AlAYEN IRAQI UNIVERSITY
Health and Medical Technologies
Anaesthesia Department

Medical physics

Heat Capacity

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Dr. Fouad Abbas

Heat Capacity

When thermal energy is added to, or taken away from a substance ,The temperature will change is not the same for all objects, even when the amount of thermal energy added is the same.

for example, that a cup of water will get much hotter than a pan قالةof water, if the same amount of thermal energy is added to each of them. This is because

a-temperature change depends on the amount of matter

being heated.

b-Temperature change also depends on the type of material being heated.

heat capacity (***H_{cap}***) of that object is The amount of energy that must be added to an object to raise its temperature by one degree

The thermal energy required to change the temperature of an object by several degrees is given in Equation (1)

If thermal energy is measured in calories and temperature

in degrees Celsius
then heat capacity is given in calories/degree C or in joules/degree C.

Change in thermal energy = (Heat capacity) x (Change in Temperature)

$$Q = H_{cap} \times \Delta T \qquad \text{.....(1)}$$

Q = heat added or subtracted (calories or joules)

H_{cap} = heat capacity (calories/ ^{o}C or joules/ ^{o}C)

ΔT = change in temperature = $T_{final} - T_{initial}$ (Celsius degrees)

Example What is the heat capacity iron if 9,000 joules of thermal energyare required to increase the temperature of the iron by 20 ^{o}C?

$$Q = H_{cap} \times \Delta T$$

$$H_{cap} = \frac{Q}{\Delta T} = \frac{9000}{20} = 450 \text{ joule} / {}^{o}\text{C}$$

Specific Heat

If we divide the heat capacity of an object by its mass, we obtain a quantity known as the ***specific heat*** (**S** *heat*) of the object.

The specific heat does not dependon the size or shape of an object, but only on the material from which it is made. Waterhas a large specific heat of 1 calorie per gram *degree Celsius or 4,186 joules per kilogram * degree Celsius.

The heat required to change the temperature of an object can be expressed as Change in thermal energy = (Specific heat) x (Mass) x (Change in Temperature)

$$Q = S_{heat} \times M \times \Delta T \quad \text{.....(2)}$$

Where Q = heat added or subtracted (calories or joules)

S_{heat} =specific heat (calories/gram ^{o}C or joules/gram ^{o}C)

M = mass (grams)

ΔT = change in temperature = $T_{final} - T_{initial}$ (Celsius)

Example How much thermal energy is needed to raise 200 grams of iron by 10 °C? *The specific heat of iron is 0.450 J/g °C.

$Q = S_{heat} \times M \times \Delta T = (0.450 \text{ J/g °C}) \times 200 \text{ g} \times 10 \text{ °C} = 9{,}000 \text{ J}$

What is the heat capacity of this object?

$$H_{cap} = \frac{Q}{\Delta T} = \frac{9{,}000 \text{ J}}{10 \text{ °C}} = 900 \text{ J/°C}$$

Latent Heat

The second thing that can happen when thermal energy is transferred to or from a system is that the state of the system can change.

Changes from the solid to the liquid or from the liquid to the gaseous state, and vice versa, are called ***phase changes***. They always involve a transfer of heat which flow from one object to another can change either the average kinetic energy of the random motion of the molecules with changes the temperature of the object, which causes the phase of the object to change.

Consider what happens when, for instance, a pot of water is heated on a stove. At first, the temperature rises. Upon reaching 100 °C (212 °F) the temperature stops increasing, even though the flame keeps supplying heat at the same rate as before. We know that the thermal energy supplied goes into breaking the bonds between the molecules, while the kinetic energy of the molecules remains unchanged . A similar phenomenon occurs when ice melts.

We call the heat required to produce a phase change the ***latent heat (L_{heat})***. Two examples of latent heat are the heat of freezing and the heat of vaporization. The heat of freezing is the amount of thermal energy given off as a liquid freezes, and the heat of vaporization is the amount of thermal energy that must be added to change a liquid to a gas.

