Application of radioactivity and Hazards of radiations.

Radioisotopes find numerous applications in a variety of areas such as medicine, agriculture, biology, chemistry, archeology, engineering and industry. Some of the are given below:

(1) **Age determination (carbon dating):** Radioactive decay follows a very exact law, and is virtually unaffected by heat, pressure, or the state of chemical combination of the decaying nuclei, it can be used as a very precise clock for dating past events. For instance, the age of earth has been determined by uranium dating technique as follows. Samples of uranium ores are found to contain Pb^{206} as a result of long series of α- and β-decays. Now if it is assumed that the ore sample contained no lead at the moment of its formation, and if none of the lead formed from U^{238} decay has been lost then the measurement of the Pb^{206}/U^{238} ratio will give the value of time t of the mineral.

$$\frac{\text{No. of atoms of } Pb^{206}}{\text{No. of atoms of } U^{238} \text{ left}} = e^{-\lambda t - 1},$$ where λ is the decay constant of uranium-238

Alternatively, $$\boxed{t = \frac{2.303}{\lambda} \log \frac{\text{Initial amount of } U^{238}}{\text{Amount of } U^{238} \text{ in the mineral present till date}}}$$

Similarly, the less abundant isotope of uranium, U^{235} eventually decays to Pb^{207}; Th^{232} decays to Pb^{208} and thus the ratios of Pb^{207}/U^{235} and Pb^{208}/Th^{232} can be used to determine the age of rocks and minerals. Many ages have been determined this way to give result from hundreds to thousands of millions of years,.

Besides the above long-lived radioactive substances viz. U^{238}, U^{235} and Th^{232} (which have been present on earth since the elements were formed), several short-lived radioactive species have been used to determine the age of wood or animal fossils. One of the most interesting substances is ${}_6C^{14}$ (half-life 5760 years) which was used by **Willard Libby** (Nobel lauret) in determining the age of carbon-bearing materials (e.g. wood, animal fossils, etc.) Carbon-14 is produced by the bombardment of nitrogen atoms present in the upper atmosphere with neutrons (from cosmic rays).

$${}_7N^{14} + {}_0n^1 \rightarrow {}_6C^{14} + {}_1H^1$$

Thus carbon-14 is oxidized to CO_2 and eventually ingested by plants and animals. The death of plants or animals puts an end to the intake of C^{14} from the atmosphere. After this the amount of C^{14} in the dead tissues starts decreasing due to its disintegration.

$${}_6C^{14} \rightarrow {}_7N^{14} + {}_{-1}e^0$$

It has been observed that on an average, one gram of radioactive carbon emits about 12 β-particles per minute. Thus by knowing either the amount of C-14 or the number of β-particles emitted per minute per gram of carbon at the initial and final (present) stages, the age of carbon material can be determined by using the following formulae.

$$\lambda = \frac{2.303}{t}\log\frac{N_0}{N_t} \text{ or } t = \frac{2.303}{\lambda}\log\frac{N_0}{N_t}$$

Where t = Age of the fossil, λ = Decay constant, N_0 = Initial radioactivity (in the fresh wood), N_t = Radioactivity in the fossil

The above formula can be modified as

$$t = \frac{2.303}{\lambda}\log\frac{\text{Initial ratio of } C^{14}/C^{12} \text{ (in fresh wood)}}{C^{14}/C^{12} \text{ ratio in the old wood}}$$

$$= \frac{2.303}{\lambda}\log\frac{\text{Initial amount of } C^{14}/C^{12} \text{ (in fresh wood)}}{\text{Amount of } C^{14} \text{ in the old wood}} = \frac{2.303}{\lambda}\log\frac{\text{Radioactivity in fresh wood due to } C^{14}}{\text{Radioactivity in old wood due to } C^{14}}$$

$$= \frac{2.303 \times T_{1/2} \text{ of } C^{14}}{0.693}\log\frac{\text{counts min}^{-1}\, g^{-1} \text{ of } C^{14} \text{ in fresh wood}}{\text{counts min}^{-1}\, g^{-1} \text{ of } C^{14} \text{ in old wood}}$$

Similarly, tritium $_1H^3$ has been used for dating purposes.

(2) **Radioactive tracers (use of radio–isotopes):**A radioactive isotope can be easily identified by its radioactivity. Because of similar physical and chemical properties of radioisotopes and non-radioisotopes of an element, if a small quantity of the former is mixed with normal isotope, then chemical reactions can

be studied by determining the radioactivity of the radioisotope. The radioactivity can, therefore act as a tag or label that allows studying the behavior of the element or compounding which contains this isotope. An isotope added for this purpose is known as isotopic tracer. The radioactive tracer is also known as an isotopic tracer. The radioactive tracer is also known as an indicator because it indicates the reaction. Radioisotopes of moderate half-life periods are used for tracer work. The activity of radioisotopes can be detected by means of electroscope, the electrometer or the Geiger-Muller counter. Tracers have been used in the following fields:

(i) **In medicine:**Radioisotopes are used to diagnose many diseases. For example, Arsenic – 74 tracer is used to detect the presence of tumors, Sodium –24 tracer is used to detect the presence of blood clots and Iodine –131 tracer is used to study the activity of the thyroid gland. It should be noted that the radioactive isotopes used in medicine have very short half-life periods.

