Chapter 3: Energy Transfer

Section 3.2 - The law of conservation of energy

Aims

- To state the law of conservation of energy and the conditions under which it is valid.
- To list and explain the different types of systems: open, closed, and isolated.
- To study a case of an isolated system: the calorimeter.

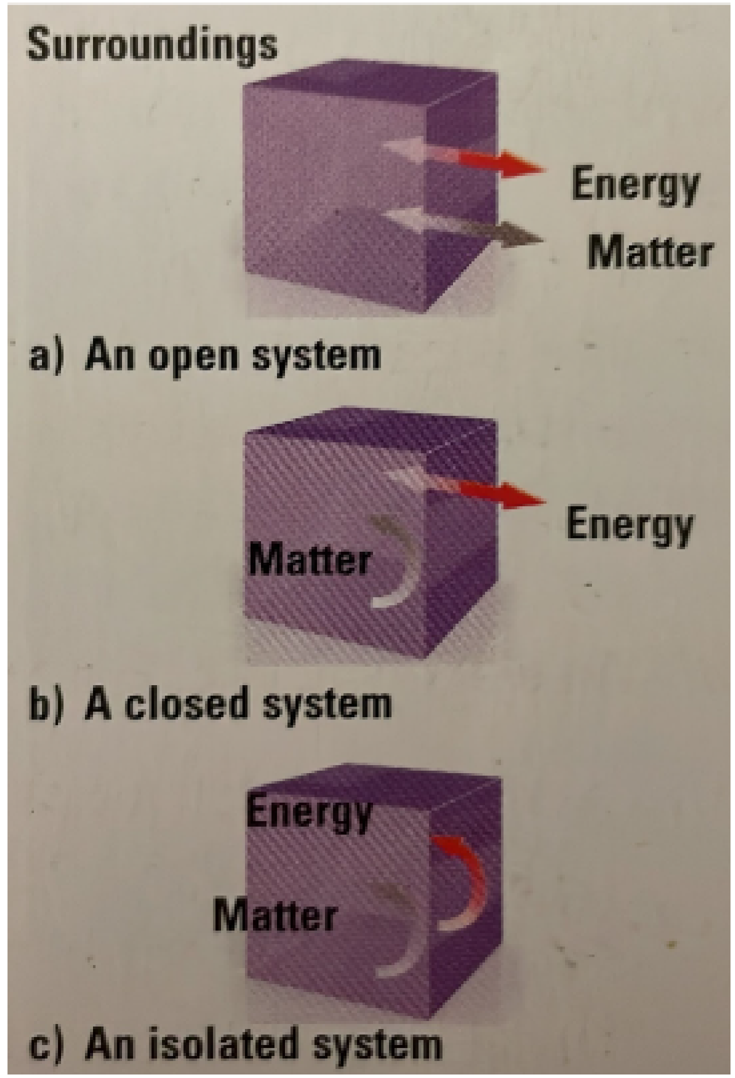
The law of conservation of energy

- The **law of conservation of energy** states that energy can be transferred or transformed but that it cannot be created or destroyed.
- **Thermodynamics** is the study of energy changes.
- The law of conservation of energy is the first law of thermodynamics.

Systems

A system is the location being observed, separated from it surroundings.

