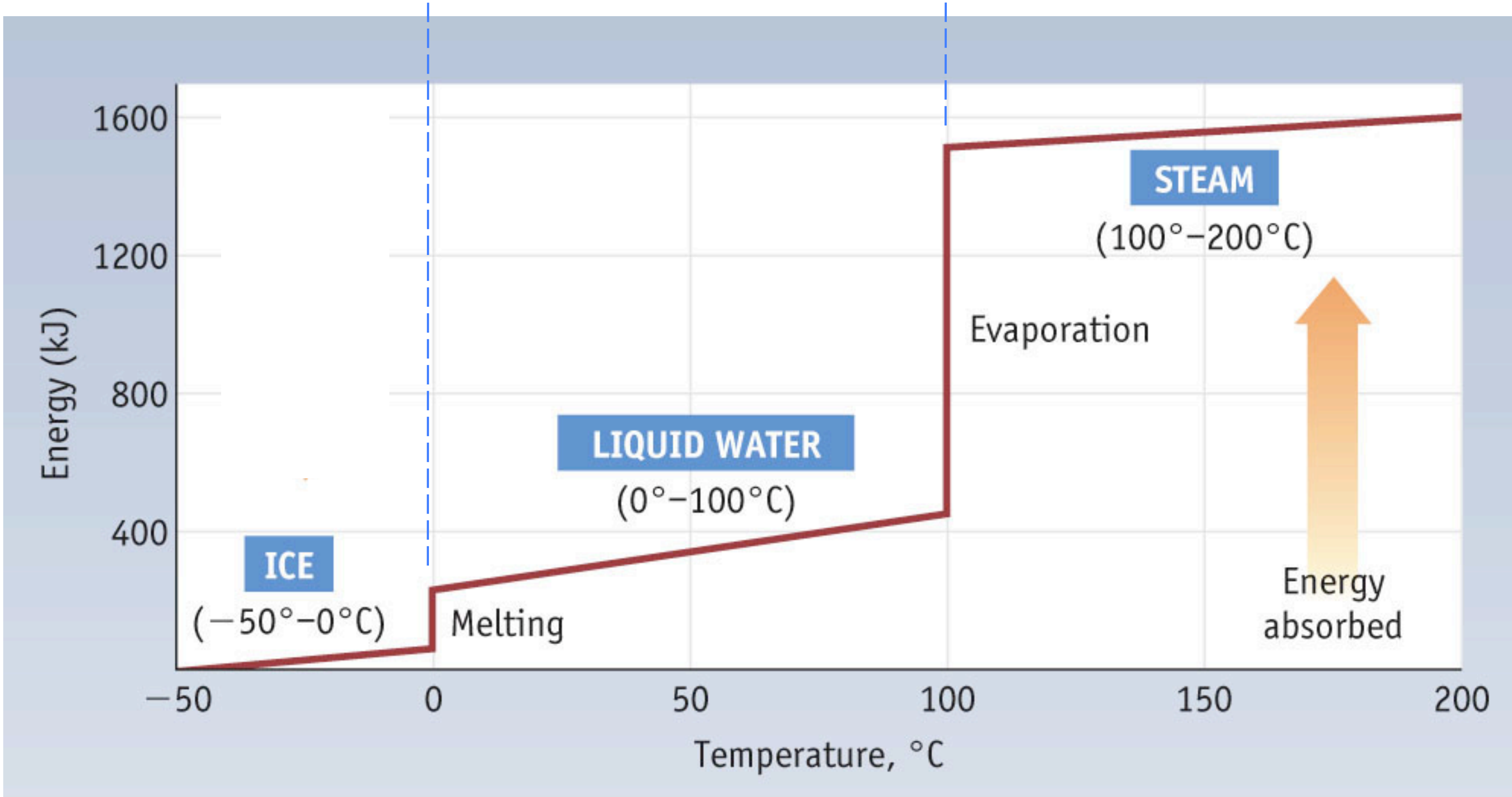


Fig. 5-9, p. 219

ΔH_{fusion} $\Delta H_{vaporization}$

$q = C_{ice} m \Delta T$ $q = C_{water} m \Delta T$ $q = C_{steam} m \Delta T$

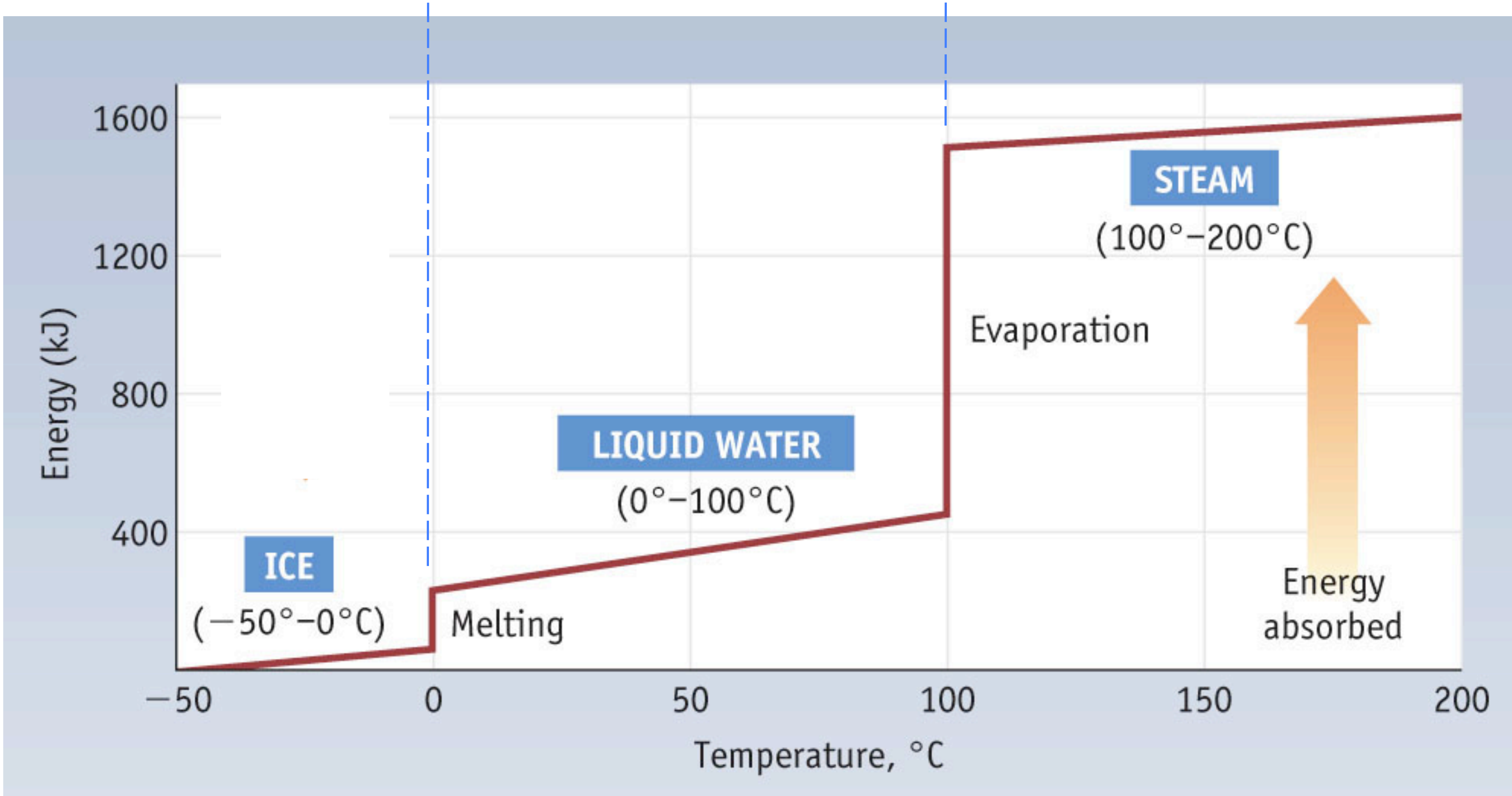
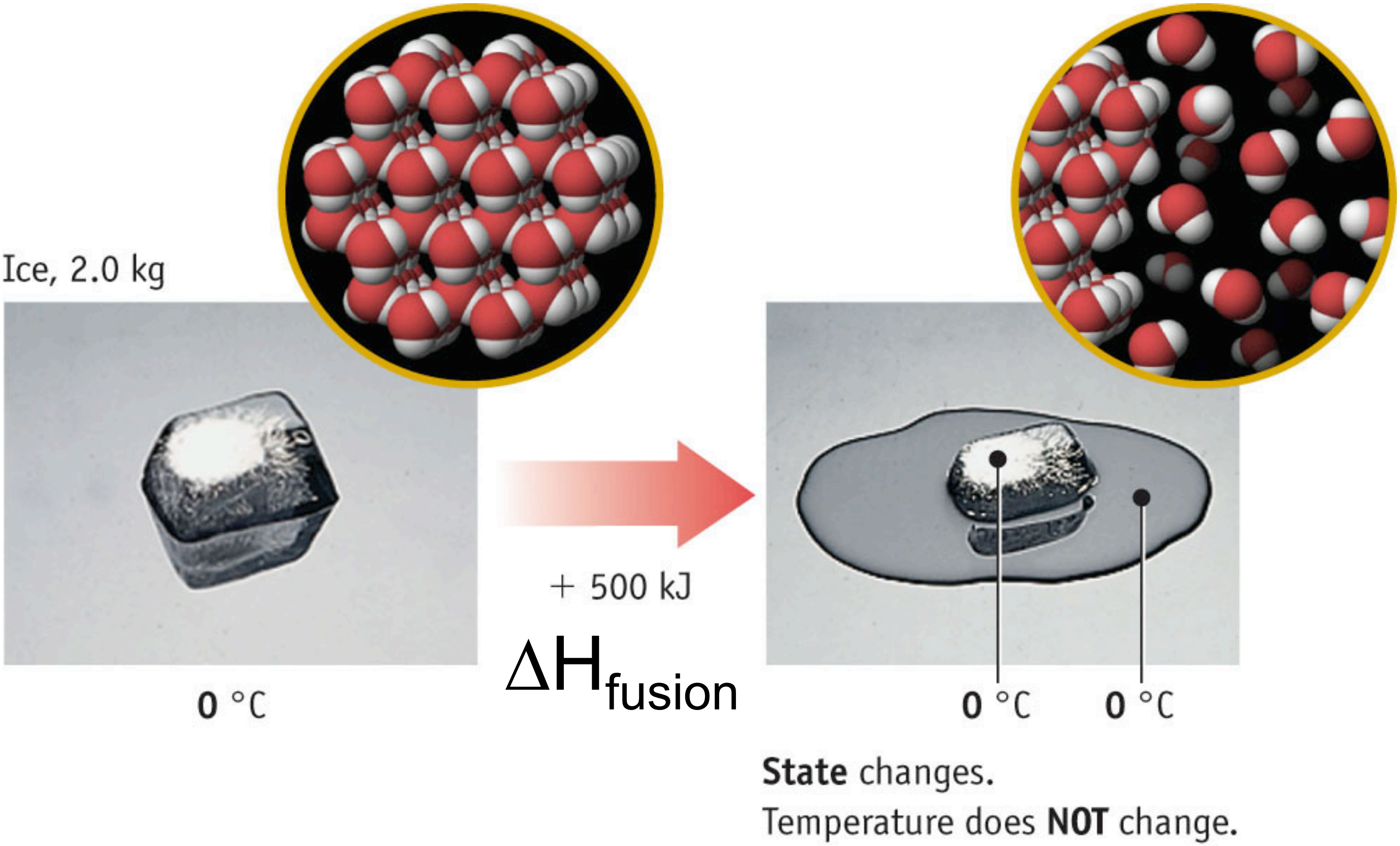


