Thermal Energy and Heat

Thermal energy and heat are not exactly the same thing, and both are completely different from temperature.

Thermal energy is the sum of the potential energy (distance between particles) and the kinetic energy (movement of particles) possessed by the molecules of an object. A hot object has more thermal energy than a cold one because the particles are moving faster.

Heat is thermal energy being absorbed, released, or transferred from one object to another. When heat is added to a solid, the molecules vibrate faster and move further apart thus increasing the amount of kinetic energy that they possess. This increase in kinetic energy in turn increases the amount of thermal energy the solid has and due to this transfer of energy, we can say that heat has been added.

Three factors affect the amount of heat transferred:

- mass - it takes more energy to heat a greater mass of a given substance
- temperature - it takes more energy to achieve a greater temperature change
- material - different materials require different amounts of thermal energy to reach the same temperature

Specific Heat Capacity

The quantity of heat needed to change the temperature of a unit mass through a unit change in temperature is referred to as the **specific heat capacity**. Substances with a small specific heat capacity warm rapidly because they absorb less heat for a given temperature change. They also cool rapidly because they have less heat to give up.

Kelvin: K

$K = {}^{\circ}C + 273$

heat (J) → $Q = m\Delta Tc$ ← specific heat capacity ($\frac{J}{kg \cdot K}$ or $\frac{J}{kg \cdot {}^{\circ}C}$)

m: mass (kg)

ΔT: change in temperature (K or °C)

Effects of Specific Heat Capacity

Beach Breezes

Water has a specific heat capacity five times that of sand. Therefore, it takes more energy to heat up water than sand. As a result, sand on a beach gets much hotter than water on a sunny day. The air above the sand heats up and rises due to convection currents, and the cold air from over the water comes in to take its place. This is why the breeze often travels toward the beach from the water on a hot day.

Climate

The winds in Canada are mainly westerly due to the jet stream. As a result, on the west coast the winds blow off the Pacific Ocean on the land. Because of the high specific heat capacity of water, the temperature of the ocean remains fairly constant throughout the year. During the winter, some of the moving air mass picks up heat from the ocean and carries it inland. This means that west coast cities are generally warm during the winter months. Soil and rock have lower specific heat capacities and therefore change temperature faster. Since wind reaches east coast cities from over the land, they are cooler than west coast cities.

The Principle of Heat Exchange

When two substances of different temperatures are mixed, the amount of heat lost by the hotter substance in cooling is equivalent to the amount of heat gained by the cooler substance in warming. Considering the law of conservation of energy, the total energy of the system should remain zero as theoretically, no energy would be lost to the surrounding environment. The calculation of heat exchanged when objects of different temperatures are mixed is called the **method of mixtures**.

Examples:

An 80 kg patient has the flu and his temperature increases from 37°C to 39°C. How much extra heat do the chemical reactions in his cells have to generate to cause this temperature change?

$$Q = m\Delta T c$$
$$= 80(2)(3470)$$
(2 ← 39-37)
$$(= 555200)$$
$$560000 \text{ or } 5.6\times10^5 \text{ J}$$

A gold-coloured bar of mass 4.0 kg is placed in boiling water until its temperature stabilizes at 100°C. It is then immersed in 0.50 kg of water in an aluminum calorimeter of mass 0.10 kg, both at a temperature of 20°C. The mixture reaches a final temperature of 35°C. Calculate the specific heat capacity of the golden bar.

calorimeter: container used to measure the amount of heat exchanged

① heat gained by the cold water in warming: $\Delta T = 35-20 = 15°C$
$$Q = (0.50)(15)(4200) = 31500 \text{ J}$$

② heat gained by the calorimeter: $Q = (0.10)(15)(900) = 1350 \text{ J}$

③ heat lost by the golden bar: $\Delta T = 100-35 = 65°C$
$$Q = (4.0)(65)(c) = 260c$$

$$Q_{lost} = Q_{gained}$$
$$③ = ① + ②$$
$$260c = 31500 + 1350$$
$$c = \frac{32850}{260} (= 126.346) = 130 \text{ J/kg}\cdot°C$$
← The bar is real gold!

Assigned questions: #7, 8