

# Quiz on Chapter 11

# Quiz 9

1. **C&J page 316 (top), Check Your Understanding #6: “... use a straw ...”**

## Quiz 9

1. C&J page 316 (top), Check Your Understanding #6: "... use a straw ..."
2. What volume of helium has the same mass as  $5.0 \text{ m}^3$  of nitrogen?  
(Nitrogen molecule is diatomic with an atomic mass of 14.)  
(Helium has an atomic mass of 4)  
  
a)  $35 \text{ m}^3$    b)  $27 \text{ m}^3$    c)  $7.0 \text{ m}^3$    d)  $3.5 \text{ m}^3$    e)  $0.72 \text{ m}^3$

## Quiz 9

1. **C&J page 316 (top), Check Your Understanding #6: “... use a straw ...”**
2. **What volume of helium has the same mass as  $5.0 \text{ m}^3$  of nitrogen?  
(Nitrogen molecule is diatomic with an atomic mass of 14.)  
(Helium has an atomic mass of 4)**  
  
a)  $35 \text{ m}^3$    b)  $27 \text{ m}^3$    c)  $7.0 \text{ m}^3$    d)  $3.5 \text{ m}^3$    e)  $0.72 \text{ m}^3$
3. **A swimmer is swimming underwater in a large pool. The force on the back of the swimmer's hand is about one thousand newtons. The swimmer doesn't notice this force. Why not?**  
  
a) This force is actually smaller than the force exerted by the atmosphere  
b) The force is large, but the pressure on the back of the hand is small.  
c) The force is exerted on all sides equally.  
d) The swimmer is pushing on the water with the same force.  
e) I do not know, but I'm sure I would feel that kind of force.

4. Snow shoes have a much larger area than a regular shoe or boot.  
How does this improve a hiker's ability to walk across a snowy region??
- a) The hiker's weight is distributed over the area the shoes reducing the pressure on the snow.
  - b) The snow shoes increase the normal force of the snow on the hiker.
  - c) The snow shoes increase the upward pressure of the snow on the hiker.
  - d) The snow shoes compact the snow making it harder to sink into it.
  - e) The hiker's weight is reduced by wearing large area snow shoes.

# Quiz 9

b) No air on the moon

1. **C&J page 316 (top), Check Your Understanding #6: “... use a straw ...”**
2. **What volume of helium has the same mass as  $5.0 \text{ m}^3$  of nitrogen?  
(Nitrogen molecule is diatomic with an atomic mass of 14.)  
(Helium has an atomic mass of 4)**  
**a)  $35 \text{ m}^3$    b)  $27 \text{ m}^3$    c)  $7.0 \text{ m}^3$    d)  $3.5 \text{ m}^3$    e)  $0.72 \text{ m}^3$**

$\text{N}_2$  atomic weight 28, He atomic weight 4.

Ratio is 7. Volume is 7 times bigger =  $35 \text{ m}^3$

3. **A swimmer is swimming underwater in a large pool. The force on the back of the swimmer's hand is about one thousand newtons. The swimmer doesn't notice this force. Why not?**  
**a) This force is actually smaller than the force exerted by the atmosphere**  
**b) The force is large, but the pressure on the back of the hand is small.**  
**c) The force is exerted on all sides equally.**  
**d) The swimmer is pushing on the water with the same force.**  
**e) I do not know, but I'm sure I would feel that kind of force.**

4. Snow shoes have a much larger area than a regular shoe or boot.  
How does this improve a hiker's ability to walk across a snowy region??

- a)** The hiker's weight is distributed over the area the shoes reducing the pressure on the snow.
- b)** The snow shoes increase the normal force of the snow on the hiker.
- c)** The snow shoes increase the upward pressure of the snow on the hiker.
- d)** The snow shoes compact the snow making it harder to sink into it.
- e)** The hiker's weight is reduced by wearing large area snow shoes.

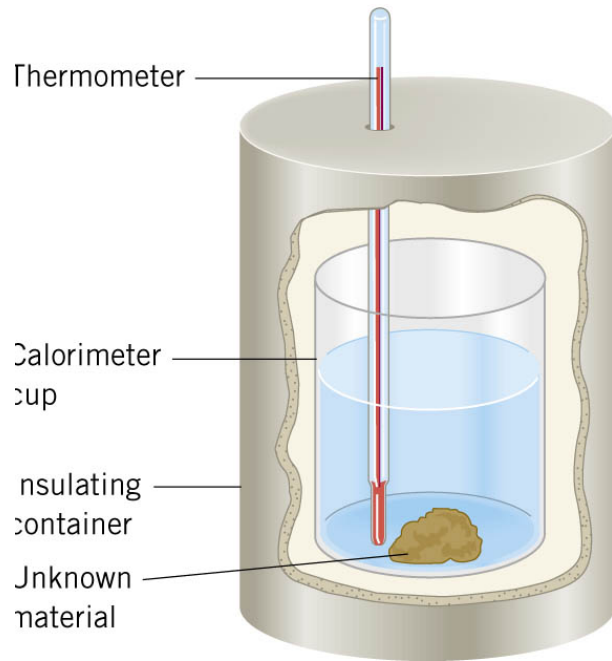
# *Chapter 12*

## ***Temperature and Heat***

***continued***



## 12.7 Heat and Temperature Change: Specific Heat Capacity



### CALORIMETRY

If there is no heat loss to the surroundings, the heat lost by the hotter object equals the heat gained by the cooler ones. **Net heat change equals zero.**

A calorimeter is made of 0.15 kg of aluminum and contains 0.20 kg of water, both at 18.0 C°. A mass, 0.040 kg at 97.0 C° is added to the water, causing the water temperature to rise to 22.0 C°. What is the specific heat capacity of the mass?

