2. GENERAL INTRODUCTION
ISOTOPES:

A. Historical: The existence of elements differing in mass and having identical chemical properties came to be known through the study of radio-active decay. It was observed that Radium C., the end product in the decay of radium, was possessing identical properties with those of ordinary lead. Thorium and Ionium considered to be separate elements, were observed by Marckweld and Keelman(6) to be having identical properties. Many more pairs of elements of this nature were brought to light by various other investigators and the presence of chemically identical substances with different radio-active properties became a common occurrence. F. Soddy(7) concluded that such elements differed in their atomic weights. This fact has been abundantly confirmed by actual atomic weights determinations(8,9). The existence of isotopes in stable elements was discovered first by J.J. Thomson(10). F.W. Aston(11) measured the masses and relative abundances of isotopes of various elements with the mass spectroscope designed by him.

B. Occurrence and Relative Abundances: Out of 92 elements existing in nature, 67 occur in more than one isotopic modification. The earlier belief regarding the relative abundance of isotopes was that the same was constant in nature except for some radio-active elements. It was further confirmed by the mass-spectrographic measurements. Later investigations showed that the abundances of most of the isotopes varied in nature. Study was made by H.T. Emelius(12) on the density of water from various
sources, the results of which showed difference in densities. Variation up to 4% in the isotopic abundance of Oxygen has been reported.

C. Physical and Chemical Difference between Isotopes: The chemical and physical properties of the isotopes were believed to be identical, except for the ones which had direct dependence on the mass of the atom as density rates of diffusion etc. H.C. Urey and D. Rittenberg calculated the equilibrium constants for exchange reactions between isotopes of hydrogen and concluded that such reactions were possible. H.C. Urey and L. Greiff calculated equilibrium constants for reactions involving other isotopes also and reached similar conclusions. Similar theoretical calculations have shown that the isotopes differ in their thermodynamic properties and the difference is higher for lower atomic weight isotopes (maximum for hydrogen) and goes on decreasing with the increasing atomic weights of elements.

**HEAVY WATER:**

A. Discovery: in 1927, Aston measured the atomic weights of hydrogen by his mass-spectrometer. The ratio of Hydrogen to Oxygen masses obtained by him agreed perfectly with that obtained chemically i.e. \( \frac{1.00777}{16.00000} \). The mass of oxygen atom was taken as 16 by Aston. In 1929, F.W. Giauque and H.W. Johnston observed that oxygen, instead of existing exclusively as atoms of mass 16, as hitherto believed, also contained two more isotopic modifications of masses 17 and 18; the ratio of the three being 3:150:1:5. The average atomic
weight of oxygen, therefore, becomes 16.0035 which is 1.00022 times larger than 16.000,000. This much difference in atomic weights of oxygen, led to a discrepancy of 2 in 10,000 between the atomic weights of hydrogen measured by chemical and mass-spectrographic methods. R.T. Birge and D.H. Mensel \(^{(17)}\) were the first to attribute this discrepancy to the presence of a heavier isotope of hydrogen in the ordinary gas.

In 1931, H.C. Urey and F.G. Brickwedde, G.M. Murphy \(^{(18)}\), while studying a sample of hydrogen (a residue left after the evaporation of large amounts of liquid hydrogen) discovered two very faint lines near the Balmer lines of ordinary hydrogen. The wavelengths of these lines agreed with the calculated for the Balmer lines of hydrogen of mass 2. E.W. Washburn and H.C. Urey \(^{(19)}\) showed that there is a preferential release of hydrogen to Deuterium on electrolysis of ordinary water under certain conditions, thereby giving further evidence of the fact. G.N. Lewis and R.T. Mac-Donald \(^{(20)}\) succeeded in producing 99.5\% heavy water by the continuous electrolysis of large amounts of water.

B. Properties and Importance: Deuterium is a valuable moderator in nuclear reactors because of its capture cross section for slow neutrons. The property of deuterium makes it possible to produce power in reactors with the production of plutonium using natural, unenriched U\(^{235}\) as fuel. Such reactors are preferred in countries where enriched uranium is not available but which have supply of heavy water.

Another possible use for heavy water is as solvent for uranium or plutonium salts in aqueous homogeneous reactors. It
is advantageous as it permits operation with less highly enriched fuel than if light water is used as solvent.

C. Process of Production: A number of processes are now commercially being employed for the manufacture of heavy water.

The electrolytic process proposed by Washburn and Urey\(^{20}\) and used by Lewis and MacDonald\(^{21}\) for the preparation of the first samples of heavy water has been exploited to the greatest extent by the Norsk Hydro Co. in their large plant at Haakon, Norway. The plant employs cheap hydroelectric power to produce electrolytic hydrogen for the ammonia synthesis and having heavy water as a bye-product.

The German scientists Harteck, Hoyer and Suess\(^{22}\) brought to light the ingenious idea of transferring deuterium from the hydrogen to the leaner water by the exchange reaction under certain conditions

\[
\text{HD} + \text{H}_2\text{O} \rightleftharpoons \text{HDO} + \text{H}_2
\]  \hspace{1cm} (2)

The value of \(K\) is nearly 5.0 for this reaction. A nickel catalyst was developed by them for this purpose.

Plants for the production of heavy water by the distillation of hydrogen were designed by the German engineers\(^{22}\) during the world war and more recently by Hydrocarbon Research Inc.\(^{23}\) in U.S.A. Plant similar in principle is proposed to be employed at Nangal in India for the production of heavy water.

Plants using electrolysis of water or distillation of hydrogen can separate deuterium only to the extent which is present in the hydrogen gas produced for other purposes, whereas other methods like dual temperature exchange reactions are capable of giving unlimited production.