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PHYSICS

Class 10th (KPK)

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Chapter # 18

NUCLEAR PHYSICS

COMPREHENSIVE QUESTIONS

Give an extended response to the following question.

Q1. What is nucleus? How a Nuclide represented symbolically?

Ans. **Atomic Nucleus:**

A region consisting of protons and neutrons at the center of an atom is called atomic nucleus.

Explanation:

As we know that atom consists of a small positively charged heavy nucleus (containing protons and neutrons) with negatively charged light electrons revolving around the nucleus in circular paths.

Structure of Atomic Nucleus:

The nucleus is spherical in shape. It is very small as compared to the overall size of the whole atom. It is about 10,000 times smaller than atom. So, the diameter of the nucleus is about 10^{-15}m and the diameter of an atom is 10^{-10}m.

In order to describe atomic nucleus, few quantities are discussed below:

Nucleons:

The particles present inside the nucleus i.e. protons and neutrons taken together are called nucleons.

Atomic Number (Z):

The number of proton inside the nucleus of an atom is called atomic number. It is denoted by "Z". It is sometimes also called charge number.

Mass Number (A):

The number of nucleons (Protons + Neutrons) in the nucleus is called Mass Number. It is denoted by "A". It is also called Nucleon number. It can be calculated by formula

A=Z+N

Where, Z=number of protons and N=number of neutrons

Neutron Number (N):

The number of neutrons in the nucleus is called neutron number. It is denoted by "N". The number of neutrons "N" can be calculated by subtracting" Z" from "A" i.e.

N=A-Z

Nuclides:

The nuclei of an atom which have the same number of neutrons and protons are termed as nuclides.

In case of neutral atom, the number of protons and electrons are same. The number of neutrons may be same to the protons or may be different. So, if an atom possesses same number of protons and neutrons, then nucleus of such atom is called nuclides.

Symbolic Representation of Nuclides:

Any nuclide can be represented by its mass number "A" and atomic number "Z". For any element "X" the symbolic representation of nuclide is written as:

$$^{A}_{Z}X$$

Where "A" represents number of nucleons, "Z" represents number of protons and "X" represents the chemical symbol for the element.

Example:

A Hydrogen atom can be written as $^{1}_{1}H$, having Z=1 and A=1. It consists of one proton and no neutron in the nucleus.

Q2. What is radioactivity? Give the nature, ionizing and penetration abilities of the three types of radioactive emissions.

Ans: Radioactivity:

The spontaneous release of subatomic particles by unstable atoms as their nuclei tend to break apart into other particles to attain stability is called radioactivity.

Radioactive element:

An element that possesses such property i.e. emits nuclear radiation is called radioactive element.

Explanation:

The phenomena of radioactivity was first discovered by French scientist Henri Becquerel. The elements (nuclides) which have atomic number greater than 82 such as Radium (Z=88), Uranium (92), and Polonium (Z-84) etc. are unstable by nature. In order to attain stability, these elements all the time emit three types of powerful radiations i.e. alpha (α) particles/rays, beta (β) rays and gamma (γ) rays.

As a result of emission of these radiations undergo a process of decay and gradually transfer atoms of one element into another. Radioactivity does not depend upon temperature and physical state of matter. It is a spontaneous process. Presently, artificial radioactive elements have been prepared. For an artificially prepared element, it is not necessary that Z>82.

Unit of Radioactivity:

A common unit of activity is the curie(Ci). The SI unit of radioactivity is the Becquerel which is denoted by "Bq". One Becquerel is the quantity of radioactive material in which one nucleus decays per second. $1Ci=3.70x10^{10}B_q$.

Nature of Emissions:

All these kinds of radiation have different nature which are described below.

(a)Alpha (α) emissions (Rays):

Alpha rays are positively charged particles and they are in fact the particles of helium (H_e) nuclei (i.e. two protons and two neutrons being together) emitted from the nucleus. When the ratio of neutrons to protons in the nucleus is too low, certain atoms restore the balance by emitting alpha particles. Alpha emissions occur in very large atoms i.e. they have high atomic numbers. It is denoted by symbol "α"

(b) **<u>Ionizing ability of alpha rays:</u>**

The phenomena by which radiation can split matter into positive and negative ions is called ionization. Alpha rays ionize the air through which they pass much strongly due to its large mass and charge than beta and gamma radiation.