Water and Al rise in temperature ( $\Delta T > 0$ )

Unknown stuff drops in temperature ( $\Delta T < 0$ )

$$\Delta T_w = \Delta T_{Al} = +4^\circ\text{C}; \quad \Delta T_{Unk} = -75^\circ\text{C}$$

Al  $\equiv$  Aluminum, W  $\equiv$  water, Unk  $\equiv$  unknown

**Net heat change equals zero.**

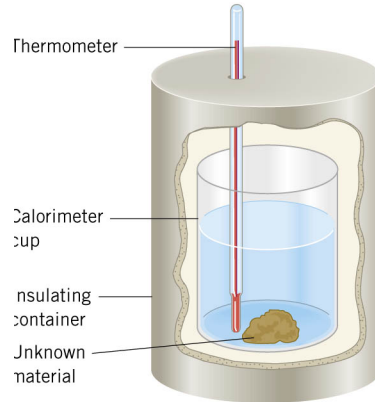
**Beware**, C&J take  $\Delta T$  always positive and use Heat Lost by 1 = Heat gained by 2  
**No good**, if there are 3 objects!

$$\sum Q = m_{Al} c_{Al} \Delta T_{Al} + m_w c_w \Delta T_w + m_{Unk} c_{Unk} \Delta T_{Unk} = 0$$

**Three heat changes must sum to zero**

## 12.7 Heat and Temperature Change: Specific Heat Capacity

A calorimeter is made of 0.15 kg of aluminum and contains 0.20 kg of water, both at 18.0 C°. A mass, 0.040 kg at 97.0 C° is added to the water, causing the water temperature to rise to 22.0 C°. What is the specific heat capacity of the mass?



Water and Al rise in temperature ( $\Delta T > 0$ )

Unknown material drops in temperature ( $\Delta T < 0$ )

$$\Delta T_w = \Delta T_{Al} = +4^\circ\text{C}; \quad \Delta T_{Unk} = -75^\circ\text{C}$$

$$c_{Al} = 900 \text{ J/kg} \cdot \text{C}^\circ$$

$$c_w = 4190 \text{ J/kg} \cdot \text{C}^\circ$$

Net heat change equals zero.

$$\sum Q = m_{Al} c_{Al} \Delta T_{Al} + m_w c_w \Delta T_w + m_{Unk} c_{Unk} \Delta T_{Unk} = 0$$

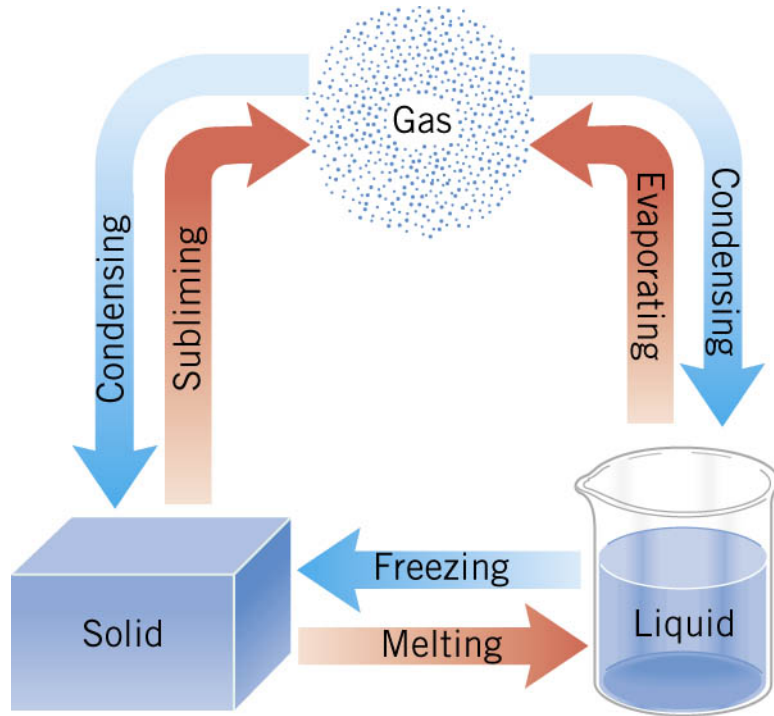
$$c_{Unk} = \frac{m_{Al} c_{Al} \Delta T_{Al} + m_w c_w \Delta T_w}{-m_{Unk} \Delta T_{Unk}};$$

$$= \frac{[(0.15\text{kg})(900 \text{ J/kg} \cdot \text{C}^\circ) + (0.20\text{kg})(4.19 \times 10^3 \text{ J/kg} \cdot \text{C}^\circ)](4\text{C}^\circ)}{-(0.04\text{kg})(-75\text{C}^\circ)}$$

$$= 1.3 \times 10^3 \text{ J/(kg} \cdot \text{C}^\circ)$$

## 12.8 Heat and Phase Change: Latent Heat

### THE PHASES OF MATTER



There is internal energy added or removed in a change of phase.

Typically, solid  $\rightarrow$  liquid (melt) or liquid  $\rightarrow$  gas (evaporate) requires heat energy to be **ADDED**.

Typically, gas  $\rightarrow$  liquid (condense), or liquid  $\rightarrow$  solid (freeze) requires heat energy to be **REMOVED**.

