

HEAT

1. What is heat? What is the unit of heat?

Heat is a form of energy. This means that the unit of heat should be the joule (J). Besides the joule, the conventional unit of heat which is called the calorie is still in use. A calorie (cal) as a unit of heat is defined as the amount of heat energy needed to raise the temperature of 1 gram of water through 1 Celcius degree or 1 Kelvin degree (to be more precise, from 14.5⁰ C to 15.5⁰ C).

2. What happen to a system or a body when heat energy is added to it?

When heat energy is added to a system, at least 2 different things can happen:

- a. The temperature of the system increases;
- b. The system may expand.

Now, let us look just at the first, that is, the increase of the temperature of a system when heat energy is added. The amount of heat needed to raise the temperature of a body through a certain range is different for different bodies. A quantity that describes the ability of a body to absorb the heat and increase its temperature is specific heat.

Suppose that a body of mass m is at temperature T . When an amount of heat ΔQ is supplied to this body, its temperature increases to $T + \Delta T$. The amount of heat needed is:

$$\Delta Q = m c \Delta T \quad (1)$$

where c is specific heat of the material.

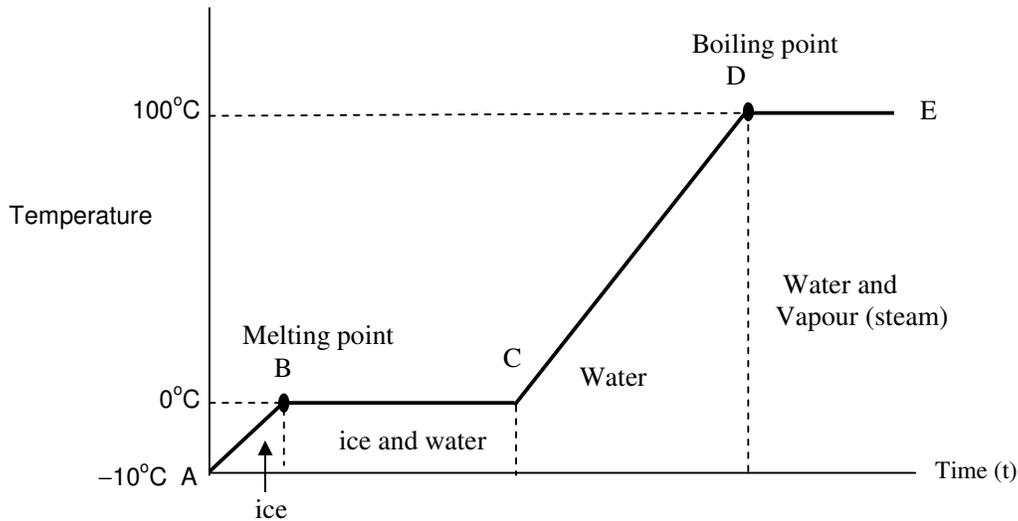
If we rewrite Equation 1 as:

$$c = \frac{\Delta Q}{\Delta T} \quad (2)$$

we define *specific heat* as the amount of heat that must be added to a material of a unit mass to raise its temperature through 1 degree. From Equation 2, the unit of c will be cal/g-C^0 , kcal/kg-C^0 , or J/kg-C^0 . For example, the specific heat of water is 1 cal/g-C^0 (or 1 kcal/kg-C^0), of ice is 0.5 cal/g-C^0 (or 0.5 kcal/kg-C^0).

3. Phase Change and Latent Heat

Depending on temperature and pressure, all matter can exist in a solid, liquid, or gaseous state. These three forms of matter are also called *phases of matter*. Let us now look closely at the phase change of ice into water. To start with, let us have a cylinder half-filled with ice at -10^0C and a thermometer dipping in it to register the temperature, the pressure being equal to atmospheric pressure. Heat the bottom of the cylinder and as time passes, the temperature increases, as indicated by the thermometer. Figure 1 shows the plot of the temperature T versus time t .



Once the temperature reaches 0°C , the ice starts melting. Even though heat energy is being supplied, the temperature does not change until all the ice has melted and changed into water. This is indicated by the first horizontal line BC. Thus a phase change has taken place from a solid to liquid without a change of temperature. The heat supplied is used to increase the energy of the molecules so that they can break loose from their bonds in the solid structure and change into a liquid.

Once all the ice has melted, the temperature once again starts rising, as shown in Figure 1. When the water reaches a temperature of 100°C , it starts changing into steam. The temperature does not change as indicated by the second horizontal line DE, until all the water has changed into steam. The heat is again being used to break loose the molecules of water into free molecules in the steam or gaseous phase. Once all the water has changed into steam, the temperature starts increasing again. We conclude that the heat supplied can be used to change the phase or to increase the temperature. The reverse of this process - changing steam into water and water into ice - takes place when heat is taken out.

The temperature at which a solid changes into a liquid is called its *melting point*; the temperature at which a liquid changes into a solid is called its *freezing point*. As noted above, the melting and freezing point of water is 0°C . As we shall see, the melting point depends upon the pressure. Different materials need different amounts of heat to change phases. The *heat of fusion* L_f of a solid is the amount of heat needed to convert a unit mass of a solid into liquid at the same temperature and pressure. Thus, 1 kg of ice at 0°C and 1 atm (atmosphere) pressure needs 80 kcal (kilo calori) to change into water. Therefore, the heat of fusion of water is 80 kcal/kg .

The *heat of vaporization* L_v of a liquid is defined as the amount of heat needed to change a unit mass of the liquid to the vapor phase while keeping the temperature and the pressure constant. The heat of vaporization of water at 100°C and 1 atm pressure is 539 kcal/kg . The process in which the molecules escape directly from a solid into the gas phase without going through the liquid phase is called *sublimation*.