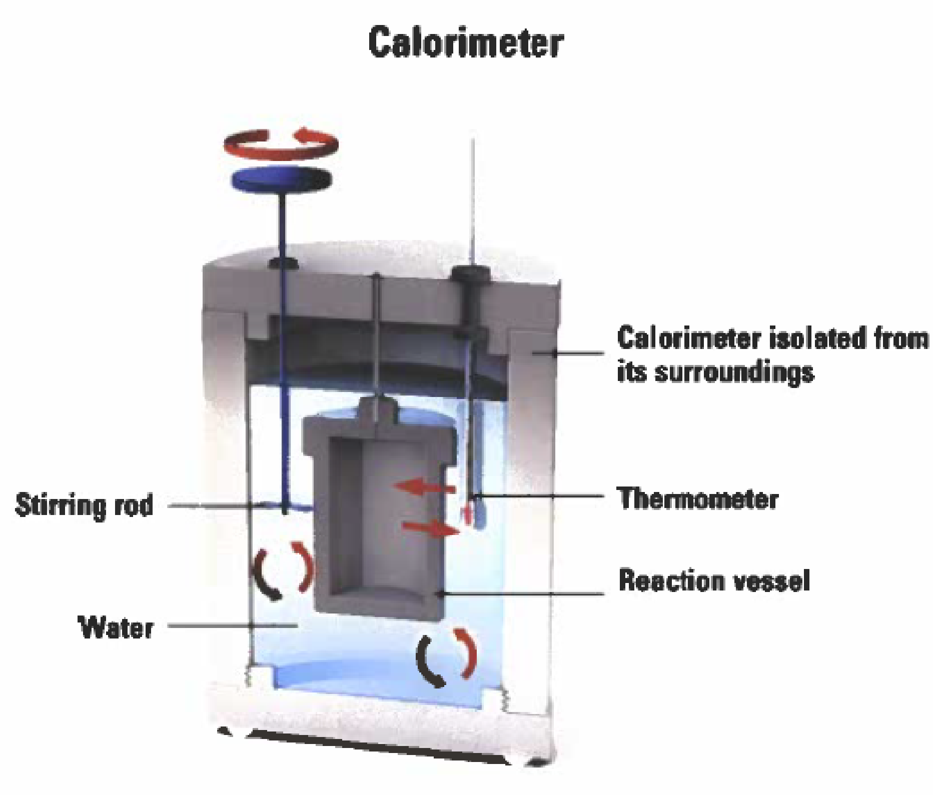
Three types of systems: open, closed and isolated.



Calorimetry

- **Calorimetry** is the process of experimentally determining the quantities of heat involved in a transformation.

- A **calorimeter** is an instrument used to measure the quantities of heat involved in a transformation.



Chapter 3: Energy Transfer

Section 3.3 - Relationship between thermal energy, specific heat capacity, mass and temperature change

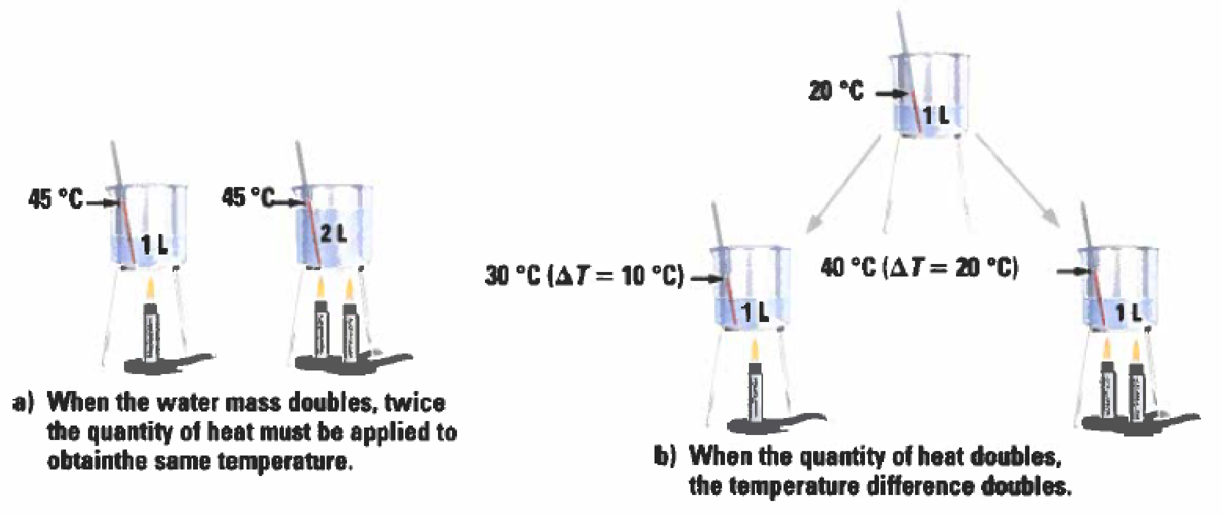
Aims

- To define the concept of specific heat capacity.
- To study the factors on which thermal energy depends: mass, specific heat capacity, and temperature change.
- To calculate the thermal energy that a certain mass of substance releases or absorbs when its temperature varies.