Fig. 5-9, p. 219

Fusion / Melting ΔState, constant T



ΔH_{fusion}

Fig. 5-10, p. 220

Heat Capacity (ΔT, constant state)

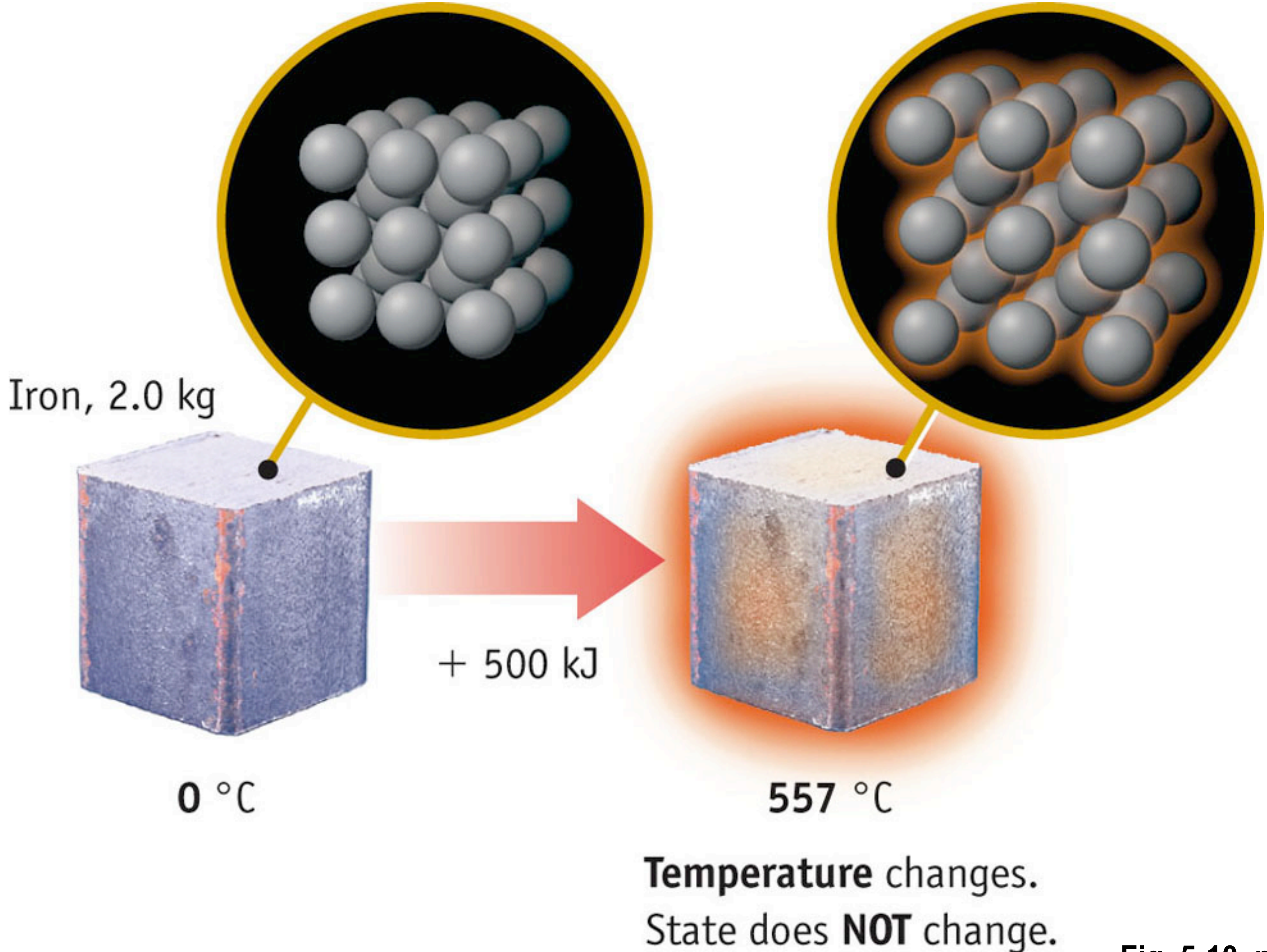


Fig. 5-10, p. 220

Energy of a System

Energy of a System

We can also do WORK on a system, as a way of putting energy into the system

Energy of a System

We can also do WORK on a system, as a way of putting energy into the system

Or the system can do work, which takes energy out of the system

Change in energy content

Energy transferred as work to or from the system

$$\Delta U = q + w$$

Energy transferred as heat to or from the system

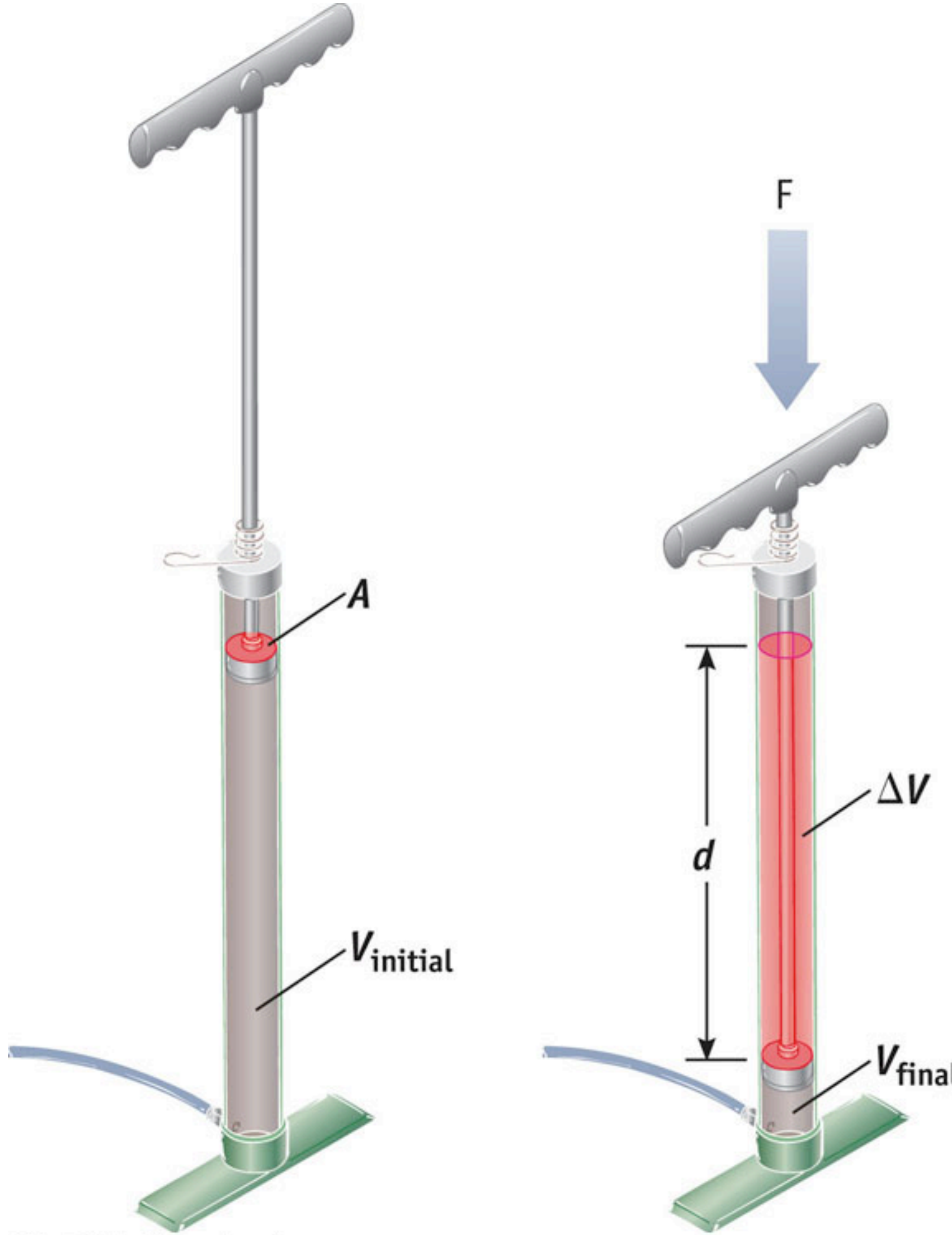
Positive value:
energy INTO the system

Work (at constant pressure)

Change in volume

$$w = -P \times \Delta V$$

Pressure



A Closer Look, p. 225

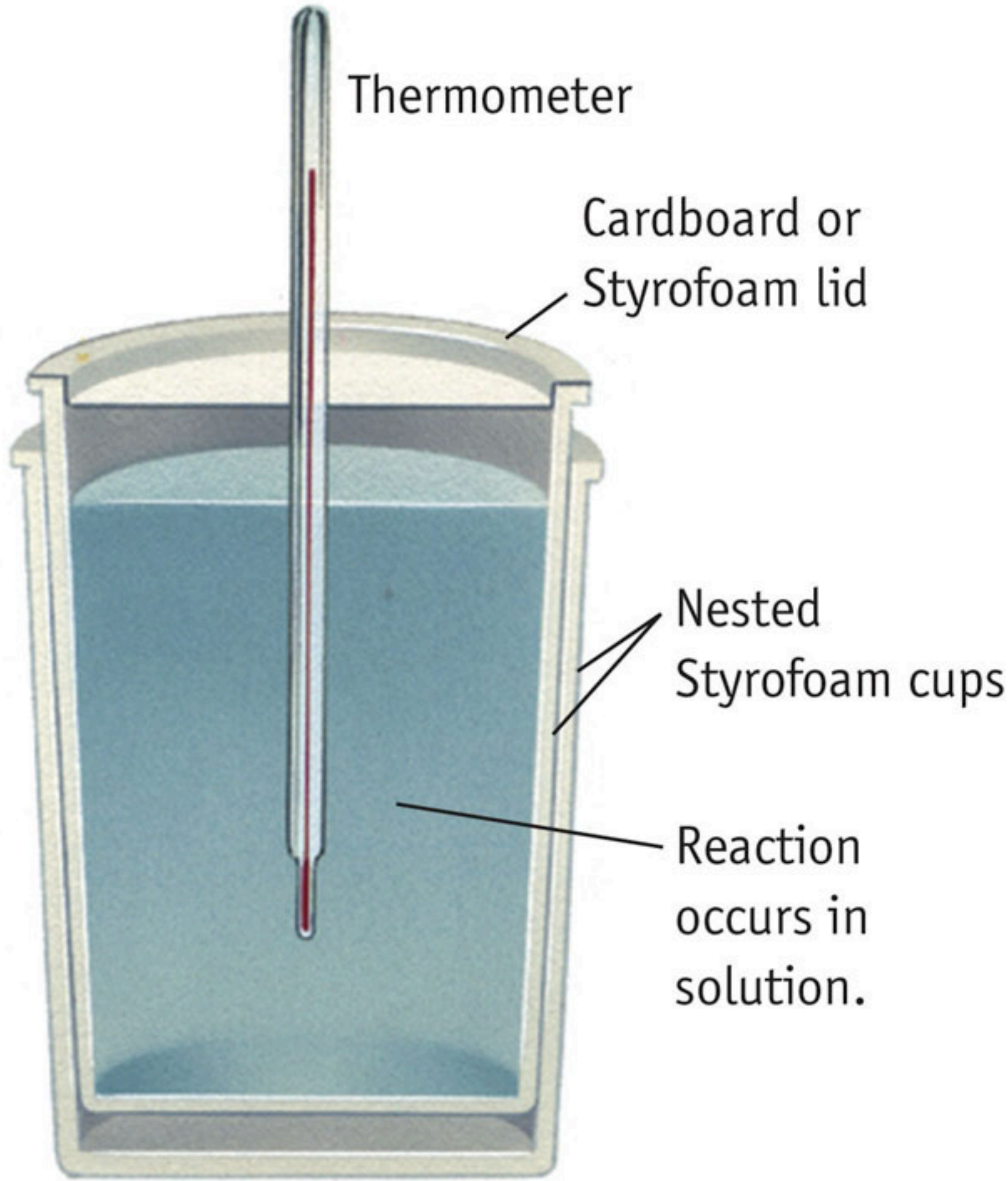

Thermometer
Cardboard or Styrofoam lid
Nested Styrofoam cups
Reaction occurs in solution.