(ii) **In agriculture:**The use of radioactive phosphorus ${}^{32}P$ in fertilizers has revealed how phosphorus is absorbed by plants. This study has led to an improvement in the preparation of fertilizers. ${}^{14}C$ Is used to study the kinetics of photo synthesis.

(iii) **In industry:**Radioisotopes are used in industry to detect the leakage in underground oil pipelines, gas pipelines and water pipes. Radioactive isotopes are used to measure the thickness of materials, to test the wear and tear inside a car engine and the effectiveness of various lubricants. Radioactive carbon has been used as a tracer in studying mechanisms involved in many reactions of industrial importance such as alkylation, polymerization, catalytic synthesis etc.

(iv) **AnalyticalStudies:**Several analytical procedures can be used employing radioisotopes as tracers.

(a) **Adsorption and occlusion studies:**A small amount of radioactive isotope is mixed with the inactive substance and the activity is studied before and after adsorption. Fall in activity gives the amount of substance adsorbed.

(b) **Solubility of sparingly soluble salt:**The solubility of lead sulphate in water may be estimated by mixing a known amount of radioactive lead with ordinary lead. This is dissolved in nitric acid and precipitate as lead sulphate by adding sulphuric acid. Insoluble lead sulphate is filtered and the activity of the water is measured. From this, the amount of $PbSO_4$ still present in water can be estimated.

(c) **Ion-exchange technique:**Ion exchange process of separation is readily followed by measuring activity of successive fractions eluted from the column.

(d) **Reaction mechanism:** By labelling oxygen of the water, mechanism of ester hydrolysis has been studied.

$$R-C\begin{matrix} \nearrow O \\ \searrow OR \end{matrix} + H\overset{*}{O}H \rightarrow R-C\begin{matrix} \nearrow O \\ \searrow \overset{*}{O}H \end{matrix} + R'OH$$

(e) **Study of efficiency of analytical separations:**The efficiency of analytical procedures may be measured by adding a known amount of radio-isotopes to the sample before analysis begins. After the completion, the activity is again determined. The comparison of activity tells about the efficiency of separation.

(3) **Use of $\gamma-$rays:**$\gamma-$rays are used for disinfecting food grains and for preserving food stuffs. Onions, potatoes, fruits and fish etc., when irradiated with $\gamma-$rays, can be preserved for long periods. High yielding disease resistant varieties of wheat, rice, groundnut, jute etc., can be developed by the application of nuclear radiations. The $\gamma-$ray's radiations are used in the treatment of cancer. The $\gamma-$

radiations emitted by cobalt –60 can burn cancerous cells. The $\gamma -$ radiations are used to sterilize medical instruments like syringes, blood transfusion sets. Etc. These radiations make the rubber and plastics objects heat resistant.

Hazards of radiations: The increased pace of synthesis and use of radio isotopes has led to increased concern about the effect of radiations on matter, particularly in biological systems. Although the radioisotopes have found wide spread uses to mankind such as atomic power generation, dating, tracer technique, medicinal treatment, the use of nuclear energy is an extremely controversial social and political issue. You should ask yourself, how you would feel about having a nuclear power plant in your town. The accident of Chernobyl occurred in 1986 in USSR is no older when radioisotopes caused a hazard there. The nuclear radiations (alpha, beta, gamma as well as X-rays) possess energies far in excess of ordinary bond energies and ionization energies. Consequently, these radiations are able to break up and ionize the molecules present in living organisms if they are exposed to such radiations. This disrupts the normal functions of living organisms. The damage caused by the radiations, however, depends upon the radiations received. We, therefore, conclude this chapter by examining the health hazards associated with radioisotopes.

The resultant radiation damage to living system can be classified as:

(i) **Somatic or pathological damage:**This affects the organism during its own life time. It is a permanent damage to living civilization produced in body. Larger dose of radiations cause immediate death whereas smaller doses can cause the development of many diseases such as paralysis, cancer, leukemia, burns, fatigue, nausea, diarrhea, gastrointestinal problems etc. some of these diseases are fatal.

Many scientists presently believe that the effect of radiations is proportional to exposure, even down to low exposures. This means that any amount of radiation causes some finite risk to living civilization.

(ii) **Genetic damage:**As the term implies, radiations may develop genetic effect. This type of damage is developed when radiations affect genes and chromosomes, the body's reproductive material. Genetic effects are more difficult to study than somatic ones because they may not become apparent for several generations.