### HEAT ADDED OR REMOVED IN CHANGING THE PHASE OF A SUBSTANCE

The heat that must be supplied or removed to change the phase of a mass  $m$  of a substance is the “latent heat”,  $L$  :

$$Q = mL$$

**SI Units of Latent Heat:** J/kg

## 12.8 Heat and Phase Change: Latent Heat

**Table 12.3** Latent Heats<sup>a</sup> of Fusion and Vaporization

Substance	Melting Point (°C)	Latent Heat of Fusion, $L_f$ (J/kg)	Boiling Point (°C)	Latent Heat of Vaporization, $L_v$ (J/kg)
Ammonia	−77.8	$33.2 \times 10^4$	−33.4	$13.7 \times 10^5$
Benzene	5.5	$12.6 \times 10^4$	80.1	$3.94 \times 10^5$
Copper	1083	$20.7 \times 10^4$	2566	$47.3 \times 10^5$
Ethyl alcohol	−114.4	$10.8 \times 10^4$	78.3	$8.55 \times 10^5$
Gold	1063	$6.28 \times 10^4$	2808	$17.2 \times 10^5$
Lead	327.3	$2.32 \times 10^4$	1750	$8.59 \times 10^5$
Mercury	−38.9	$1.14 \times 10^4$	356.6	$2.96 \times 10^5$
Nitrogen	−210.0	$2.57 \times 10^4$	−195.8	$2.00 \times 10^5$
Oxygen	−218.8	$1.39 \times 10^4$	−183.0	$2.13 \times 10^5$
Water	0.0	$33.5 \times 10^4$	100.0	$22.6 \times 10^5$

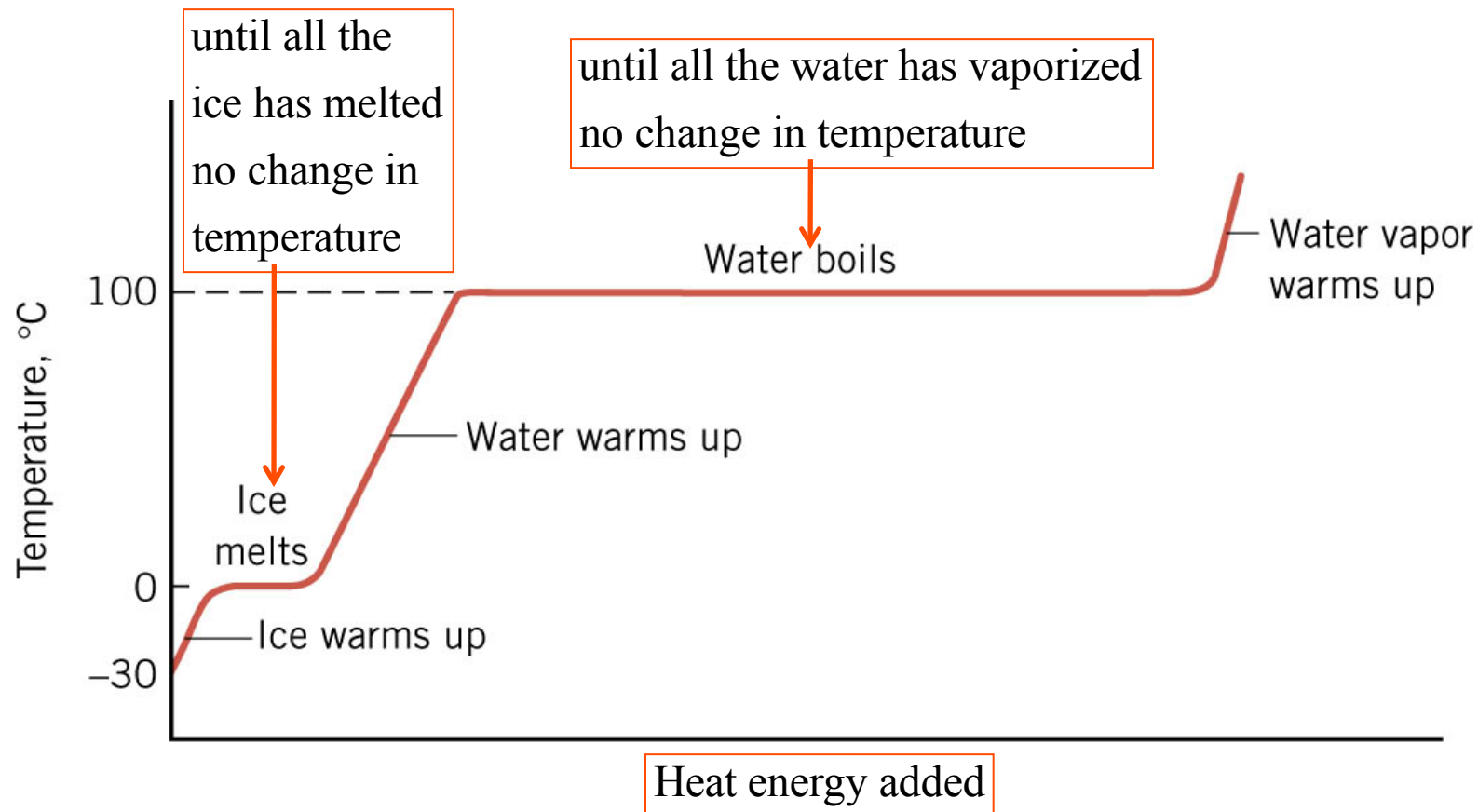
<sup>a</sup>The values pertain to 1 atm pressure.

Add heat: Ice  $\rightarrow$  Water  $L_f > 0$   
Remove heat: Water  $\rightarrow$  Ice  $L_f < 0$

Add heat: Water  $\rightarrow$  Vapor  $L_v > 0$   
Remove heat: Vapor  $\rightarrow$  Water  $L_v < 0$

## 12.8 Heat and Phase Change: Latent Heat

During a phase change, the temperature of the mixture does not change (provided the system is in thermal equilibrium).



## 12.8 Heat and Phase Change: Latent Heat

### Example 14 Ice-cold Lemonade

Ice at 0°C is placed in a Styrofoam cup containing 0.32 kg of lemonade at 27°C. Assume that mass of the cup is very small and lemonade behaves like water.

After ice is added, the ice and lemonade reach an equilibrium temperature ( $T = 0\text{ C}^\circ$ ) with some ice remaining. How much ice melted?

