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Physical, Chemical and Biological Effects of Radiation

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Introduction

Unstable nuclei may unit a quantity of energy of particle is called radiation. This emitted atomic energy or particle is called radiation. There are two kinds of radiation : One is tiny fast moving particles that have both energy and mass known as particle radiation. The other is pure energy with no mass. Large unstable atoms can become more unstable by emitting radiation. This process is called radioactive decay. The sources of radiation are natural background and man-made.

The natural background sources are cosmic radiation, terrestrial radiation and internal radiation.

The cosmic radiation are the radiation from space due to the interaction of charged particles from the sun and the stars with the earth's atmosphere and magnetic field.

Terristorial radiations occurs naturally in the soil, water and vegetation. The major isotopes of concern are uranium and its decay products.

Internal radiations are the radioactive sources such as 40K, 14C, 210Pb found inside the bodies of all people.

Now the man-made radiation sources may be divided into two groups. The man made radiation sources that result in an exposure to members of the televisions, Medical X-rays, Nuclear medicine, Building materials, Nuclear fuels (radioactive materials-mining, milling, disposal of spent fuels, shipmen, weapons testing and accidents).

Occupationally exposed individuals are exposed according to their occupations and to the sources with which they work- Nuclear fuel cycle, Nuclear medicine departments, Radiology departments, National and University research labs etc.

It was been found that the ionizing radiation exposed to the public is 81% from natural sources and 19% from man-made sources.

Physical Effects of Radiation

Radiations from radioactive nuclei are used in many industrial processes, taking advantage of their ability to knock out electrons from atoms, molecules and crystals and thus induce physical, chemical or biological changes.

The radiation increases the hardness of many materials, change the colour of diamonds and disperse static electricity by ionizing air and thus making it electrically conducting. The effects of radiations are generally small at high temperature. It is believed that the internal changes are caused in the crystal lattice due to displacement of the atoms from their equilibrium position in the lattice. New vacancies in some equilibrium sites are produced and a permanent defects of the solid results, followed by the change in physical properties of the solid.

The effect of radiation on non-metallic substances such as plastic and ceramics is of great interest. When polythene is irradiated with gamma rays, its flow temperature can be increased from 120 to over 200°C while its tensile strength

is increased by 60%. The former improvement allows it to go through sterilization procedures necessary in medical applications.

The irradiation of rubber tires increase their wear life and improves their smoothness in running. Air friction on airplane wings causes accumulation of charge, which sometimes encourages icing. A radioactive source is mounted on the edge of the wings to overcome this problem. The effective nights of lightning rods are substantially increased by mounting small amount of radioactive source to dissipate static charges accumulated there. The accuracy of high precision balances may be affected by charge accumulations. A small radioactive ring if fitted with such a balance will dissipated these changes.

When a (alpha), b (Beta) and (gamma) g rays are absorbed in a matter, the energy of the radiation in converted into heat, which can be converted into electric power or other form of power. SNAP (Systems for Nuclear Auxiliary Power) series of devices were the reactor power plants to operate successfully in space. They are very useful in unmanned metrological stations and orbiting satellites. The energy released in radio activity can be converted into light by exposing luminescent materials to it, as in watch dials.

Chemical Effects of Radiations

Chemical effects of radiation from radioactive substances were first studied in 1910 by S.C. Lind in USA. Since early 1950, radiations induced nuclear reactions played important role in industries. These excitations and ionization can produce free radicals, break chemical bonds or produce new chemical bonds and cross linkage between macromolecules.

Radiation Effects of Water and Aqueous Solution

The primary effect on pure water is the production of unstable water ions, which then produce H. or .OH radicals through ionization and excitation processes.

H_2O + radiation $\rightarrow H_2O^+ + e^-$

$H_2O + e^- \rightarrow H_2O^*$

$H_2O^* \rightarrow .H + .OH$

The free radicals can also be produced through the secondary radiations as –

$H_2O^- \rightarrow H. + OH^-$

$H_2O^+ \rightarrow H^+ + .OH$

The free radicals then combine

$H. + H. \rightarrow H_2$

$.OH + .OH \rightarrow H_2O_2$

$H. + .OH \rightarrow H_2O$

After successive collisions, it can be stabilized through salvation by the polar water molecules with in about 10^{-10} sec.

$H_2O + e^- \rightarrow e^-$ aqueous

Such a solvated e^- behaves as an reactive species and undergoes the reaction.