Fig. 5-14, p. 230

Energy is a **State Function**

Energy is a **State Function**

A state function defines a system independent of “how you got there”

Energy is a **State Function**

A state function defines a system independent of “how you got there”

State Functions:

NOT State Functions:

Energy is a **State Function**

A state function defines a system independent of "how you got there"

State Functions:

Energy (ΔU, ΔH)

NOT State Functions:

Energy is a **State Function**

A state function defines a system independent of "how you got there"

State Functions:

- Energy (ΔU, ΔH)
- Pressure

NOT State Functions:

Energy is a **State Function**

A state function defines a system independent of "how you got there"

State Functions:

- Energy (ΔU, ΔH)
- Pressure
- Volume

NOT State Functions:

Energy is a **State Function**

A state function defines a system independent of “how you got there”

State Functions:

- Energy (ΔU, ΔH)
- Pressure
- Volume
- Temperature

NOT State Functions:

Energy is a **State Function**

A state function defines a system independent of "how you got there"

State Functions:

- Energy (ΔU, ΔH)
- Pressure
- Volume
- Temperature
- Elevation

NOT State Functions:

Energy is a **State Function**

A state function defines a system independent of “how you got there”

State Functions:

- Energy (ΔU, ΔH)
- Pressure
- Volume
- Temperature
- Elevation
- Your bank balance

NOT State Functions:

Energy is a **State Function**

A state function defines a system independent of “how you got there”

State Functions:

- Energy (ΔU, ΔH)
- Pressure
- Volume
- Temperature
- Elevation
- Your bank balance

NOT State Functions:

- Driving distance to Boston

Energy is a **State Function**

A state function defines a system independent of "how you got there"

State Functions:

- Energy (ΔU, ΔH)
- Pressure
- Volume
- Temperature
- Elevation
- Your bank balance

NOT State Functions:

- Driving distance to Boston
- q

Energy is a **State Function**

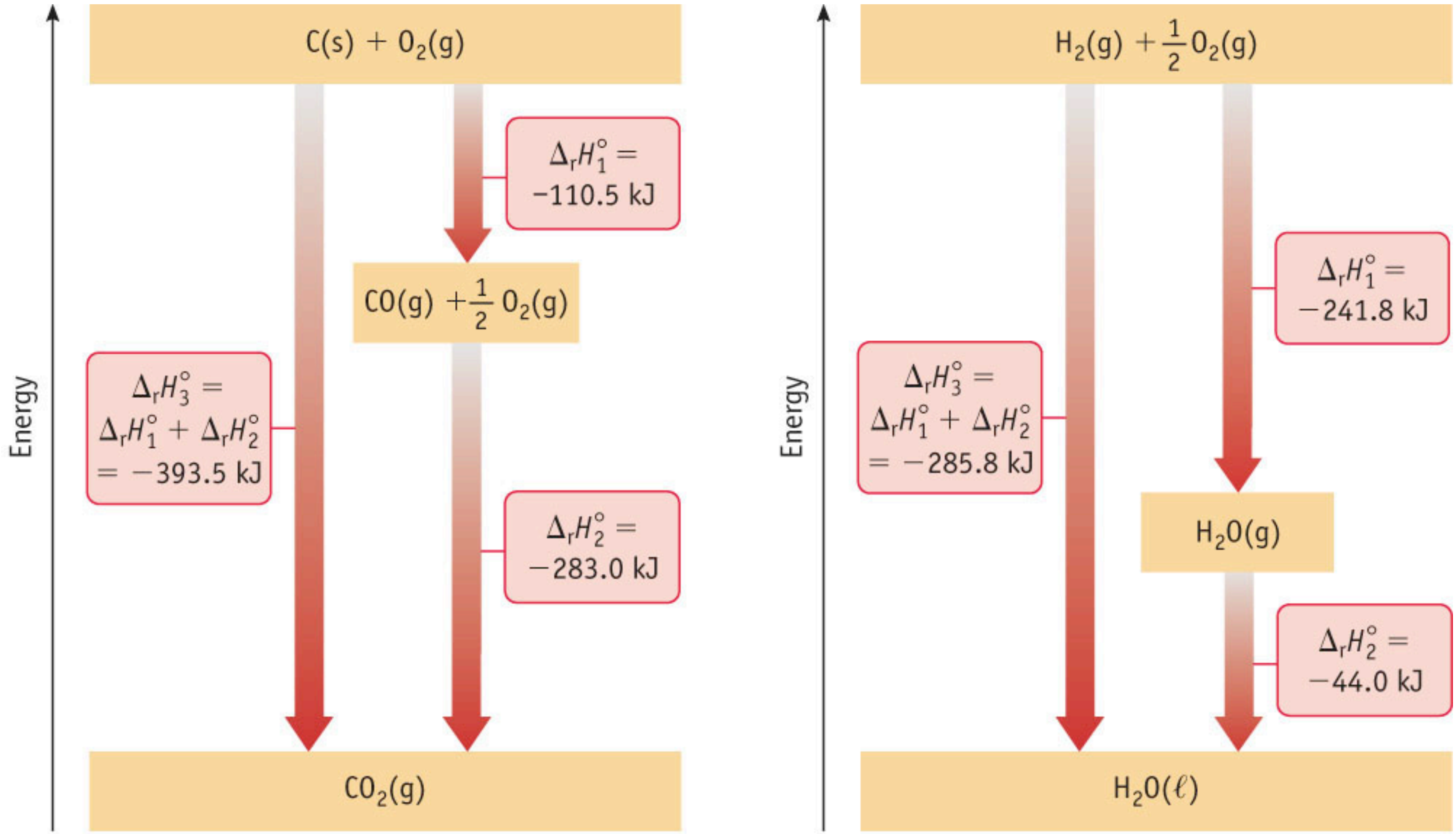
A state function defines a system independent of "how you got there"

State Functions:

- Energy (ΔU, ΔH)
- Pressure
- Volume
- Temperature
- Elevation
- Your bank balance

NOT State Functions:

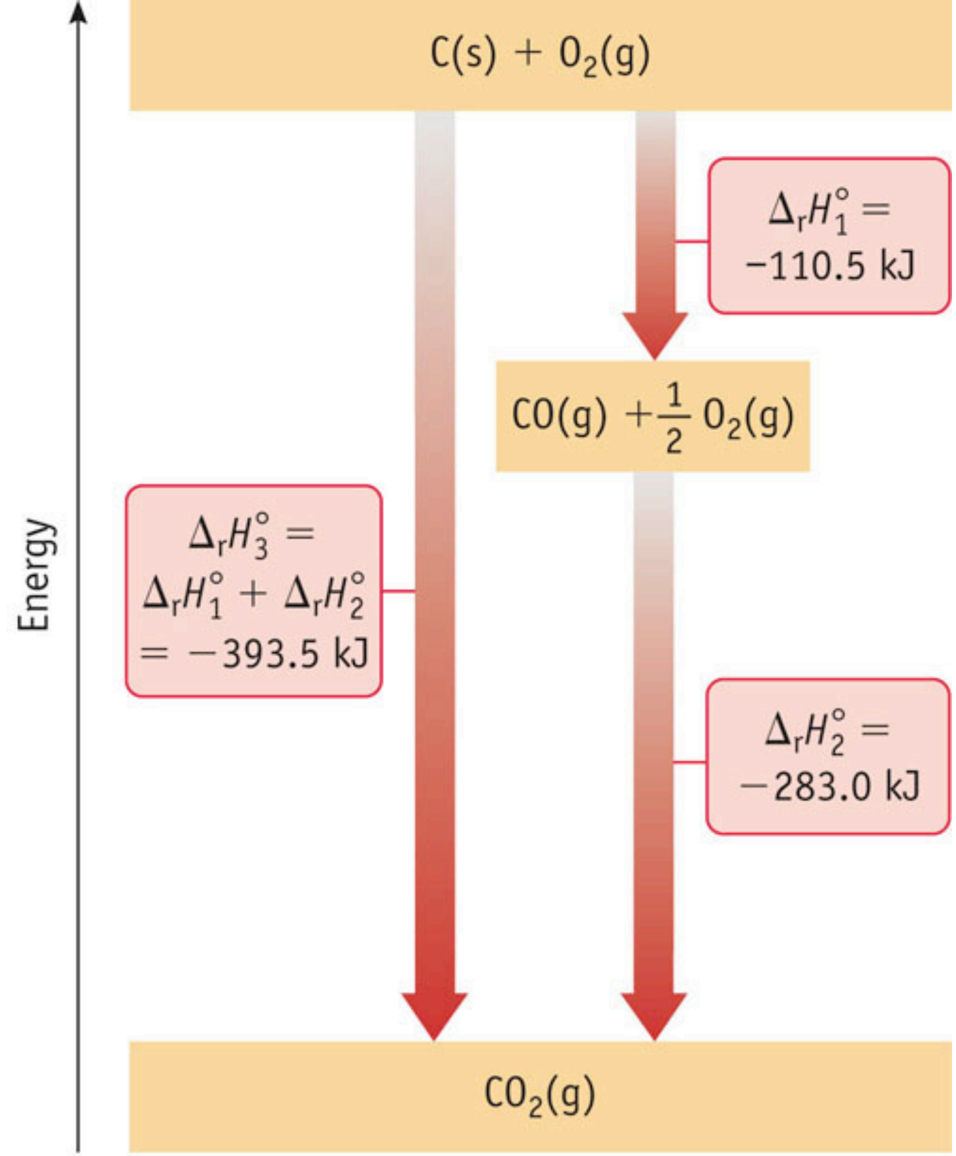
- Driving distance to Boston
- q
- w



(a) The formation of CO_2 can occur in a single step or in a succession of steps. $\Delta_r H^\circ$ for the overall process is -393.5 kJ, no matter which path is followed.