Heat redistributes.  
No heat added or lost.

$$\sum Q = \underbrace{m_I L_I}_{\text{Heat for Ice} \rightarrow \text{Water}} + \underbrace{m_W c_W \Delta T_W}_{\text{Heat change of lemonade}} = 0$$

$$\Delta T_W = -27\text{ C}^\circ$$

$$m_I L_I + m_W c_W \Delta T_W = 0$$

$$m_I = \frac{-m_W c_W \Delta T_W}{L_I}$$

$$= \frac{-(0.32\text{kg})(4.19 \times 10^3 \text{J/kg} \cdot \text{C}^\circ)(-27\text{C}^\circ)}{33.5 \times 10^4 \text{J/kg}} = 0.011\text{ kg}$$

In C&J, you must use  $\Delta T_{\text{lemonade}} > 0$  &  $(mL_f)_{\text{gained}} = (cm\Delta T)_{\text{lost}}$

### Clicker Question 12.2

A 10.0 kg block of ice has a temperature of 0 C°. How much heat must be added to melt half the ice? Latent heat of fusion for water is  $33.5 \times 10^4$  J/kg .

$$Q = mL_f$$

- a) 167 J
- b)  $1.67 \times 10^6$  J
- c)  $33.5 \times 10^5$  J
- d)  $33.5 \times 10^3$  J
- e) 33.5 J

### Clicker Question 12.2

A 10.0 kg block of ice has a temperature of 0 C°. How much heat must be added to melt half the ice? Latent heat of fusion for water is  $33.5 \times 10^4$  J/kg .

$$Q = mL_f$$

a) 167 J

b)  $1.67 \times 10^6$  J

c)  $3.35 \times 10^5$  J

d)  $3.35 \times 10^6$  J

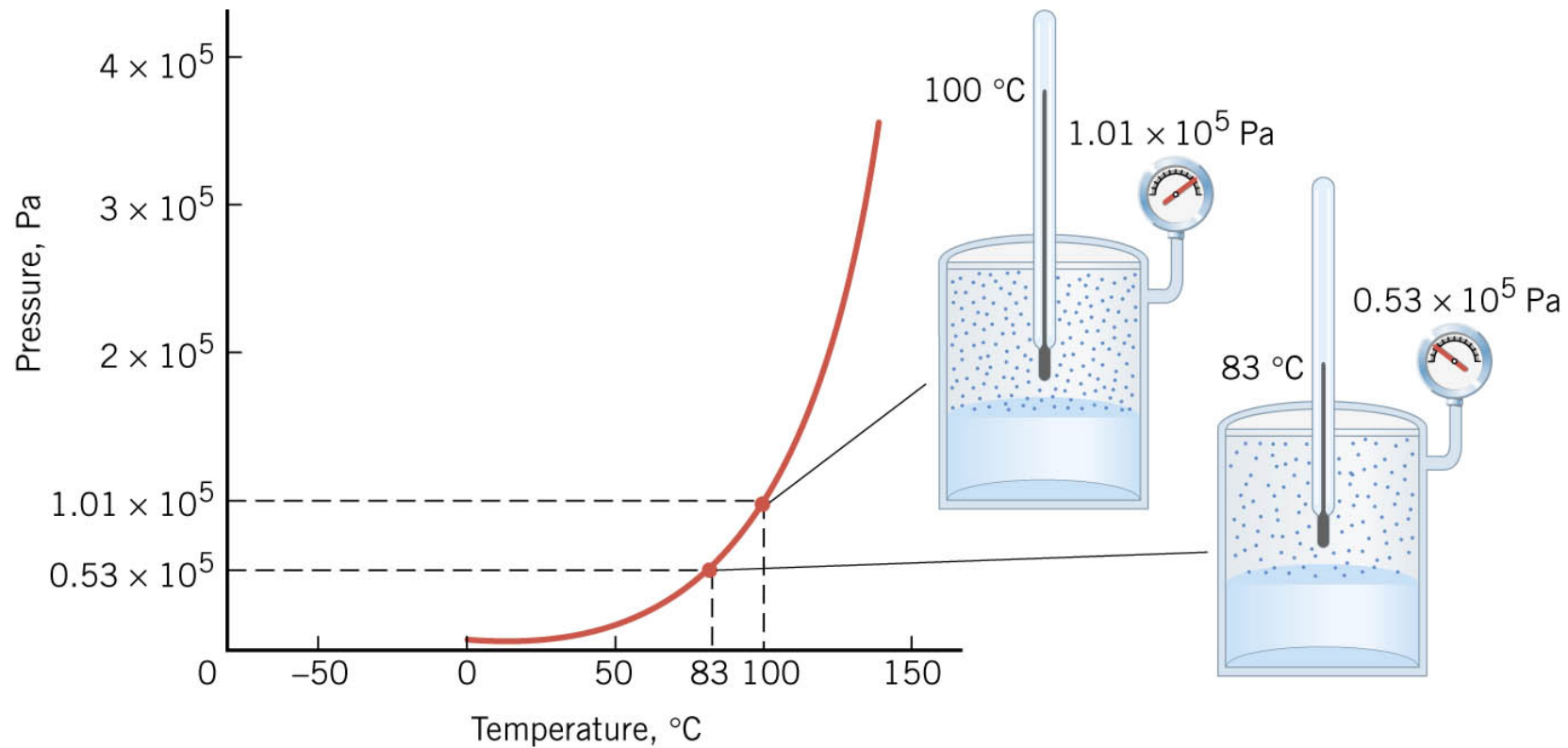
e) 33.5 J

$$\begin{aligned} Q &= mL_f \\ &= (5.00 \text{ kg})(33.5 \times 10^4 \text{ J/kg}) \\ &= 1.67 \times 10^6 \text{ J} \end{aligned}$$



## 12.9 Equilibrium Between Phases of Matter

Water is not "boiling". The water vaporizes and condenses at the same rate.