(c) **<u>Penetration Ability of Alpha rays:</u>**

Penetrating ability is how deeply a radiation can go into a material. The penetrating power of alpha rays are very low e.g. in air, they penetrate only a few "cm".

(2) (a) **<u>Beta (β) emissions:</u>**

Beta emission is that type of radioactive emission in which atomic nucleus emits a beta particle. These particles consist of electrons emitted from the nucleus. Beta rays are denoted by symbol "β".

Beta particle emission occurs when the ratio of neutrons to protons in the nucleus is too high. In this case, an excess neutron transforms into a proton and an electron. The proton stays in the nucleus and the electron is ejected energetically. They are negative charge particles and charge on each particle is equal to charge on an electron.

(b) **<u>Ionizing Ability of β-rays:</u>**

They have low ionization effect than α-particles due to their high velocity. There ionization is 1/100 times less than that of α-particles.

(c) **<u>Penetrating ability of β-rays:</u>**

They have high penetrating power α-rays due to their lighter mass and high velocity. For example, they can easily pass through "1cm" thick sheet of Aluminum and has a range of about 1m in air.

(3) (a) **<u>Gamma (γ) emissions:</u>**

Gamma emission is that type of radioactive emission in which an atomic nucleus emits gamma rays. So, Gamma rays are electromagnetic radiations emitted from the nucleus. They have no charge. Gamma rays are denoted by "γ". Gamma ray emission occurs when the nucleus of a radioactive atom has too much energy.

(b) **<u>Ionizing ability of γ-rays:</u>**

Gamma rays have very low ionization power than α and β-rays.

(c) **<u>Penetration ability of γ-rays:</u>**

They have very high penetration power than α and β rays. Gamma rays can easily pass through several centimeters of lead and has infinite range in air.

Q3. What are nuclear transmutations? What changes in the composition of nucleus is observed when alpha or beta particles are emitted? Explain by symbolic equations.

Ans. **<u>Nuclear Transmutation (Nuclear Decay):</u>**

<u>Definition</u>:

The process through which an unstable nucleus (parent nucleus) changes into a more stable nuclide (daughter nucleus) is called nuclear transmutation (or nuclear decay).

Explanation:

In radioactivity, an unstable nucleus emits radiations to become more stable. Among 3000 known nuclides, only 257 are stable. In nuclear transmutations, the original element is called parent and newly formed element is termed as daughter. Following changes are observed in the composition of nucleus, when alpha or beta particles are emitted.

1.Alphadecay:

In alpha decay, the original "parent" nuclide is converted to a "daughter" by the emission of alpha(α) particle. Balancing the reaction shows that the daughter nuclide has a nucleon number reduced by four and a charge (atomic number) reduced by two.

Mathematically:

The symbolic equation can be written as

$^{A}_{Z}X \; = \; ^{A-4}_{Z-2}Y + \alpha + Q$ ------------------ (i)

In eq. (i), "Q" is the energy released in the process. Nuclide "X" changes into nuclide "Y" with the emission of alpha "α" particle and the release of energy "Q".

Examples:

1. When Uranium-238 undergoes α-decay, it converts into thorium-234

$^{238}_{92}U = {}^{234}_{90}Th + {}^{4}_{2}He$ (α) + Q

2. When polonium-218 undergoes α-decay, it converts into lead -214.

$^{218}_{84}Po \rightarrow {}^{214}_{82}Pb + {}^{4}_{2}He$ (α) + Q

2.Betadecay:

Unlike α-decay, beta (or electron) decay of nuclei does not change the number of nucleons (mass number). In essence, β-decay changes a neutron into a proton.

Mathematically:

The symbolic equation can be written as:

$^{A}_{Z}X = {}_{Z+1}{}^{A}Y + \beta^{-} + Q$ ------------ (i)

In eq. (i) Nuclide "X" (parent) changes into nuclide "Y" (daughter) with the emission of beta "β" particle and release of energy "Q" in the process.

Examples:

1. When carbon-14 undergoes β-decay, it converts into nitrogen-14.

$^{14}_{6}C = {}^{14}_{7}N + \beta^{-} + Q$

2. When iodine-131 undergoes β-decay, it converts into xenon -131.

$^{131}_{53}I = {}^{131}_{54}X + {}^{0}_{1}e$ (β) + Q

Q4. Radioactive sources are said to have half life. What is the meaning of half life?

