Physics D—Chapter 12

Temperature
and
Heat

Temperature

- Average kinetic energy of particles in a substance
- *Internal Energies*
  - include translational, rotational, and vibrational
  - Symbol => U
- Adding energy to a substance usually
  - Makes particles move faster
  - Raises the temperature

Temperature Scales

Scale	Ice point	Steam point
Fahrenheit	32°F	212°F
Celsius	0°C	100°C
Kelvin (absolute)	273.15 K	373.15 K

Temperature Conversions

$$T_F = \frac{9}{5} T_C + 32.0$$

$$T = T_C + 273.15$$

Linear Thermal Expansion

- If the temperature of a solid increases so does its length
- All substances expand at different rates represented by a *coefficient of Linear Thermal expansion*– p. 351

$$\Delta L = \alpha L_0 \Delta T$$

Volume Thermal Expansion

- If the temperature of a substance increases so does its volume
- All substances expand at different rates represented by a *coefficient of Volumetric Theremal expansion*– p. 351

$$\Delta V = \beta V_0 \Delta T$$

- Water is an exception from 4º C to 0 º C

Heat

- Energy transferred between objects because of a difference in temperature
  - Moves from hot to cold
  - You experience heat as sensations of cold or hot
  - Symbol => Q Units => Joules
- Heat is **never contained in an object;** that would be….
  - **Internal Energy**

Specific Heat Capacity

- Quantity of energy needed to raise the temperature of 1 kg of a substance 1º C
- Different for each substance—p.359
  - C_{water} = 4186 J/Kg·°C
- Assumes constant pressure

$$c = \frac{Q}{m\Delta T}$$

$$Q = cm\Delta T$$

Example Problem

- How much heat is needed to change the temperature of 50.0 g of water from 4.5 ºC to 83.0 ºC ?

Example Problem

$$m = 0.0500kg$$

$$T_i = 4.5^\circ C$$

$$T_f = 83.0^\circ C$$

$$c_p = 4186J/kg \bullet^\circ C$$

$$Q = c_p m\Delta T$$

$$Q = 4186J/kg\cdot^\circ C(0.0500kg)(83^\circ C - 4.5^\circ C)$$

$$Q = 16{,}400J$$

Calorimetry

- Experimental procedure for measuring energy transferred in the form of heat

$$Q_w = -Q_x$$

$$c_{p,w}m_w\Delta T_w = -c_{p,x}m_x\Delta T_x$$

Example Problem

- A 115 g mass of lead at 100.0 degrees Celsius is placed in a 220 g sample of water at 20.0 ºC . What is the final temperature reached by the two substances?

Example Problem

$$m_L = 0.115kg$$
$$T_{Li} = 100.0^\circ C$$
$$m_w = 0.22kg$$
$$T_{wi} = 20.0^\circ C$$

$$T_{wf} = T_{Lf} = T_f$$

Example Problem

$$c_{p,w} m_w \Delta T_w = -c_{p,x} m_x \Delta T_x$$
$$c_{p,w} m_w (T_{wf} - T_{wi}) = -c_{p,x} m_x (T_{xf} - T_{xi})$$
$$4186(.22)(T_f - 20) = -128(.115)(T_f - 100)$$
$$921T_f - 18400 = -14.7T_f + 1470$$

Example Problem

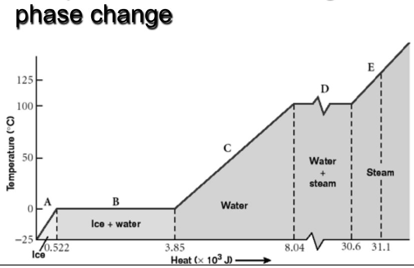
$$921T_f - 18400 = -14.7T_f + 1470$$
$$935.7T_f = 19870$$
$$T_f = 21.2^\circ C$$

Warm-up Problem

- Vinegar, which contains acetic acid, can be used as an effective and environmentally-friendly household cleanser. Suppose you mix 0.340 kg of vinegar at 21.0 degrees Celcius with 1.00 kg hot water at 90.0 degrees Celcius in a plastic bucket. The solution of vinegar and water reaches a final equilibrium temperature of 73.7 degrees Celcius. Disregarding energy transfer as heat to the surrounding air and bucket, what is the specific heat capacity of vinegar?
- c-3810 J/kg•°C

Phase Changes

- Temperature does not change during a phase change



Latent Heat

- Heat required to cause a phase change
- Different for each substance – p. 364
  - Solid => Liquid $Q = mL_f$
  - Liquid => Gas $Q = mL_v$

Example Problem

- A beaker with 25 g of ice at -12º C is heated until it is water at 25 º C. How much heat was required to complete this change?

Example Problem

$m = 0.025 kg$

$T_i = -12^{\circ} C$

$T_f = 25^{\circ} C$

$c_{p,i} = 2.09 \times 10^3 J/Kg \cdot {}^{\circ}C$

$c_{p,w} = 4.186 \times 10^3 J/Kg \cdot {}^{\circ}C$

$L_{f,w} = 3.33 \times 10^5 J/kg$

$$Q_{total} = Q_{ice} + Q_{melt} + Q_{water}$$

$$Q_{ice} = c_p m \Delta T$$

$$Q_{melt} = m L_f$$

$$Q_{water} = c_p m \Delta T$$

Example Problem

$$Q_{ice} = c_p m \Delta T$$

$$Q_{ice} = (2.09 \times 10^3 J/kg \cdot K)(0.025 kg) 12^{o}C$$

$$Q_{ice} = 630 J$$

Example Problem

$$Q_{melt} = m L_f$$

$$Q_{melt} = 0.025 kg (3.33 \times 10^5 J/kg)$$

$$Q_{melt} = 8300 J$$

Example Problem

$$Q_{water} = c_p m \Delta T$$

$$Q_{water} = (4.186 \times 10^3 J/kg \cdot K)(0.025 kg) 25^{o}C$$

$$Q_{water} = 2600 J$$

Example Problem

$$Q_{total} = Q_{ice} + Q_{melt} + Q_{water}$$

$$Q_{total} = 630 J + 8300 J + 2600 J$$

$$Q_{total} = 11500 J$$