Only when the temperature and vapor pressure correspond to a point on the curved line do the liquid and vapor phases coexist in equilibrium.

## 12.9 Equilibrium Between Phases of Matter

As is the case for liquid/vapor equilibrium, a solid can be in equilibrium with its liquid phase only at specific conditions of temperature and pressure.

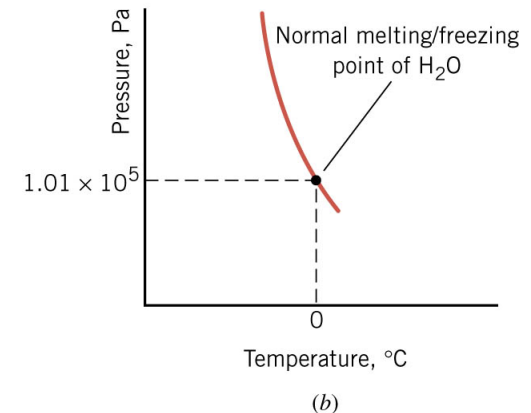
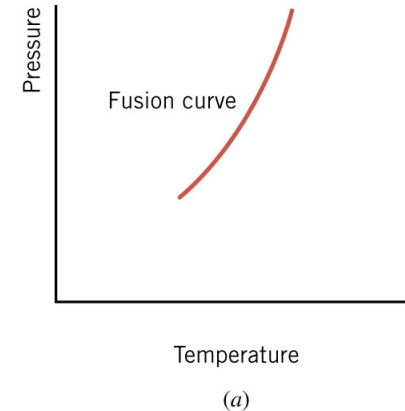
For normal liquids and solids, at higher pressures, the melting point is higher.

Water/Ice phase changes are strange.  
At lower pressures, the melting point is higher.

Water boiling point behaves normally.

At lower pressure the boiling point is less than  $100\text{ }^{\circ}\text{C}$

On top of Mt. Everest the boiling point of water is  $69\text{ }^{\circ}\text{C}$ . Not hot enough to make tea.



## 12.10 Humidity

Air is a mixture of gases.

The total pressure is the sum of the ***partial pressures*** of the component gases.

The partial pressure of water vapor depends on weather conditions. It can be as low as zero or as high as the vapor pressure of water at the given temperature.

To provide an indication of how much water vapor is in the air, weather forecasters usually give the ***relative humidity***:

$$(\% \text{ relative humidity}) = \frac{(\text{Partial pressure of water vapor})}{(\text{Equilibrium vapor pressure of water at current temperature})} \times 100$$

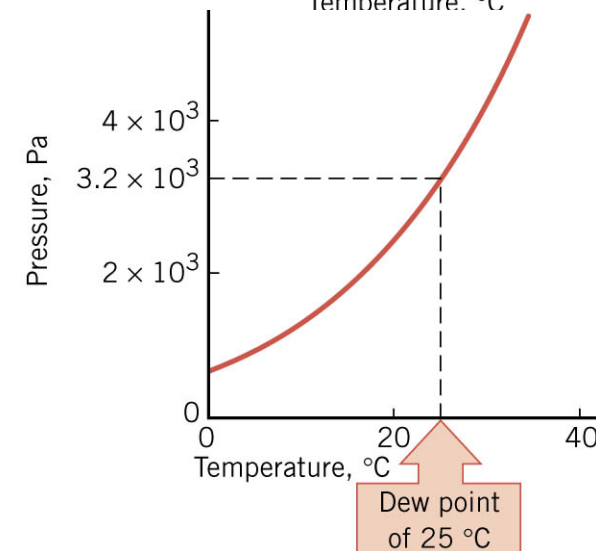
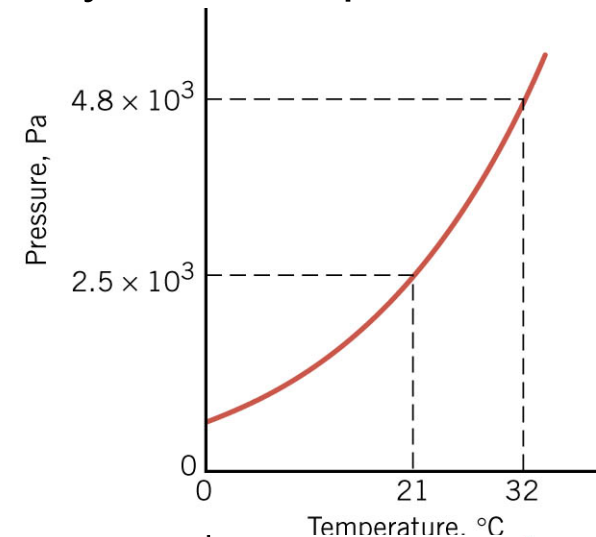
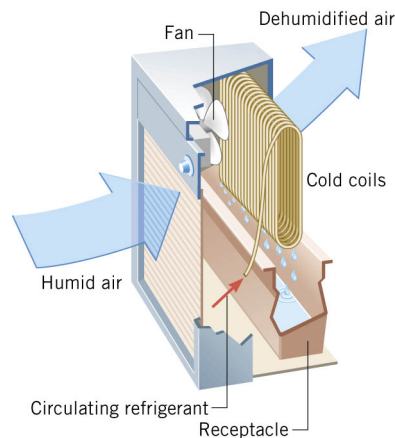
## 12.10 Humidity

### Example 17 Relative Humidities

One day, the partial pressure of water vapor is  $2.0 \times 10^3$  Pa. Using the vaporization curve, determine the relative humidity if the temperature is  $32^\circ\text{C}$ .

$$\text{Relative humidity} = \frac{2.0 \times 10^3 \text{ Pa}}{4.8 \times 10^3 \text{ Pa}} \times 100 = 42\%$$

The temperature at which the relative humidity is 100% is called the **dew point**.



