Introduction to Physical Science

Heat Capacity

Presented by Robert Wagner

Heat

- Heat is the spontaneous transfer of energy due to a temperature difference
  - SI unit = Joule
- Heat is often measure in calories
  - 1 calorie is the temperature needed to raise the temperature of 1.00 g of water by 1.00°C
- More often used - kilocalorie
  - This is what we call a Calorie when taking about food energy

Mechanical Equivalent of Heat

- Heat is a form of energy
- Mechanical Equivalent of Heat
  - The work needed to produce the same effects as heat transfer
  - 1.000 kcal = 4186 Joules
- James Prescott Joule
  - Experiment: Gravitational potential energy —> Kinetic Energy —> Heat

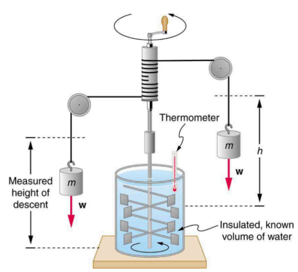


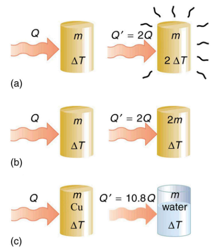
Figure 14.3 Schematic depiction of Joule's experiment that established the equivalence of heat and work.

Heat and Phase Changes

- When heat is added or removed from a system —> internal energy changes
  - May increase/decrease temperature
  - May involve a phase change

Temperature Change and Heat Capacity

- If there are no phase changes, the heat transfer depends on
  - Change in temperature
  - Mass of the system
  - The substance and phase of the substance
-
  - c = specific heat - amount of heat needed to raise the temperature of 1.00 kg by 1.00°C.
    - SI unit:
    - Also used:



Example

- An 0.500 kg aluminum pan is used to heat 0.250 liters of water from 20.0°C to 80.0°C. How much heat is required?
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

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$m_{pan} = 0.500\,kg\,;\ V_{water} = 0.250\,L\,;\ \Delta T = 60.0^oC$

$c_{water} = 4186\,J/kg\cdot{}^o\,C\,;\ c_{Al} = 900.J/kg\cdot{}^o\,C$

(See Table 14.1)

$m_{water} = V_{water}\cdot\rho_{water} = 0.250\,L\cdot 1000\,kg/m^3 = 0.250\,kg$

$Q_w = m_w c_w \Delta T$

$Q_w = (0.250\,kg)(4186\,J/kg\cdot{}^o\,C)(60.0^oC) = 62.8kJ$

$Q_{Al} = m_{Al} c_{Al} \Delta T$

$Q_{Al} = (0.500\,kg)(900\,J/kg^oC)(60.0^oC) = 27.0\,kJ$

$Q_{Total} = Q_w + Q_{Al} = 62.8\,kJ + 27.0\,kJ = 89.8\,kJ$

Example

- Calculate the temperature increase of 100. Kg of brake material with an average specific heat of 800. J/kg°C if the material retains 10% of the energy from a 10,000. kg truck descending 75.0 m at a constant speed
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

Figure 14.5 The smoking brakes on this truck are a visible evidence of the mechanical equivalent of heat.

Example

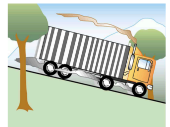

Figure 14.5 The smoking brakes on this truck are a visible evidence of the mechanical equivalent of heat.

- Calculate the temperature increase of 100. Kg of brake material with an average specific heat of 800. J/kg°C if the material retains 10% of the energy from a 10,000. kg truck descending 75.0 m at a constant speed
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$$m_{truck} = 10000.\ kg\ ;\ h = 75.0\ m\ ;$$
$$m_{brake} = 100.\ kg\ ;\ c_{brake} = 800.\ J/kg^oC$$

$$PE = m_{truck}gh = (10000\ kg)(9.80\ m/s^2)(75.0\ m)$$
$$PE = 7.35x10^6\ J$$
$$10\,\%\ of\ PE = 7.35x10^5\ J$$

$$Q = mc\Delta T\ or\ \Delta T = \frac{Q}{mc}$$

$$\Delta T = \frac{7.35x10^5 J}{(100.\ kg)(800.\ J/kg^oC)}$$

$$\Delta T = 9.2^oC$$

Summary

- Heat is the spontaneous transfer of energy due to a temperature difference
- The Mechanical Equivalent of Heat relates energy in kilocalories to energy in Joules
- The heat capacity of a substance tells how much energy is needed to raise the temperature of a kilogram of a substance by a degree Celsius