$H_2O + e^-$aqueous $\rightarrow H. + OH^-$

In the water contains dissolved oxygen, then we have perhydroxy radical as

$H. + O_2 \rightarrow HO_2$

Although HO_2 is not as reactive as H., but following reactions take place.

$HO_{2.} + .OH \rightarrow O_2 + H_2O$

$HO_{2.} + HO_2 \rightarrow O_2 + H_2O_2$

The relative yields of the products H., .OH, H_2, H_2O_2 are dependent upon the nature of the radiation.

The yields of H. & .OH are lower for alpha radiation than those for beta radiation whereas of H_2 and H_2O_2 are higher.

Biological Effects of Radiations

When radiation is absorbed in the body it causes chemical reactions to occur some of the molecular of the cell constituents are damaged or broken up and so can not normally function. The total number of ionization depends not only upon the amount of radiation passing through the cell but also upon the kind of radiation. The effects in the tissue cells are of the following types :

Swelling of the nucleus.

Swelling of the entire cell

Increase in the viscosity of the cell fluid.

Delay or prevention of cell division to form new cells

Injury of the chromosomes

Any of the above effects may occur in any tissue all. All the cells are not affected, as it is a matter of chance as to which atoms are ionized.

Penetration and Ionizing power of nuclear radiation in the human body

The ionizing powers of the different kinds of radiations differ greatly. Let us discuss the penetration of various types of nuclear radiation.

1. **Gamma rays :** These rays are electromagnetic vibrations having high penetrability as similar to the x-rays. Greater the frequency and hence energy of the vibrations the greater the power of penetration.
2. **Beta particles :** These are very much less penetrating than gamma rays, 3.15 MeV from radium C have a range in aluminum of only about 0.2" and 0.155 MeV beta particles from C-14 penetrate aluminum hardly of thickness equal to the thickness of a sheet of ordinary writing paper. In water or in the soft tissues of the human body the range of beta particles of any energy is about three times as great as in aluminum.
3. **Alpha particles :** Alpha particles have the greatest powers of ionization of all the nuclear radiations. The range is comparatively very short because of its great ionizing power and resulting rapid loss of its energy.

   Most alphas are completely stopped by a sheet of ordinary writing paper. In water or the soft tissues of the human body the alphas with energies/MeV and 10.6 MeV have ranges to about 0.003 and 0.005 inch respectively.

Radiation Sensitivity of a Tissues

Radiation sensitively of a tissue is proportional to the rate of proliferation of its cells and inversely proportional to the degree of all differentiation. The few of the tissues and organs are listed below from most radio sensitive to least radiosensitive.

Blood Forming –
Most Sensitive Organs

Reproductive Organs Skin

Bone and Teeth

Muscle

Nervous System –
Least Sensitive

Function of Self Renewal Tissues

Tissue	Function
Skin	Contains body fluids, prevents bacterial invansion
Blood Constituents	
Red Blood Cells	Transport Oxyzen
White Blood Cells	Fights infections, produce antibodies
Antibodies	Destroy foreign molecules & bacteria
Platelets	Assist in blood clotting
GI Tract Lining	Secrete digestive enzymes, prevent bacterial invasions and absorb nourishment from food.

Genetic effects : All living organisms are made up of cells and all complete cells contains the two essential substances DNA & RNA. DNA is found in the nucleus of the cell and only in the chromosomes. There is some RNA in the cell nucleus but most is in the cytoplasm, the all liquid which surrounds the nucleus.

Genetic effects are not evident in the irradiated person but become apparent in subsequent generation. Radiation interacts with water molecules to form highly reactive free radicals that are responsible for breaking strong chemical bonds in DNA. Thus the radiation can cause changes in DNA, the blue prints that ensures cell repair and replacement produces a perfect copy of the original cell. The changes in DNA are called mutations. When the genetic code is damaged permanently by means of irradiation, the distorted genetic information will be reproduced. This is called hereditary mutation. The more severe the damage produced by a given mutation, the more rapidly it will be eliminated and vice versa. A mildly damaging mutations may require a great many generations before they gradually disappear.

Conclusion

Radiation have both positive as well as negative applications.

There are many positive applications of radiations such as medical, diagnostics cancer treatment, radiation, therapy, chemical tracers to determine biological pathways, industrial measurements etc.

There are also negative applications of radiations such as genetic effects, cancer, nuclear bombs destroy and kills, nuclear power accidents, leaks and waste.

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