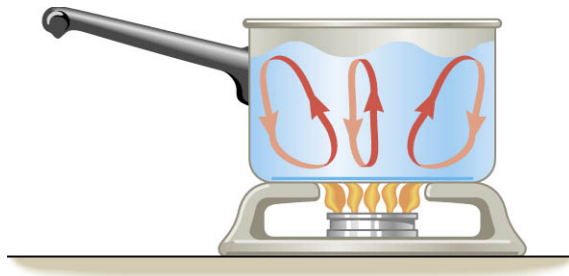
# *Chapter 13*

## ***The Transfer of Heat***

## 13.1 Convection

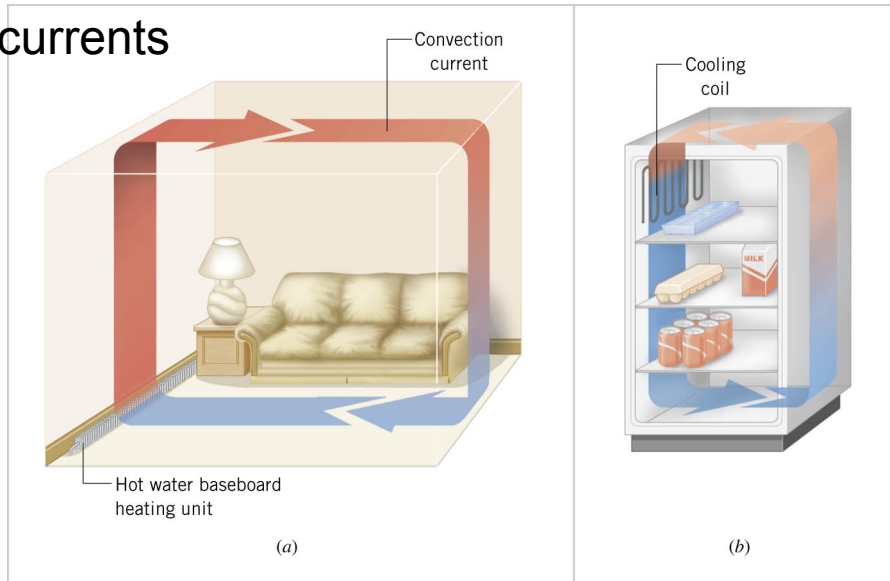
### CONVECTION

Heat carried by the bulk movement of a fluid.

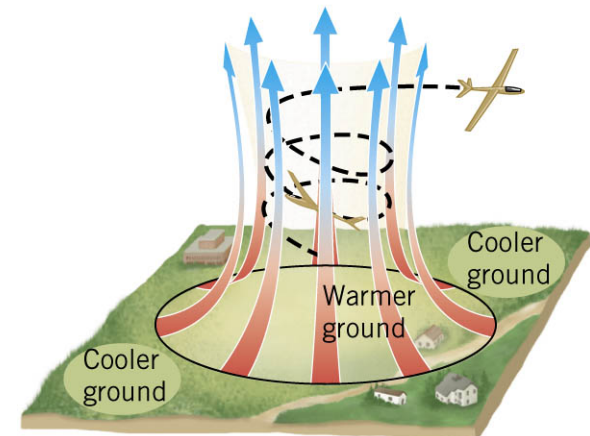


Convection  
fluid currents

Convection  
air currents



Convection  
air currents

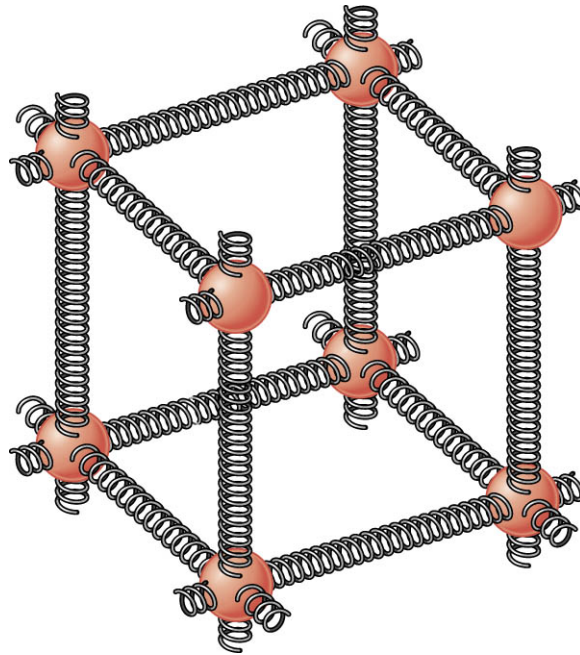


## 13.2 Conduction

### CONDUCTION

Heat transferred directly through a material, but not via bulk motion.

One mechanism for conduction occurs when the atoms or molecules in a hotter part of the material vibrate with greater energy than those in a cooler part. Though the atomic forces, the more energetic molecules pass on some of their energy to their less energetic neighbors.

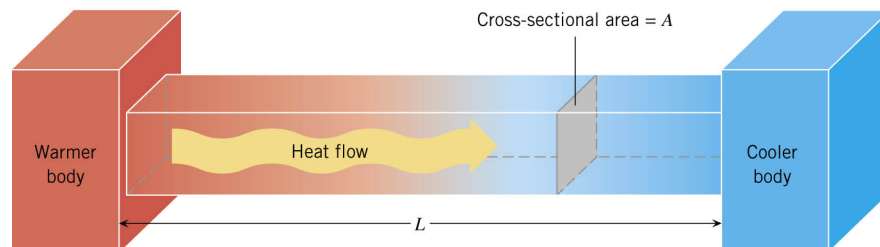


Model of solid materials.  
Atoms connected by atomic  
spring-like forces.