Heat added or subtracted for a phase change = Latent heat x Mass

$$Q = L_{heat} \times M \quad \ldots\ldots(3)$$

Q=heat (calories or joules)

L_{heat} =latent heat (calories/gram or joules/gram)

M=mass (grams)

If liquid water at 100 °C is changed into steam, the heat added and the latent heat of vaporization is 540 calories for every gram of water. If steam at 100 °C is changed into water at 100 °C, 540 calories for every gram of steam must be subtracted.

If ice at 0 °C is changed into liquid water at 0 °C, the heat added and the latent heat of melting is 80 calories for every gram of ice. If liquid water at 0 °C is change into ice at 0 °C, 80 calories for every gram of liquid water must be subtracted.

Example

How many calories of heat are required to convert 500 grams of water at a temperature of 25 °C into steam at 100 °C?

First, use Equation (2) to find the heat required to raise the temperature of thewater to 100 °C. The specific heat of liquid water is 1.00 calories/gram °C.

$$Q = s_{heat} \times M \times \Delta T$$

$$= (1.00 \text{ cal/g °C}) \times 500 \text{ g} \times (100 \text{ °C} - 25 \text{ °C}) = 37{,}500 \text{ cal}$$

Next, use Equation (3) to find the heat required for the phase change of 500 grams of water at 100 °C into steam at 100 °C. The latent heat of evaporation of water is 540 calories/gram.

$Q = L_{heat} \times M = 540 \text{ cal/g} \times 500 \text{ g} = 270{,}000 \text{ cal}$

The total heat is the sum of the heat required to heat the water to 100 °C and the heat required to convert the liquid water into steam.

Total heat = 37,500 cal + 270,000 cal = 307,500 cal

Mechanisms of Energy Transfer In Thermal Processes

The heat is a transfer of the energy from a high temperature object to a lower temperature one. There are various mechanisms responsible for the transfer: Conduction, Convection, Radiation

Conduction

is the process of transmission of heat energy from one particle of the medium to the other as they are in direct contact with each other but here each particle of the medium stays at its own position. In Physics or Chemistry, the meaning of conduction is understood mainly as the transfer

of heat energy ,Conduction can occur in solids, liquids, and gases.

Convection الحمل الحراري

Energy transferred by the movement of a substance:

- When the movement results from differences in density, it is called natural convection.
- When the movement is forced by a fan or a pump, it is called forced convection.

Radiation

Radiation does not require physical contact.

All objects radiate energy continuously in the form of electromagnetic waves due to thermal vibrations of their molecules.

Rate of radiation is given by **Stefan's law.**

$w = \sigma A e T^4$

- w is the rate of energy transfer, in Watts.
- $\sigma = 5.6696 \times 10\text{-}8 W/m2 .K4$

-A is the surface area of the object.

-e is a constant called the emissivity.

T is the temperature in Kelvins.

Regulation of heat through the human body

People are mammals الثديات , and mammals are warm- blooded creatures مخلوقات, capable of maintaining a relativelyconstant internal temperature regardless بغض النظرof the environmental temperature.

The optimal فلضلtemperature of the human body is 37 °C (98.6 °F), but various factors can affect this value, including exposure to the elements in the **environment** , **hormones** , **metabolism** , and **disease** , which can lead to high or low body temperatures.

Body temperature is regulated mainly by the **hypothalamus** in the brain.

Feedback فقاجabout body temperature is carried through the nervous system and circulatory to the brain.

Heat loss is promoted نعززby reduction of muscular activity, by **perspiration** تعرق, by heat-exchange mechanisms that allow blood to circulate near the skin surface and by reduce a metabolism .

Heat loss is reduced by the body's insulation عزلmechanisms, including reduction of blood flow to the skin, and by use of clothing, shelterماوى, and external heat sources. In addition, the body can generate heat through **shivering**ارتعاش, a response regulated by the hypothalamus and increase metabolism.

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Specific heat, heat capacity, latent heat, heat transfer , Regulation of heat through the human body.

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