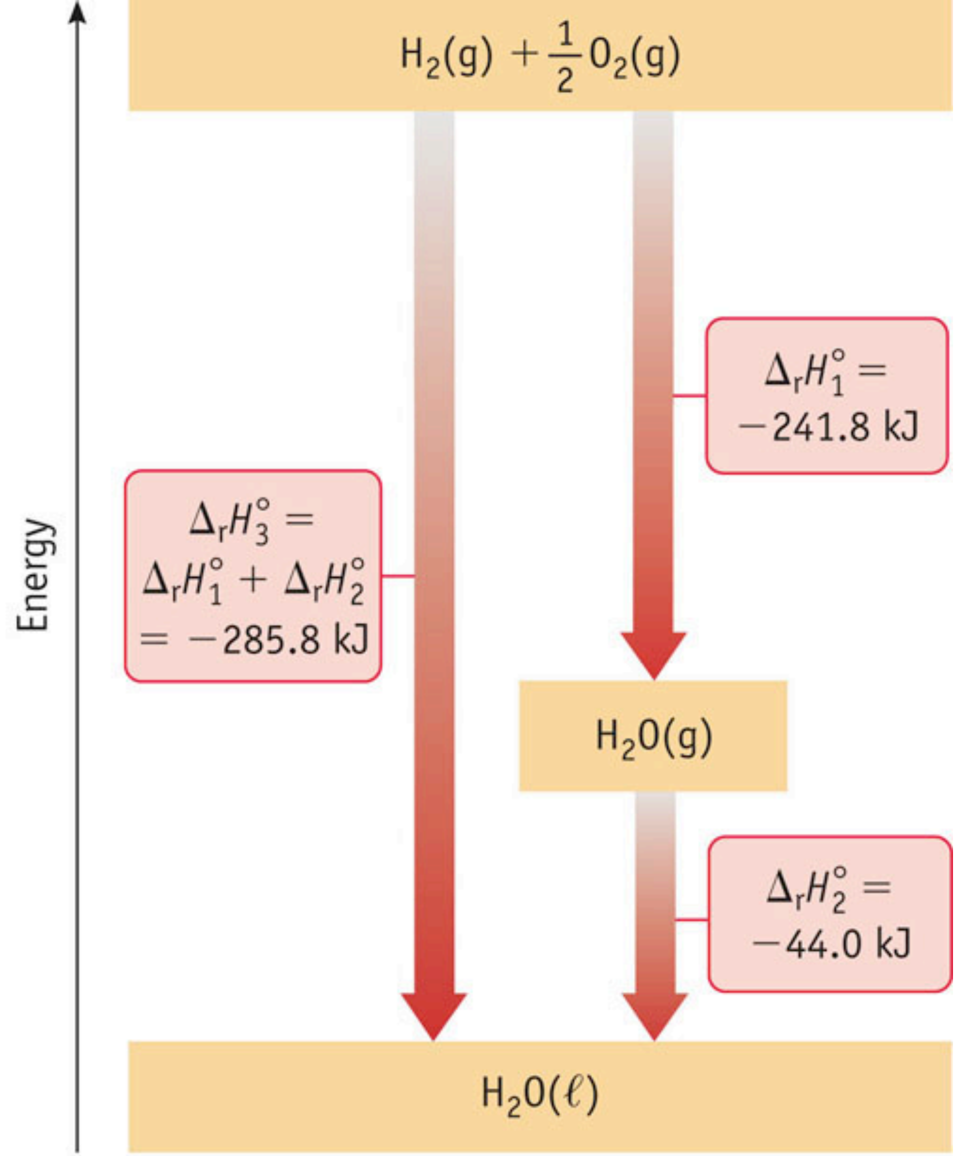
(b) The formation of $H_2O(\ell)$ can occur in a single step or in a succession of steps. $\Delta_r H^\circ$ for the overall process is -285.8 kJ, no matter which path is followed.

Fig. 5-16, p. 234



(a) The formation of CO_2 can occur in a single step or in a succession of steps. $\Delta_r H^\circ$ for the overall process is -393.5 kJ, no matter which path is followed.

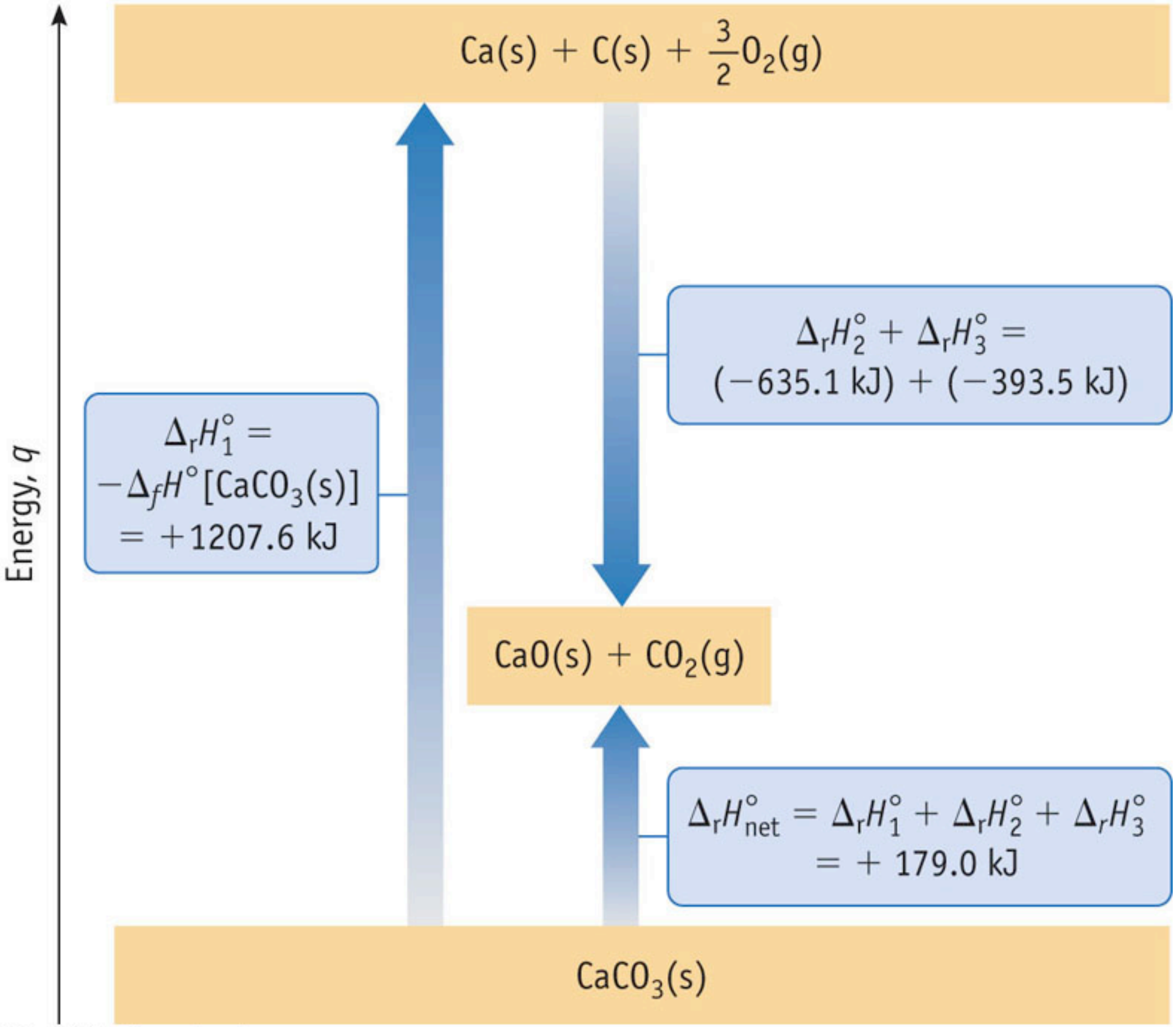
Fig. 5-16, p. 234



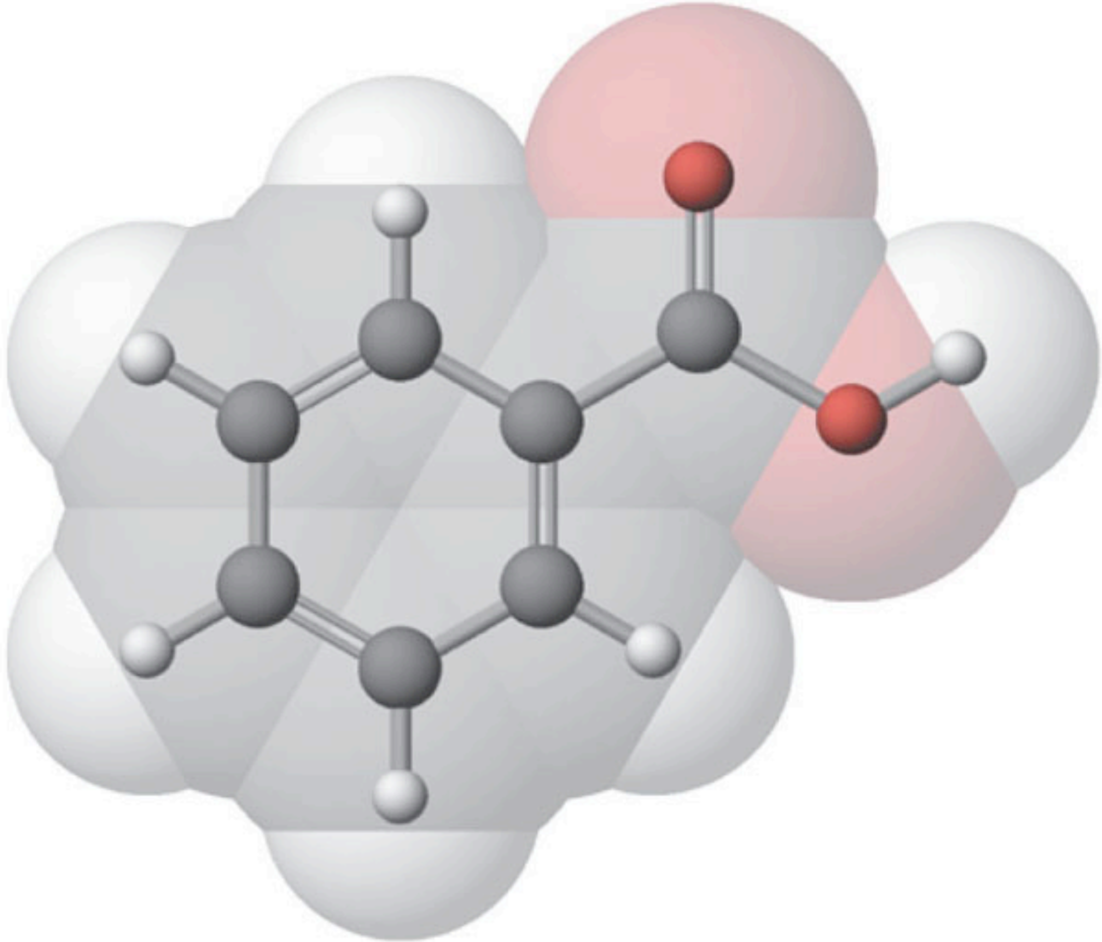
(b) The formation of $H_2O(\ell)$ can occur in a single step or in a succession of steps. $\Delta_r H^\circ$ for the overall process is -285.8 kJ, no matter which path is followed.