Materials that conduct heat well are called ***thermal conductors***, and those that conduct heat poorly are called ***thermal insulators***.

## 13.2 Conduction

### CONDUCTION OF HEAT THROUGH A MATERIAL



The heat  $Q$  conducted during a time  $t$  through a bar of length  $L$  and cross-sectional area  $A$  is

$$Q = \frac{(kA\Delta T)t}{L}$$

$k$ , is the thermal conductivity

**SI Units of Thermal Conductivity:**

$\text{J}/(\text{s} \cdot \text{m} \cdot ^\circ\text{C})$  (joule per second-meter- $^\circ\text{C}$ )

**Table 13.1 Thermal Conductivities<sup>a</sup> of Selected Materials**

Substance	Thermal Conductivity, $k$ [ $\text{J}/(\text{s} \cdot \text{m} \cdot ^\circ\text{C})$ ]
<b>Metals</b>	
Aluminum	240
Brass	110
Copper	390
Iron	79
Lead	35
Silver	420
Steel (stainless)	14
<b>Gases</b>	
Air	0.0256
Hydrogen ( $\text{H}_2$ )	0.180
Nitrogen ( $\text{N}_2$ )	0.0258
Oxygen ( $\text{O}_2$ )	0.0265
<b>Other Materials</b>	
Asbestos	0.090
Body fat	0.20
Concrete	1.1
Diamond	2450
Glass	0.80
Goose down	0.025
Ice ( $0^\circ\text{C}$ )	2.2
Styrofoam	0.010
Water	0.60
Wood (oak)	0.15
Wool	0.040

<sup>a</sup> Except as noted, the values pertain to temperatures near  $20^\circ\text{C}$ .



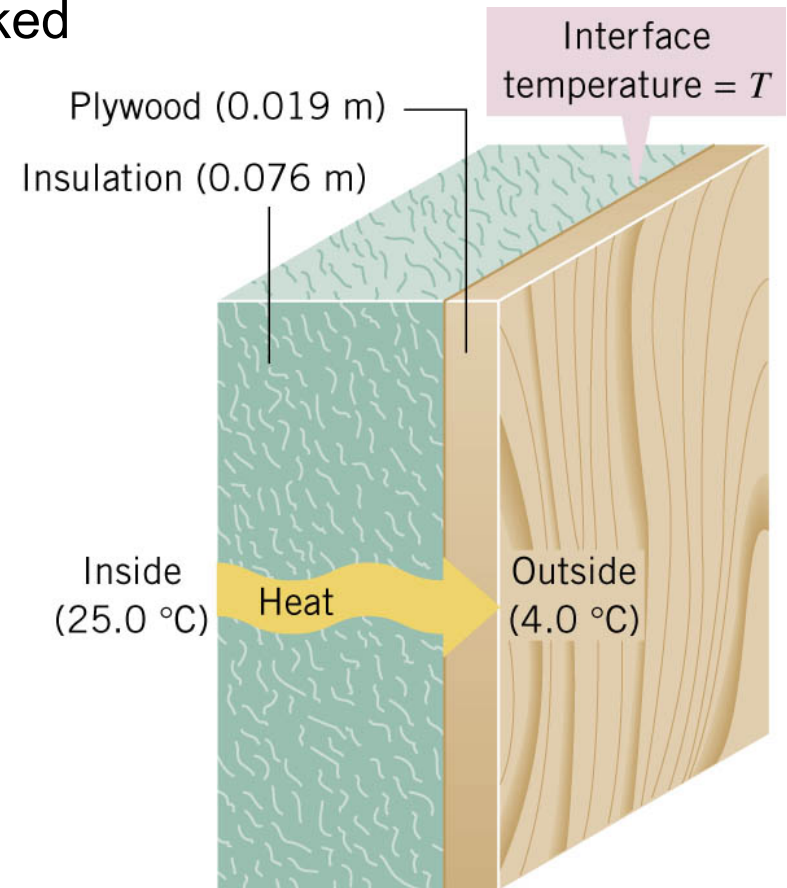
## 13.2 Conduction

### Example 4 Layered insulation

One wall of a house consists of plywood backed by insulation. The thermal conductivities of the insulation and plywood are, respectively,  $0.030$  and  $0.080 \text{ J/(s}\cdot\text{m}\cdot\text{C}^\circ)$ , and the area of the wall is  $35\text{m}^2$ .

Find the amount of heat conducted through the wall in one hour.

**Note:** Heat passing through insulation is the same heat passing through plywood.



## 13.2 Conduction

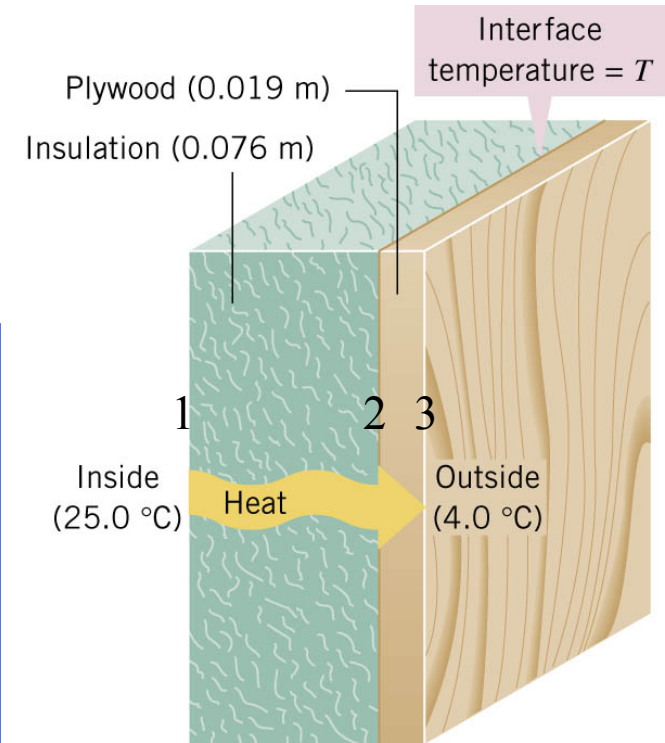
$$Q_{\text{insulation}} = Q_{12}; \quad Q_{\text{plywood}} = Q_{23}$$

