6.1 Introduction to Statistical Mechanics

Upto the end of seventeenth century the physical phenomena were explained by the use of ordinary laws of mechanics. But in certain cases particularly where the system contained a large number of particles these ordinary laws could not be used either due to mathematical complications or due to their being insufficient for the interpetations of observed phenomenon. For example, we can obtain complete information concerning the motion of a mechanical system containing a large number of particles by solving the equations of motion which are equal in number to the degree of freedom of the system by the use of initial conditions of position and velocity of the mutual forces between the particles which are not known. Therefore, it is impossible to apply the ordinary laws of mechanics to a physical system containing a large number of particles. Moreover the problem of an atom with two electrons presents such great mathematical complications that no body, so far, has solved it completely by the use of ordinary laws of machanics. Therefore, it is impossible to solve the problem of a macroscopic body consisting of about 10^{23} atoms with their electrons. Such problems have been successfully solved by the *methods of Statistical Mechanics.*

Statistical Mechanics is the branch of science which establishes the interpretation of the macroscopic behaviour of a system in terms of its microscopic properties. As its name implies. Statistical Mechanics is not concerned with the actual motion of individual particle of the system; but investigates instead some average or most probable or statistical properties of the system without going into the interior details of the characteristics of its constituents. *The larger is the number of particles in the physical system considered, the more nearly correct are the statistical predictions. The smaller is the number particles* (or degrees of freedom) *in a mechanical system, the methods of Statistical Mechanics cease to have meaning.* From the size of Avogadro Number $N_0 = 6 \times 10^{23}$ /g mole, it is clear that even a small volume of the matter contains many atoms or molecules. Obviously, it is impossible to follow the motion of all the individual particles, but the situation is ideal for the application of the methods of Statistical Mechanics.

The methods of Statistical Mechanics are applied to draw inferences and making the deductions of some average or most probable properties of large assemblies of electrons, atoms, molecules, quanta etc. Before the advent of the quantum theory Maxwell, Boltzman. Gibbs etc. applied statistical methods making the use of classical physics. These statistical methods are known as *classical statistics or Maxwell-Boltzmann statistics.* The classicial statististics explained successfully many observed physical phenomenon like temperature, pressure, energy etc. : but could not explain adequately several other experimentally observed phenomenon like black-body radiation, specific heat at low temperature etc. For explaining such phenomenon Bose, Einsteins, Fermi and Dirac made new approach by using new quantum idea of discrete exchange of energy between systems. The new statistics, known as *quantum statistics*, was subdivided into two categories :

(i) Bose-Einstein statistics,

(ii) Fermi-Dirac statistics.

The first of these holds goods for photons, while the other for elementary material particles. The classical statistics is only the limiting case of quantum statistics.