Fig. 5-16, p. 234

Energy level diagram for the decomposition of $CaCO_3(s)$

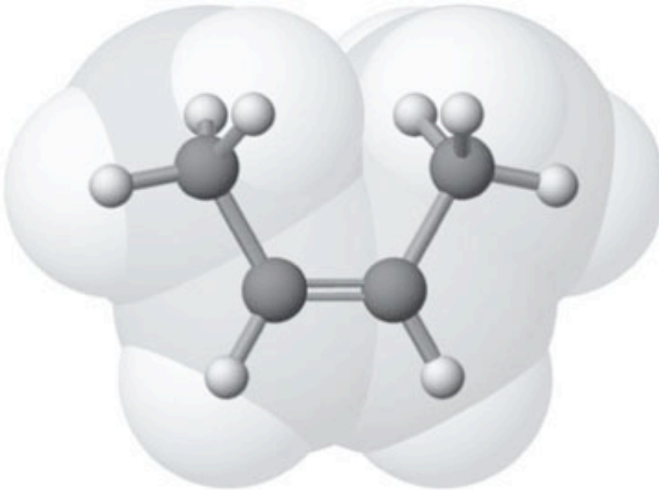


A Closer Look, p. 238

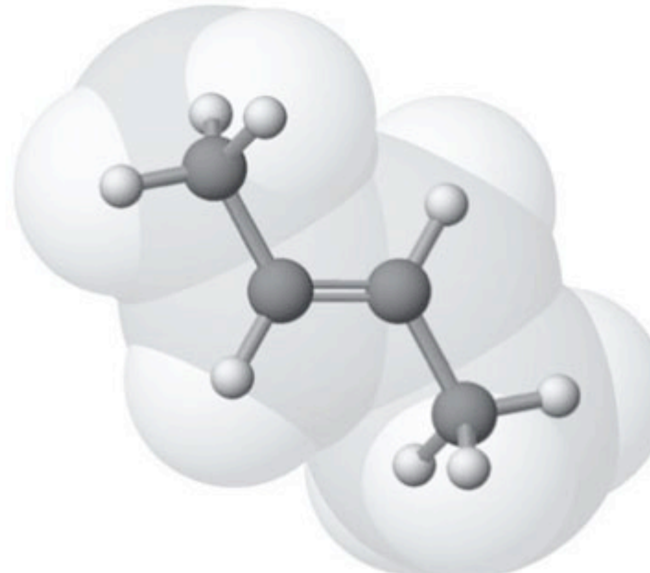


Benzoic acid, $C_6H_5CO_2H$, occurs naturally in many berries. Its heat of combustion is well known, so it is used as a standard to calibrate calorimeters.