$$T_1 = 25\text{C}^\circ, T_3 = 4\text{C}^\circ, T_2 \text{ is unknown}$$

First solve for the interface temperature using:

$$\begin{aligned} Q_{12} &= Q_{23} \\ \frac{k_{12}(T_1 - T_2)}{L_{12}} &= \frac{k_{23}(T_2 - T_3)}{L_{23}} \\ (T_1 - T_2) &= \frac{k_{23}L_{12}}{k_{12}L_{23}}(T_2 - T_3); \quad \frac{k_{23}L_{12}}{k_{12}L_{23}} = \frac{(.08)(.076)}{(.03)(.019)} = 10.7 \\ T_2 &= \frac{T_1 + 10.7T_3}{11.7} = \frac{25 + 42.8}{11.7}\text{C}^\circ = 5.8\text{C}^\circ \end{aligned}$$

$$\begin{aligned} Q_{12} &= \frac{(k_{12}A\Delta T_{12})t}{L_{12}} = \frac{.03(35)(19.2)3600}{.076}\text{J} \\ &= 9.5 \times 10^5 \text{J} \end{aligned}$$



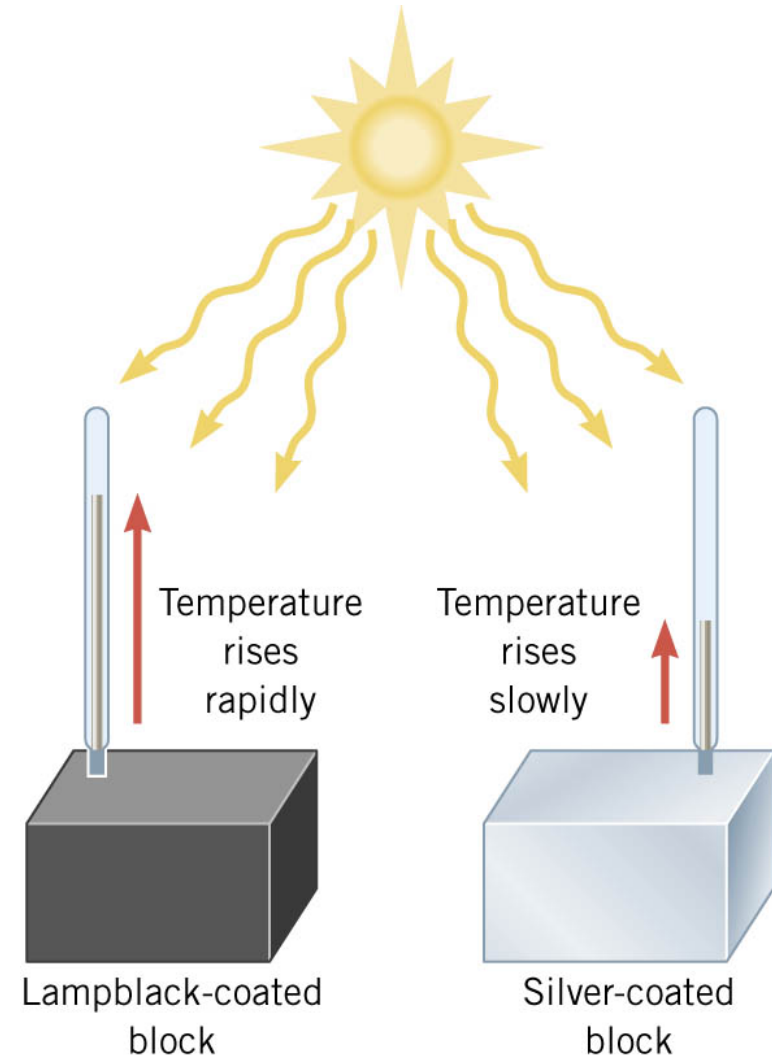
### 13.3 Radiation

## RADIATION

Radiation is the process in which energy is transferred by means of electromagnetic waves.

A material that is a good absorber is also a good emitter.

A material that absorbs completely is called a ***perfect blackbody***.



### 13.3 Radiation

## THE STEFAN-BOLTZMANN LAW OF RADIATION

The radiant energy  $Q$ , emitted in a time  $t$  by an object that has a Kelvin temperature  $T$ , a surface area  $A$ , and an emissivity  $e$ , is given by

$$Q = e\sigma T^4 At$$

emissivity  $e = \text{constant between } 0 \text{ to } 1$   
 $e = 1$  (perfect black body emitter)

Stefan-Boltzmann constant  
 $\sigma = 5.67 \times 10^{-8} \text{ J}/(\text{s} \cdot \text{m}^2 \cdot \text{K}^4)$

### Example 6 A Supergiant Star

The supergiant star Betelgeuse has a surface temperature of about 2900 K and emits a power of approximately  $4 \times 10^{30} \text{ W}$ . Assuming Betelgeuse is a perfect emitter and spherical, find its radius.

with  $A = 4\pi r^2$  (surface area of sphere with radius  $r$ )

$$\begin{aligned} r &= \sqrt{\frac{Q/t}{4\pi e\sigma T^4}} = \sqrt{\frac{4 \times 10^{30} \text{ W}}{4\pi(1)\left[5.67 \times 10^{-8} \text{ J}/(\text{s} \cdot \text{m}^2 \cdot \text{K}^4)\right](2900 \text{ K})^4}} \\ &= 3 \times 10^{11} \text{ m} \end{aligned}$$