Heat Concepts

HEAT is a form of energy. The units most commonly used in measuring heat are the joule, calorie, kilocalorie,and BTU.

1 calorie = 4.184 J

1 kilocalorie = 1000 cal (actually what nutritionists give the "calories" of food)

1 BTU = 252 cal (1BTU equals 778 ft lbs energy)

SPECIFIC HEAT, c , (or heat capacity) of a substance is the quantity of heat required to heat unit mass of substance through a temperature rise of 1 degree. Heat capacity Δ is mc

THE HEAT GAINED OR LOST by a body, m, and specific heat, c, whose state does not change through a temperature change is

$\Delta Q = mc\Delta T$

HEAT OF FUSION (H_f) of a crystalline solid is the quantity of heat required to melt unit mass of the solid at constant temperature. It is also equal to the quantity of heat given off by unit mass of the molten solid as it crystallizes at this same temperature. The heat of fusion of water at 0 degrees C is 80 cal/g or 144 BTU/lb.

HEAT OF VAPORIZATION (H_v) of a liquid is the quantity of heat required to vaporize unit mass of liquid at constant temperature. For water at 100 degrees C, H , is 540 cal/g or 970 BTU/lb.

HEAT OF SUBLIMATION of a solid substance is the quantity of heat required to convert unit mass of it from the solid to the gaseous state at constant temperature.

CALORIMETRY PROBLEMS involve the sharing of heat energy among initially hot objects and cold objects. Since energy must be conserved

heat lost = heat gained

$mc\Delta t = mc\Delta t$

ABSOLUTE HUMIDITY is the mass of water vapor present per unit volume of gas. Typical units are kg/m^3 and g/cc

RELATIVE HUMIDITY is the ratio obtained by dividing the mass of water vapor per unit volume present in the air by the mass of water vapor per unit volume present in saturated air at the same temperature x 100 to indicate percent.

TEMPERATURE is commonly measured on the Celcius scale and the Fahrenheit Scale. For scientific purposes, temperature is measured on the Kelvin scale.

$$°F = 9/5C° + 32$$
$$°C = 5/9 (F° - 32)$$
$$°K = C° + 273$$

LINEAR EXPANSION OF SOLIDS: when a solid is subjected to a rise in temperature (ΔT), an increase in length (ΔL) is very nearly proportional to its initial length (L_o) multiplied by ΔT. Therefore:

$\Delta L = Ç L \Delta T$ where the proportionality constant Ç is the linear expansion coefficient.

From the above equation Ç is the change in length per unit initial length per degree change in temperature.

For example:

if a 1.000000 cm length of brass becomes 1.000019 cm when temperature is raised 1 degree C, the linear coefficient for brass is :

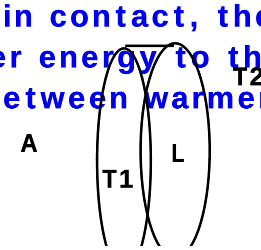
$$Ç = \frac{\Delta L}{L_o \Delta T} = \frac{0.000019 \text{ cm}}{(1\text{cm})(1°C)} = 1.9 \times 10^{-5}$$

VOLUME EXPANSION: If a volume Vo expands to $V_o + \Delta V$ when subjected to a temperature rise ΔT then

$\Delta V = ß V_o \Delta T$ where ß is the coefficient of volume expansion.

HEAT ENERGY IS TRANSMITTED by conduction, convection and radiation.

CONDUCTION occurs when heat energy moves through a material as a result of the collision between molecules of the material. The hotter a substance, the higher the average KE of the molecules. When a temperature difference exists between materials in contact, the higher-energy molecules in the warmer substance transfer energy to the lower energy molecules. A flow of heat energy occurs between warmer to cooler substances.



Consider the drawing. Its thickness L and its cross section area A. The temperature of its two faces are T_1 and T_2 with $T_1 > T_2$. We call the quantity $(T_1 - T_2)/L$ the temperature

(it is important to remember that $\Delta Q = \Delta Q$)

gradient. It is the rate of change of temperature with distance.

The quantity of heat ΔQ, transmitted from face 1 through face 2 in time Δt is proportional to Δt, the face area A, and the temperature gradient:

$$\Delta Q = k(\Delta t)\, A\, \frac{T1-T2}{L} \quad \text{or}$$

$$\frac{\Delta Q}{\Delta t} = kA\, \frac{T1-T2}{L}$$

where k is a proportionality constant which depends on the nature of the substance. It is called the coefficient of thermal conductivity. For a given substance k is the amount of heat transmitted per unit time per unit perpendicular area per unit temperature gradient.

Typical units for k are cal/s cm ^{o}C, W/m K where 1 watt (W)= 1J/s., Btu/hr ft ^{o}F. Take great care to use the units of ΔQ,t,L,T, and A appropriate to k used.

CONVECTION of heat energy occurs when a warm material is transported so as to displace a cooler material.

RADIATION is the mode of transport of heat energy through a vacuum and the empty space between molecules. It is an electromagnetic wave phenomenon. A blackbody is one that absorbs all the radiant energy falling on it. At thermal equilibrium, a body emits as much energy as it absorbs.

The **STEFAN-BOLTZMANN LAW** states that the total energy radiated per second by unit area of a surface is proportional to the absolute temperature of the surface raised to the fourth power. For a blackbody, the relation is:

energy radiated per second per square meter = $ß\, A\, T^4$

where $ß = 5.67 \times 10^{-8}\ W/m^2\ K^4$ is the Stefan-Boltzmann constant and T is Kelvin temperature.