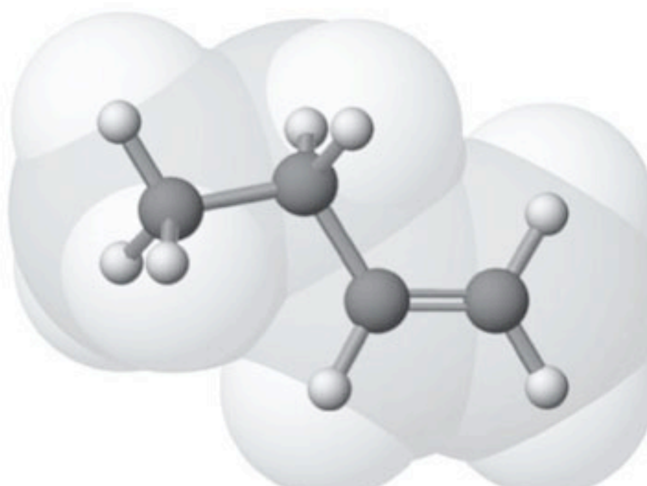
Study Question #39, p. 245



cis-2-butene

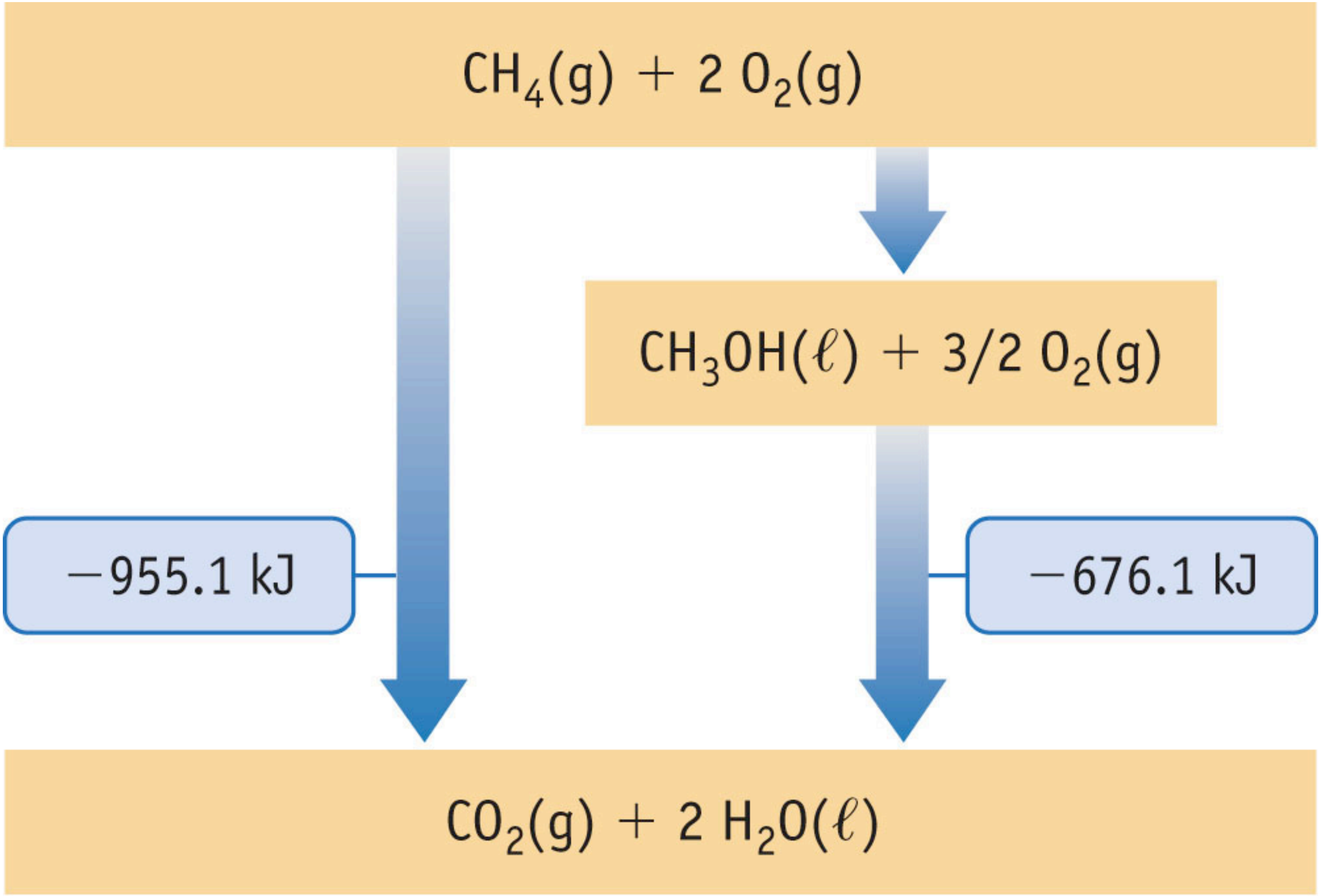


trans-2-butene

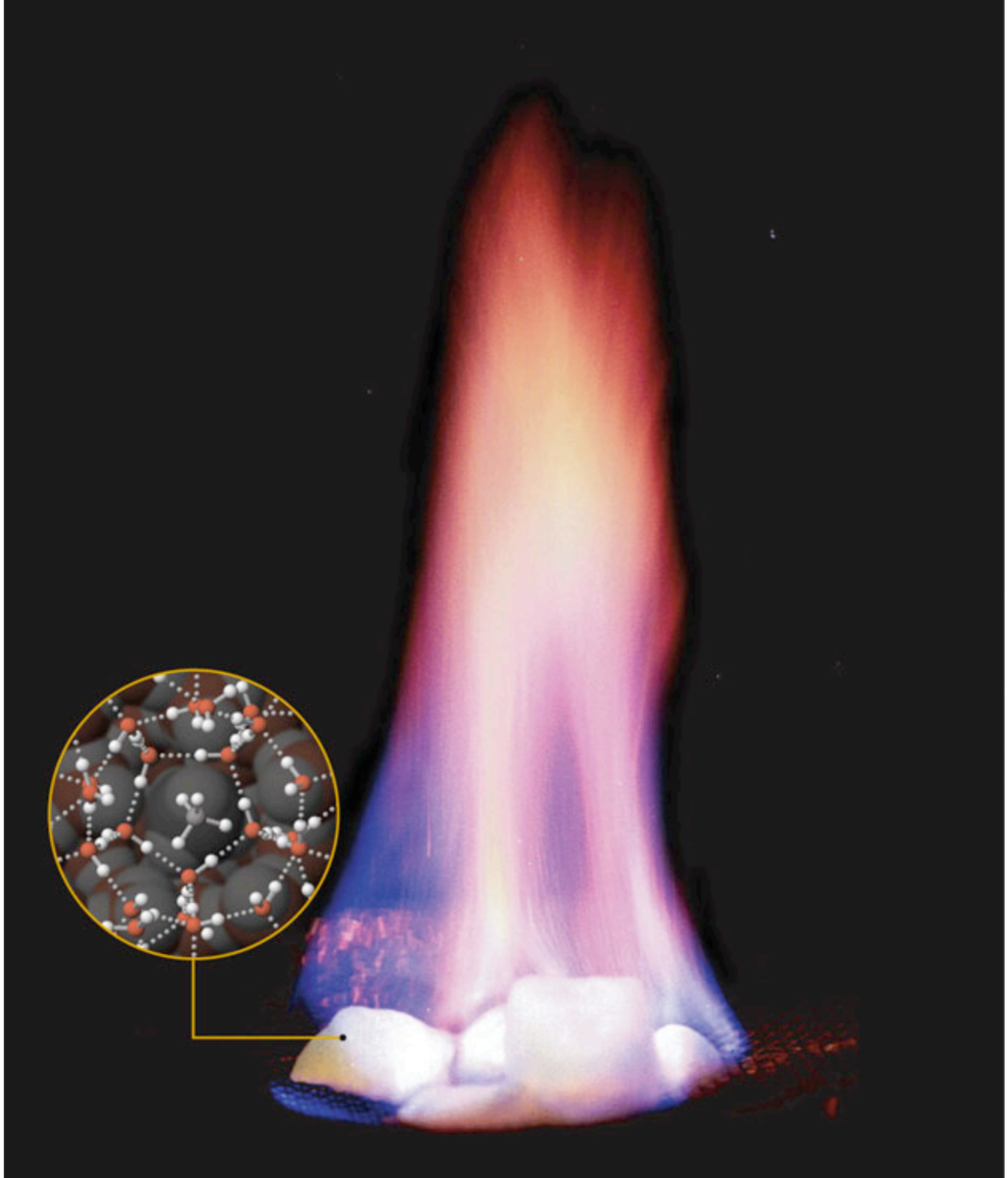


1-butene

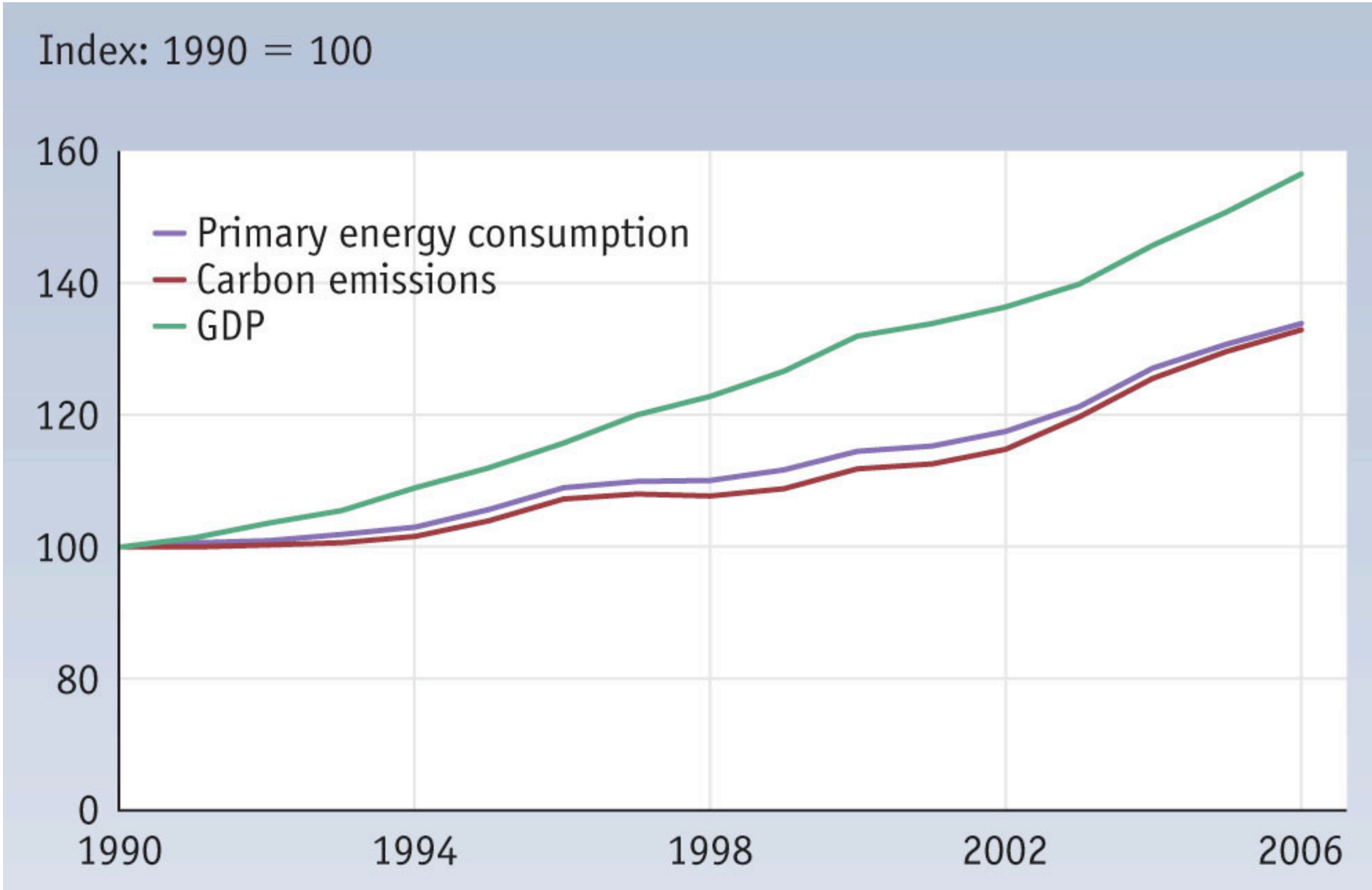
Study Question #101, p. 252



Study Question #105, p. 253



Interchapter Opener, p. 254



Interchapter, Fig. 1, p. 256

TABLE 1 Producing Electricity in the United States (2006)

Coal	50%
Nuclear	19%
Natural gas	19%
Hydroelectric	7%
Petroleum	3%
Other renewables	2%

TABLE 2 Energy Released by Combustion of Fossil Fuels

Substance	Energy Released (kJ/g)
Coal	29–37
Crude petroleum	43
Gasoline (refined petroleum)	47
Natural gas (methane)	50

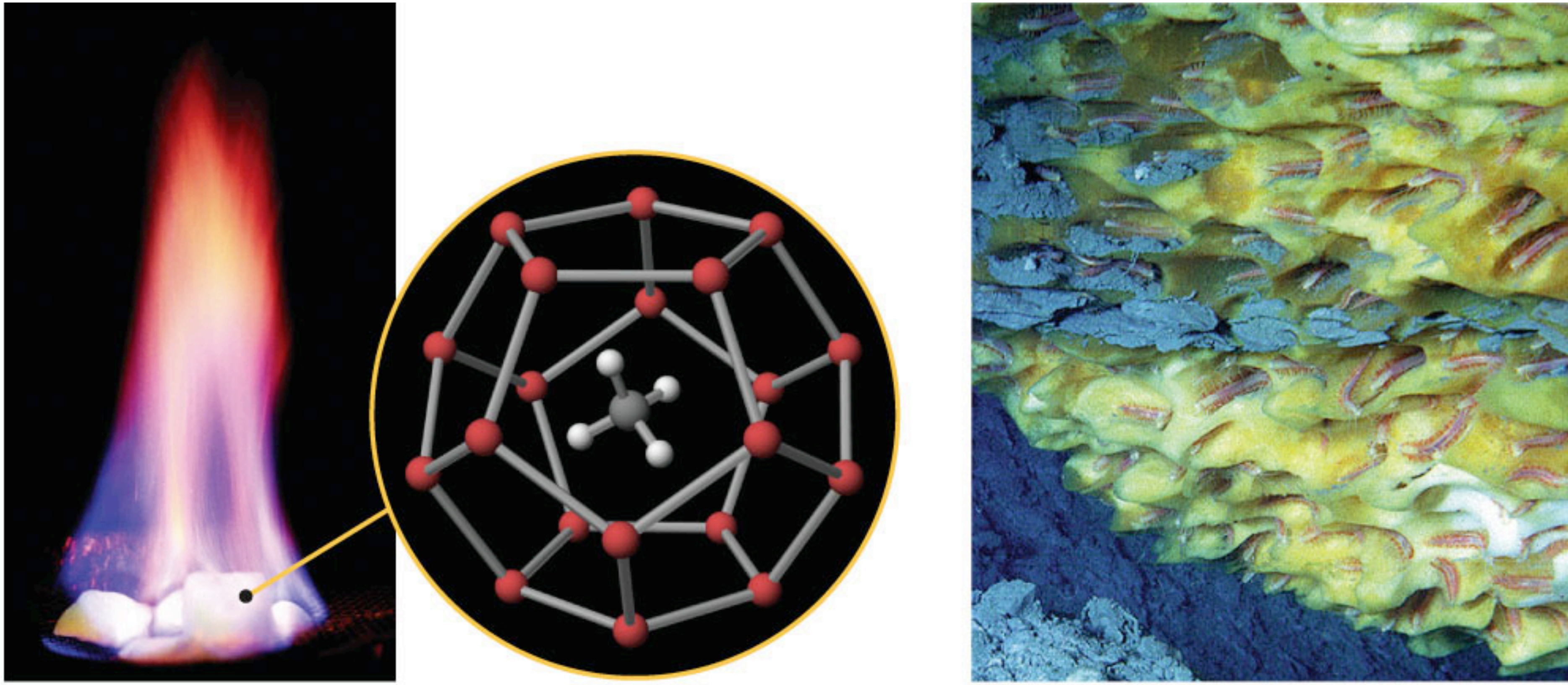
Interchapter, Table 2, p. 257

TABLE 3 Types of Coal

Type	Consistency	Sulfur Content	Heat Content (kJ/g)
Lignite	Very soft	Very low	28–30
Bituminous coal	Soft	High	29–37
Anthracite	Hard	Low	36–37

Interchapter, Fig. 3, p. 258

Interchapter, Fig. 4, p. 259

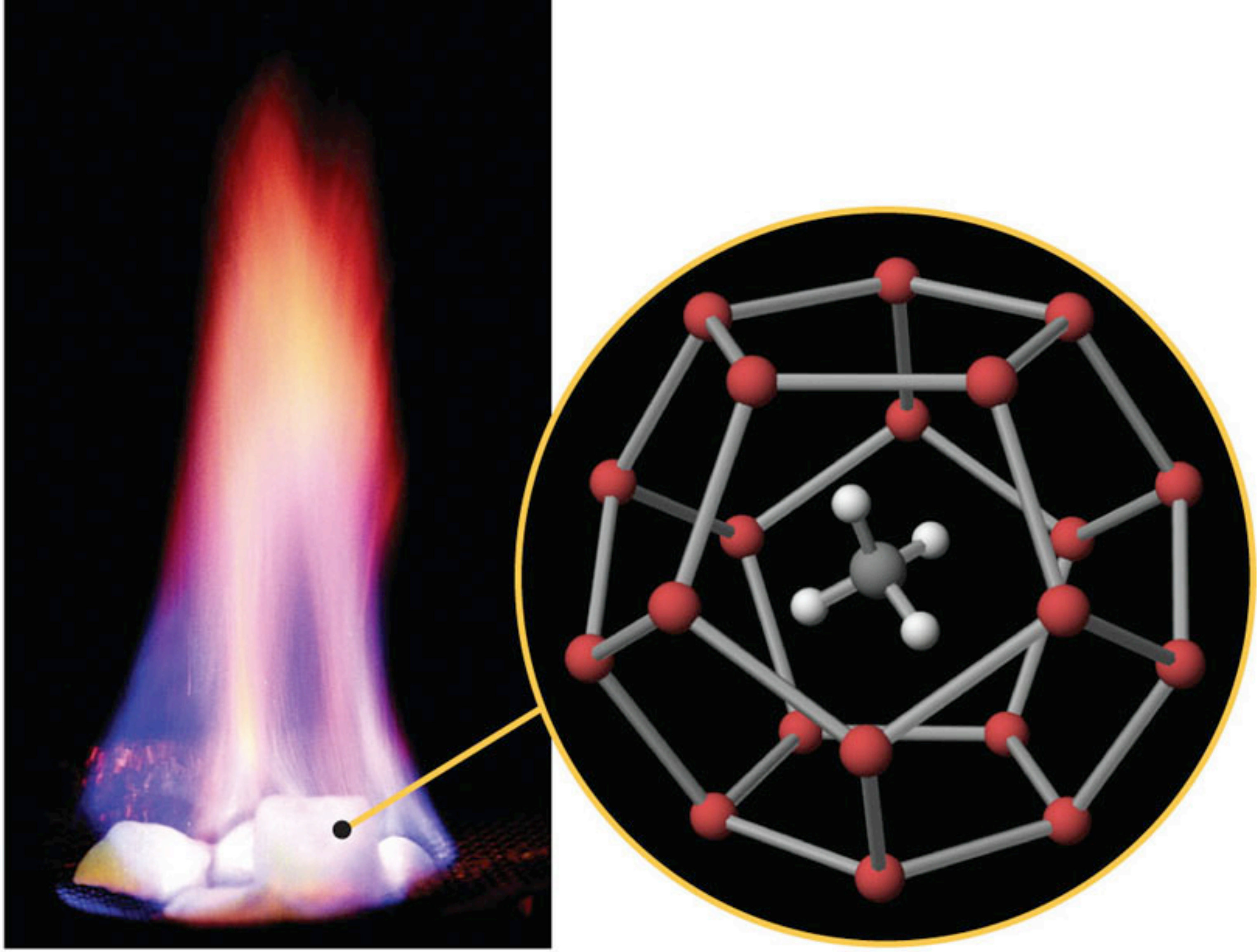


(a) Methane hydrate burns as methane gas escapes from the solid hydrate.

(b) Methane hydrate consists of a lattice of water molecules with methane molecules trapped in the cavity.

(c) A colony of worms on an outcropping of methane hydrate in the Gulf of Mexico.

Interchapter, Fig. 5, p. 260



(a) Methane hydrate burns as methane gas escapes from the solid hydrate.

