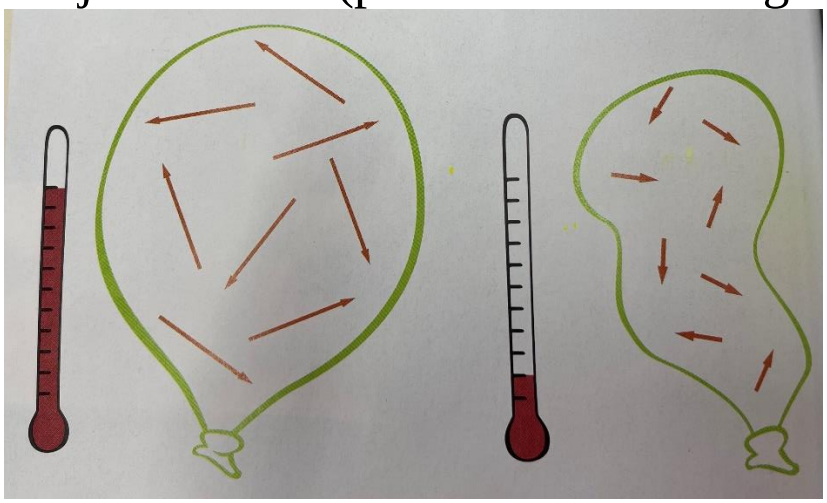
Chapter 12: Thermal Energy
Section 1: Temperature, Heat, and Thermal Energy

The temperature of an object is related to the average kinetic energy of its particles.

- The average kinetic energy of the particles that make up a hot object is greater than the average kinetic energy of particles that make up a cold object.
- Warm objects expand (greater force on the balloon)
- Cold objects shrink (particles are moving slower)



- Thermal energy of an object depends on both its temperature and the number of particles that make up that object.

Thermal conduction: the transfer of thermal energy that occurs when particles collide.

Thermal equilibrium: the state in which the rates of thermal energy transfer between two objects are equal and the objects are at the same temperature

Temperature:

- Temperatures don't have an upper limit but do have a lower limit
  - Absolute zero (0 K) – at this temperature all the thermal energy that can be removed is removed and the temperature cannot be reduced any further
  - 0 K = -273.15 ºC
  - Weather agencies report temperatures in ºF
  - Scientists use ºC and K
    - Swedish physicist Anders Celsius discovered scale
    - freezing point = 0 ºC
    - boiling point = 100 ºC

Heat (Q): transfer of thermal energy, which occurs spontaneously from a hotter object to a cooler object

- Measured in Joules (J)
- Thermal energy cannot be transferred from a colder object to a hotter object without work being done
- If thermal energy has been absorbed by an object, heat is positive
- If thermal energy is transferred from an object, heat is negative

3 types of heat:

1. Conduction: process by which heat is directly transmitted through a substance when there is a difference of temperature

2. **Convection:** heating caused by the motion of fluid in a liquid or gas due to temperature differences
    a. Large-scale atmospheric convection would be thunderstorms and hurricanes
3. **Radiation:** the transfer of energy by electromagnetic waves

Specific heat (C): the amount of energy that must be added to a unit mass of the material to raise its temperature by one temperature unit

- The SI units is measured in J/(kg*K)
- Metals have low specific heats so they are good thermal conductors
- Water has a high specific heat so it takes more energy to raise the temperature compared to other substances
    - This is good for swimming in the ocean on a hot summer's day while the sand is rather hot

Measuring heat

- Heat (Q) = $mC\Delta T$
    - m = mass in kilograms
    - C = specific heat in J/(kg*K)
    - ΔT = change in temperature ($T_f - T_i$)
        - This change can be calculated in ^oC or K
- Calorimeter: device that measures changes in thermal energy

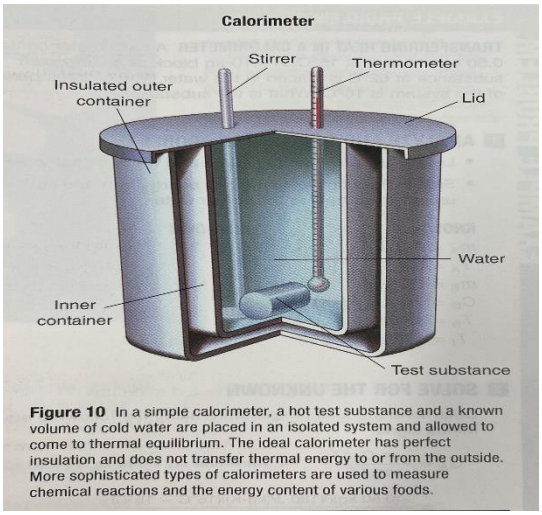


Figure 10 In a simple calorimeter, a hot test substance and a known volume of cold water are placed in an isolated system and allowed to come to thermal equilibrium. The ideal calorimeter has perfect insulation and does not transfer thermal energy to or from the outside. More sophisticated types of calorimeters are used to measure chemical reactions and the energy content of various foods.

- Carefully insulated so that thermal energy transfer to the external world is kept to a minimum

- $\Delta C_{H2O} + \Delta C_{metal} = 0$

Practice: A calorimeter contains 0.50 kg of water at 15 ºC. A 0.10 kg block of an unknown substance at 62 ºC is placed in the water. The final temperature of the system is 16 ºC. What is the substance?

Biology connection

- Most animals are cold-blooded animals
  - Body temperature depends on the environment
    - Hides under a rock to keep cool or sunning itself to keep warm
- Other animals are warm-blooded
  - Body temperatures are controlled internally
    - Stable regardless of the environment
  - To regulate body temperature, animals respond by triggers in the brain
    - Shivering and sweating to counteract a rise or fall