Thermal Properties of Matter

Temperature and Heat

These are 2 terms which have to be understood before delving deep into the thermal properties of matter. Temperature is a type of measurement that helps in measuring the degree of hotness or coldness present of a body or an object at a given point in time. Its S.I unit is Kelvin (K)

Heat, on the other hand, may be defined as that form of energy because of which, a body or an object experiences an increase or decrease in its internal energy [when the body or the object is in a static condition with no external work done either on or by the body/object]. This flow of heat between two different bodies happens due to the temperature difference between them. Joule (J) is the S.I. unit of heat. For instance, in order to increase the temperature of 1 gram of water from 14.5°C to 15.5°C, the amount of heat that is required is 1 Calorie, where 1 Calorie = 4.18 joules.

Measurement of Temperature

Before starting with the thermal properties of matter, understanding how temperature is measured is essential. In degrees, the temperature of a body or an object is measured and the unit in which it is normally measured in Celsius and Fahrenheit. But, for scientific purposes, the Kelvin scale is used as a measuring unit. The relationship between the three measuring units is shown below through an equation:

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

Name of the Scale or Symbol, i.e., Measuring Unit	Lower Fixed-Point	Upper Fixed Point	Number of Divisions on the Scale
Celsius/°C	0°C	100°C	100
Fahrenheit/°F	32°F	212°F	180

Kelvin/K	273.15K	373.15K	100
Reaumur/°R	0°R	80°R	80

Thermal Expansion

The increase in the dimension or volume of the body because of an increase in its inner temperature is known as Thermal Expansion. In all the three states of matter, i.e. solids, liquids, and gases, thermal expansion can be seen. In solids, thermal expansion occurs in length, area, and volume. However, in case of liquids and gasses, expansion is only possible in volume because of the absence of any fixed shape in the two states of matter. The property of thermal expansion varies from one substance to another, which is also dependent on the state of the substance.

Calorimetry

One of the most essential thermal properties of matter, Calorimetry is the study of changes in the heat energy of a body/object. When a high-temperature body comes in contact with a lower temperature body, the heat that the hot body loses is equivalent to the heat gained by the cold body, on a condition that there was zero escape of heat to the surroundings. Therefore, the principle of calorimetry says that,

Heat Gained = Heat Lost

Thus, to ascertain whether the body has gained heat energy or lost it, measuring the body temperature before and after the transfer of the heat energy is a must. And, the difference in body temperature indicates the change in heat energy. Hence, the transfer of heat energy during various Chemical and Physical changes in the body comes under the purview of Calorimetry.

Specific Heat Capacity

The amount of heat that the unit mass of a substance needs to raise its temperature through 1°C is called Specific Heat (s). Specific Heat is completely dependent on the temperature and the nature of the substance. Its chemical equations is given as:

$$s = \frac{1}{m}\frac{\Delta Q}{\Delta T}$$

Where m = unit mass of the substance,

ΔQ is the amount of heat energy that is required to change the temperature of the mass

ΔT = Change in Temperature

Molar Specific Heat

In thermal properties of matter, Molar specific heat or molar heat capacity (C) is the same as the above Specific Heat, with the only difference being that mass (m) of the substance is replaced by mole (n) of the substance. Thus, in the formula, n is the number of moles. The S.I unit for this is J mol-1 K-1.

- When heat added at constant pressure = *Molar Specific Heat at Constant Pressure*
- When the volume of a substance is held constant while heat is added = *Molar Specific Heat at Constant Volume*

Change of State

In our secondary education of schooling, we have been taught that there are three states of matter viz, solid, liquid, and gas. And when one of these states transforms into another state, it is referred to as the change of state. Let us take a quick look at these thermal properties of matter:

- When there is a change of state from solid to liquid, it is known as melting.
- The change of liquid to solid is called freezing.
- When the liquid state changes to vapor or gas, it is called vaporization/evaporation.
- Change of state of a gas into a liquid is called condensation.

Heat Transfer

Till now, we have understood that heat energy can be exchanged between two different bodies or transferred from one portion of the body to another portion. Thus, the study of the methods and techniques that are used to enable the transfer of heat is called Heat Transfer. To allow the transfer of heat from one body to another, there should be a difference in temperatures i.e. one body must be at a higher temperature in comparison to the other. When it comes to the thermal properties of matter, there are three ways through which heat transfer takes place.

1. Conduction
   In this method, heat is transferred from one body to another or from one part to another part of the body due to the molecules that keep vibrating at their mean positions. The two bodies (mostly solids) are in close contact with each other with no actual movement of matter.
2. Convection
   The transfer of heat due to the difference in temperatures in either liquids or gases is called convection.
3. Radiation
   Through electromagnetic waves, heat is transferred from one place to another in this radiation method. Sun's heat and light reach our Earth's surface through Radiation as it is the fastest method of heat transfer. Furthermore, it doesn't require any medium to transfer heat.

Sublimation

In the thermal properties of matter, there are few substances that do not change to or pass through all the three states of matter. Such substances directly change from their solid-state to vapor-state without changing into a liquid state and this process is called sublimation. For example, dry ice, which is in a solid-state as CO_2 sublimes.

Latent Heat

Now that you have understood the basic thermal properties of matter, let us understand Latent Heat and the different terms associated with it.

Latent Heat [L]	The amount of heat that a unit mass of a substance requires to change its state at a constant temperature is known as Latent Heat.	No specific formula. Every substance has its own fusion/vaporization heat.

Latent Heat of Fusion	When heat is either consumed or released in order to change the state of solid to liquid or is called Latent Heat of Fusion.	Latent Heat of Fusion of ice is = 80 cal g^-1
Latent Heat of Vaporization	When there is a change of state from liquid to gas either through the release of heat or by its consumption, it is called Latent Heat of Vaporization	Latent Heat of Vaporization of water is 540 cal g^-1
Specific Latent Heat	The amount of heat that leads to the change of state of 1kg of a particular substance.	L =QMm = mass of substanceQ = Heat released or consumed

Ideal Gas Equation and Absolute Temperature

Ideal Gas Equation elucidates the relationship between pressure, volume, and temperature and has been derived by combining three laws for gases, which are as follows:

Therefore, the Ideal Gas Equation is

PV = nRT

where P = Pressure of the Gas

V = Volume of the Gas

n = Number of Moles

and T = Absolute Temperature.

For an accurate study of the thermal properties of matter, a basic parameter has been set, which is defined as Absolute Temperature or Thermodynamic Temperature.

Newton's Law of Cooling

There are some laws which play a pivotal role in developing a basic understanding of different thermal properties of matter, and one such is Newton's Law of Cooling. It states that the rate of heat lost by a body is equivalent to or in direct proportion to the difference in temperature between the body and its surrounding areas. In a layman's term, the hotter the body is, the faster it cools down. Here is its equation.

$$\frac{dQ}{dt} = -k(T - Ts)$$

Where T = Temperature of the body

Ts (T base s) = Temperature of the surrounding areas

k = a positive constant that is dependent on the body area and the surface nature of the body.