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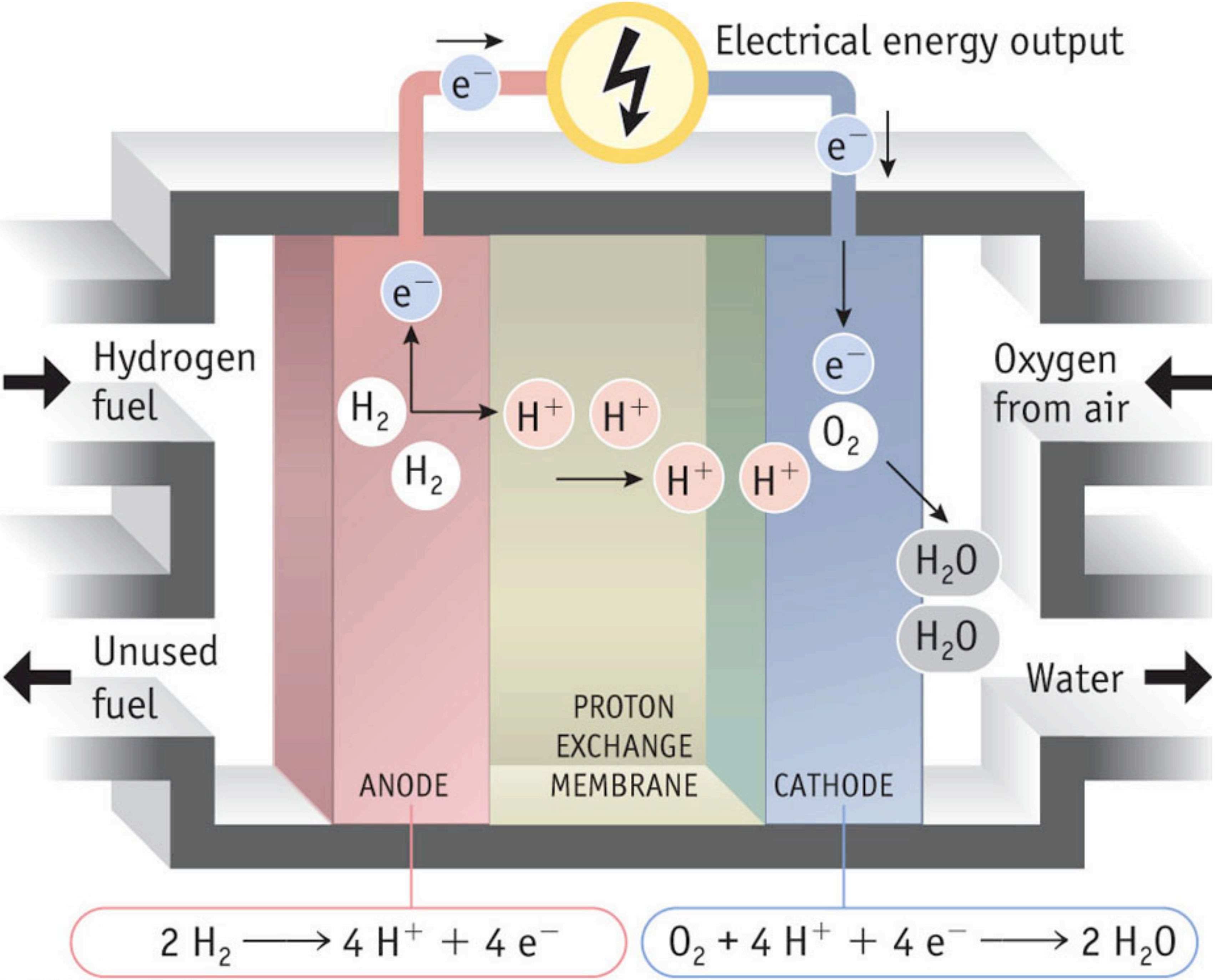
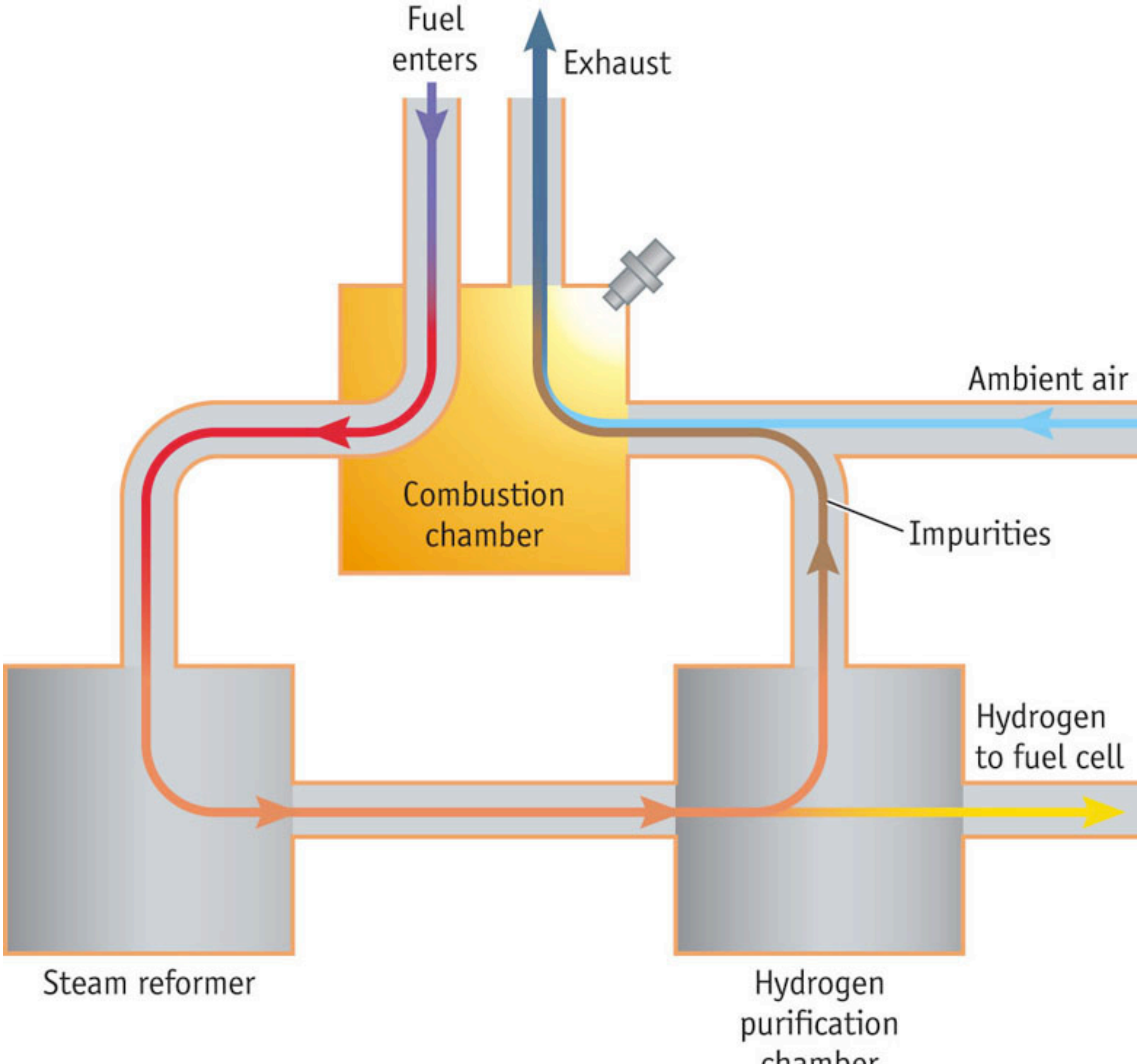
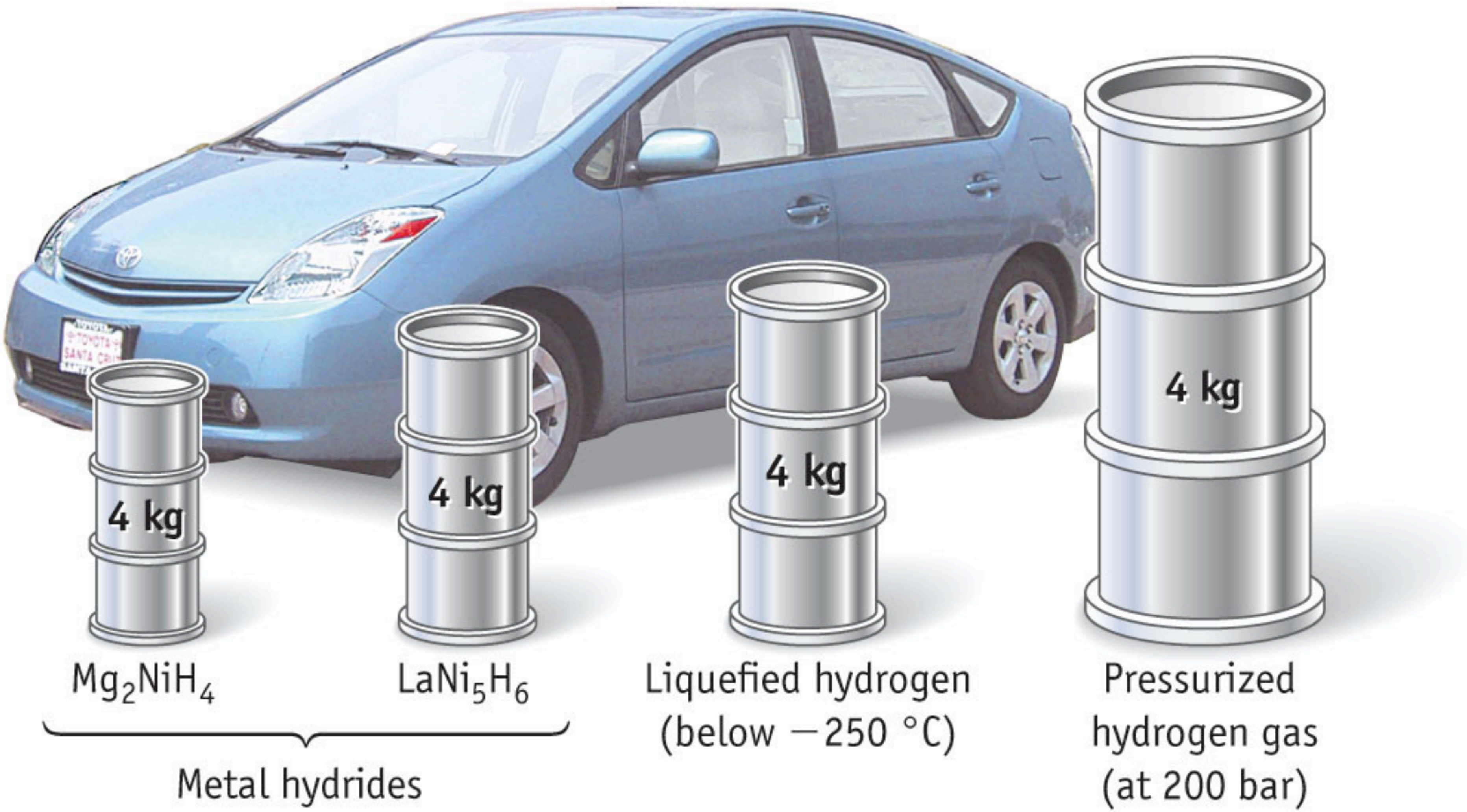
Interchapter, Fig. 5, p. 260