Thermal energy

Thermal energy depends on three factors:

- the mass of the substance
- the temperature change observed
- the nature of the substance



a) When the water mass doubles, twice the quantity of heat must be applied to obtainthe same temperature.

b) When the quantity of heat doubles, the temperature difference doubles.

Nature of a substance

Would the same quantity of heat be required to raise the temperature of a mass of water and the same mass of oil by 10°C?

Specific heat capacity

The specific heat capacity of a substance is the quantity of energy needed to increase the temperature of 1 gram of a substance by 1°C. Specific heat capacity is expressed in joules per gram per degree Celsius (J/(g·°C).

- It measures the difficulty with which the temperature of a substance can be increased or decreased.
- The higher the specific heat capacity of a substance, the harder it will be to vary its temperature.
- It depends on several factors: the nature of the atoms and chemical bonds of the substance, size, mass and molecular structure, as well as the possible attractions between the molecules.

Specific heat capacity

Consult Table 1 on page 134 in the textbook

- Water in liquid form has the highest specific heat capacity and this capacity depends on the physical state.
- Therefore, the specific heat capacity of a substance also varies as a function of its temperature.
- The values of the specific heat capacities provided in the reference table usually correspond to substances that are found at 25°C and SATP.
- Metals have lower specific heat capacities, which explains their excellent thermal conductibility.

Thermal energy

Thermal energy (Q) absorbed or released by a substance is proportional to its mass (m), its temperature change (ΔT) and its specific heat capacity (c), according to the thermal energy relationship

$$Q = mc\Delta T$$

- Mass and specific heat capacity are always positive
- Temperature change can be positive or negative depending on whether the substance is heated or cooled
- The thermal energy is positive or negative depending on the sign of the temperature change
- When thermal energy is positive, it means that the substance absorbed energy. Inversely, if thermal energy is negative it means that the substance released energy

Thermal energy

Based on the law of conservation of energy, the thermal energy released by a substance is necessarily absorbed by another substance and is not lost.

$$Q_{released} = - Q_{absorbed}$$

Example A

Calculate the quantity of thermal energy absorbed by a 5.00 kg block of concrete to raise its temperature from 17.1°C to 35.5°C.

$m = 5.00\ kg = 5000\ g = 5.00 \times 10^3\ g$

$\Delta T = T_f - T_i = 35.5\ C - 17.1\ C$

$= 18.4\ C$

$c = 2.1\ J/gC$

$Q = mc\Delta T$

$Q = (5.00 \times 10^3\ g)(2.1\ J/gC)(18.4\ C)$

$Q = 190{,}200\ J$

$Q = 1.9 \times 10^5\ J$

Example B

A 1.35 g pellet of aluminum foil is heated to 205°C, and then removed from the heat. After a few seconds, the pellet has released 176 J of heat. What is its final temperature?

$m = 1.35\ g$

$c = 0.9\ J/gC$

$Q = -176\ J$

$T_i = 205\ C$

$\Delta T = ?$

$$Q = mc\Delta T$$

$$(-176\ J) = (1.35\ g)(0.9\ J/gC)\Delta T$$

$$-144.8556\ C = \Delta T$$

$$\Delta T = T_f - T_i$$

$$-144.8556\ C = T_f - (205\ C)$$

$$205 - 144.8556\ C = T_f$$

$$60.1444\ C = T_f$$

$$60\ C = T_f$$