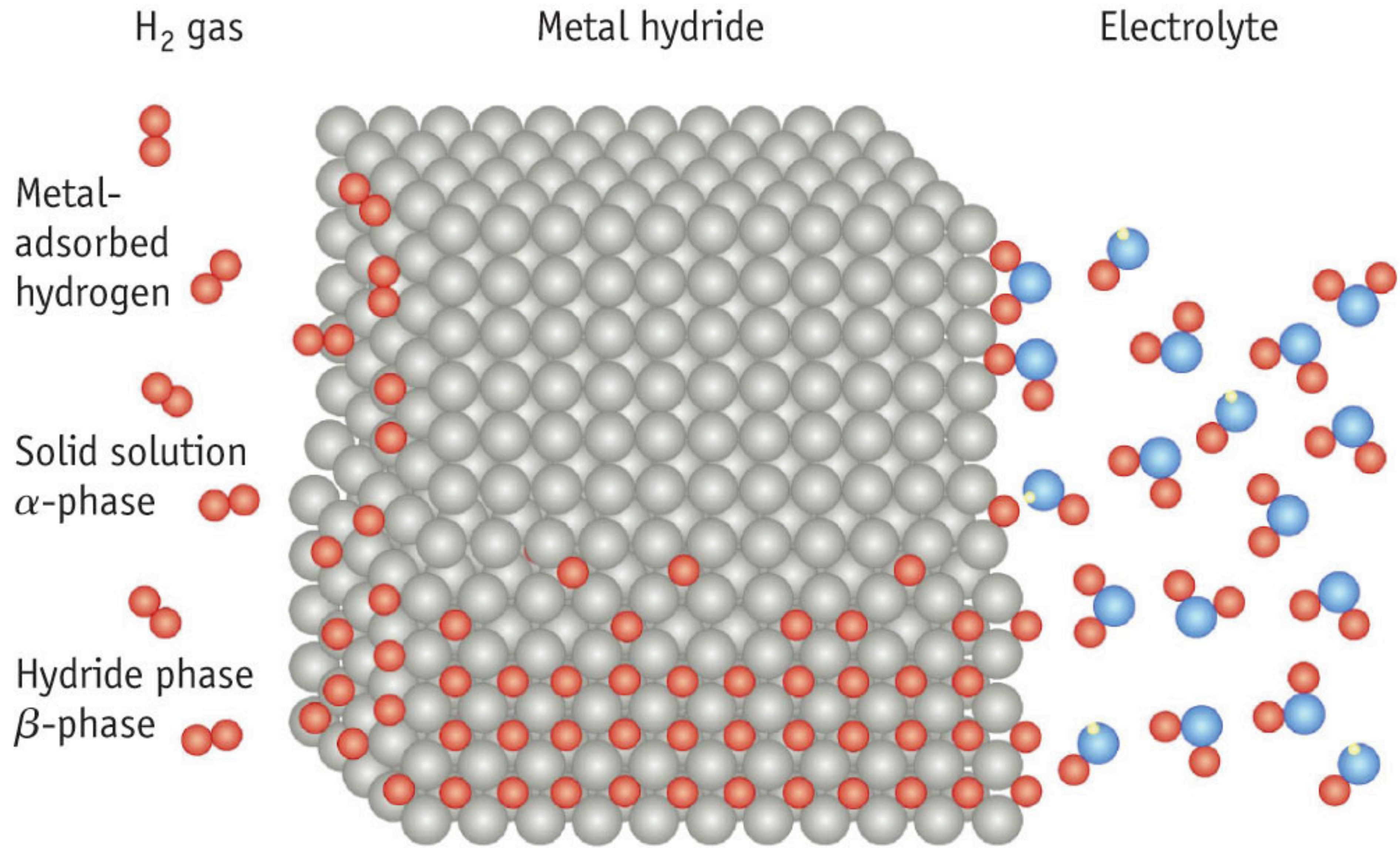
Interchapter, Fig. 9, p. 262



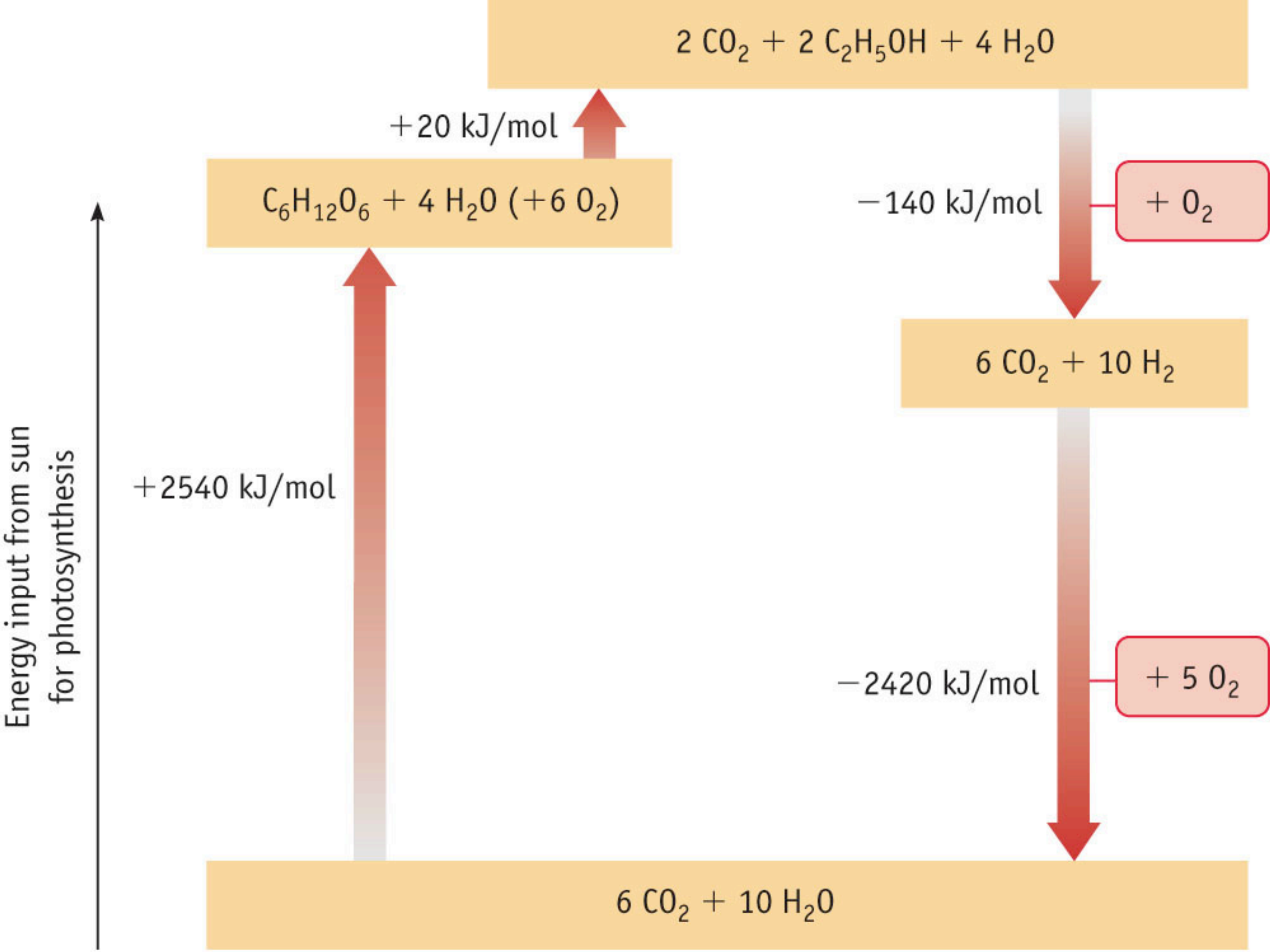
Interchapter, Fig. 11, p. 263



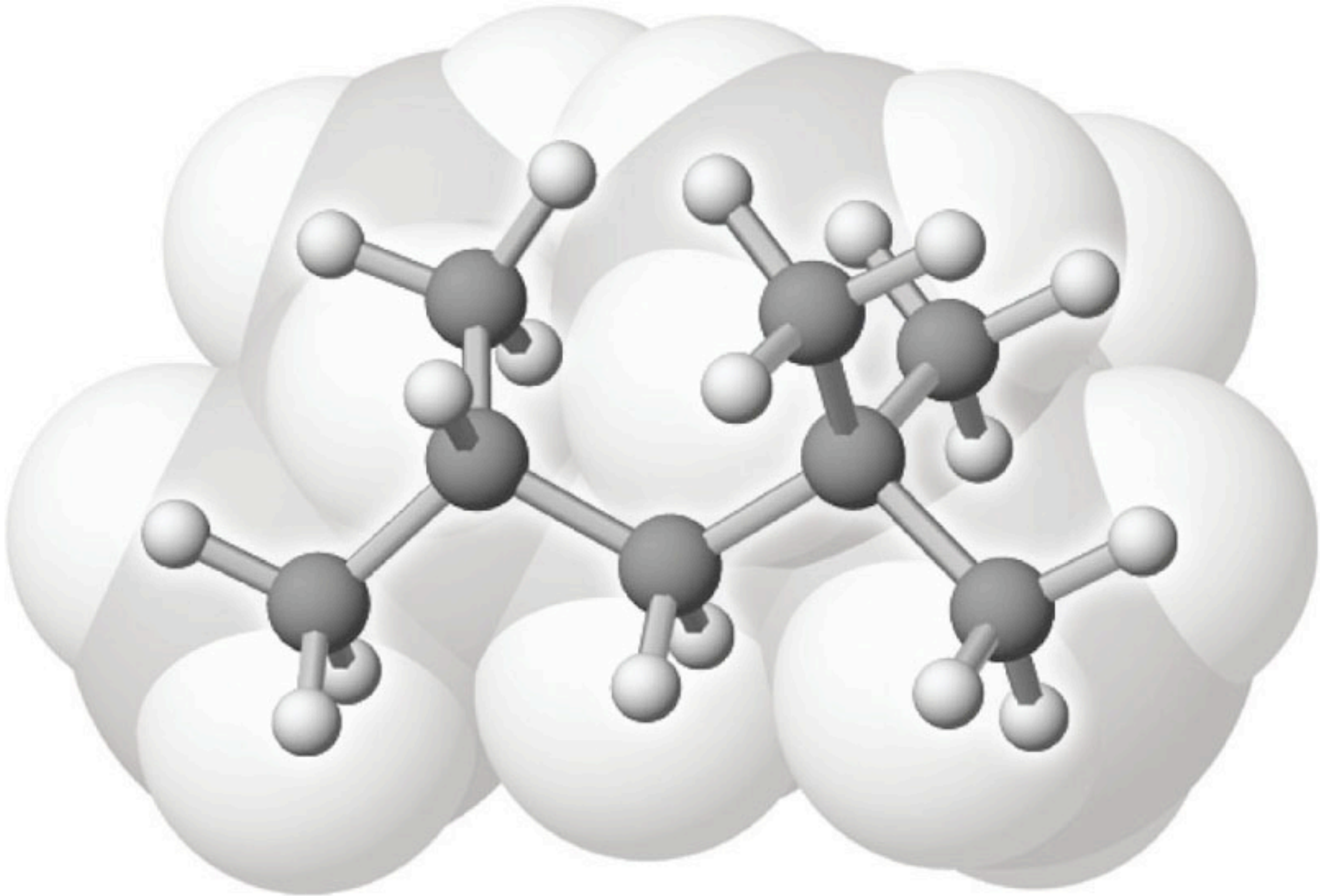
Interchapter, Fig. 12, p. 264



Interchapter, Fig. 13, p. 264



Interchapter, Fig. 16, p. 265



Isooctane
C_8H_{18}