Ans: Half life:

The time it takes for half of the radioactive nucleic atom in a sample to decay into daughter elements is called half life.

Explanation:

We know that any radioactive element emits radiations with the passage of time, this radioactive element changes into a new element. The element emitting radiation is known as parent element and new element formed is called daughter element.

Now, during this process, a stage comes when half atoms of parent element decays into daughter element. The time interval taken during this process is known as half life. The value of half life depends on the nature of the radioactive nucleus. Different materials have different half lives which ranges from 10^{10} years to a fraction of second.

For example:

If there are 40,000 atoms in parent element, then after half life of "T", 20,000 atoms of the element will decay into daughter element and the number of remaining parent atoms will be 20,000. After a lapse of another period of time, the number of atoms of the parent element will reduce to 10,000 and so on.

Mathematically:

The amount of radioactive element in the sample decreases with time as shown in the figure. Let N represent the amount of the original sample remaining after any given time interval "Δt" and "N_o" represent the original amount in the sample given in the same units as "N". Then

After 1 half-life, $N=\frac{1}{2}N_o$

After 2 half-lives, $N=\frac{1}{2}\times\frac{1}{2}N_o=\left(\frac{1}{2}\right)^2 N_o$

After 3 half-lives, $N=\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}N_o=\left(\frac{1}{2}\right)^3 N_o$

Generally,

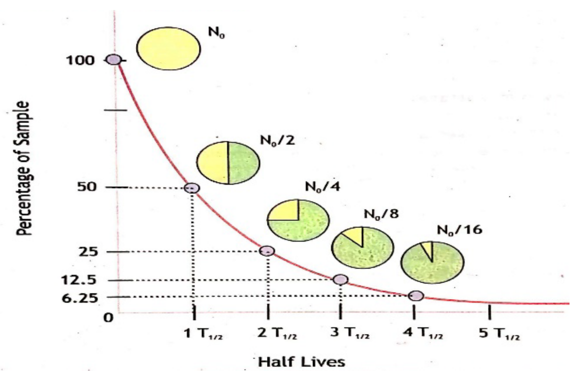
$$N=\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}\text{------}N_o=\left(\frac{1}{2}\right)^n N_o$$

Or

$$N=\left(\frac{1}{2}\right)^n N_o \text{ -------(i)}$$

By using equation (i), we can calculate the amount of sample remaining after given time interval, where as "n" is the number of half-lives. This number of half-lives is equal to the total time interval (Δt) divide by the time for one half-life ($T_{1/2}$) which is given below.

$n=\frac{\Delta t}{T_{1/2}}$



Q5. What are radioisotopes? Explain their uses for various applications?

Ans: Isotopes:

Atoms of the element having the same atomic number but different mass number are called isotopes.

Radioisotopes':

The isotope that are unstable and emit radiations are called radioactive isotopes or radioisotopes.

Examples:

Isotopes of elements that occur naturally are stable. But the isotopes that are manufactured artificially in nuclear laboratories by bombarding of subatomic particles, usually have a short life span mostly due to their unstable nature and radioactivity.

Example:

1. Natural isotopes are carbon ($^{14}_{6}C$), and uranium ($^{235}_{92}U$).
2. Arthritically produced radioisotopes are sodium ($^{24}_{11}Na$), phosphors ($^{32}_{15}P$)etc.

Uses of Radioisotopes:

As we know that radioactive isotopes emit radiations. So, these radiations are useful in so many applications in different department for various purposes. Few of the uses of radioisotopes are discussed below.

1. Use in Food Preservation:

Radioactive isotopes are used for preservation of fruits, vegetables and other food stuff. Food irradiation is a method of treating food in order to make it safer to eat and have longer shelf life. Gamma rays can penetrate the food inside packages and be used to kill bacteria, and insects in food. This process prolongs the shelf-life of the food but sometimes changes the taste.

2. Use in sterilizing:

Gamma rays are also used to sterilize hospital equipment by irradiation, especially plastic syringes that would be damages if heated.

3. Uses in Agriculture:

In agriculture, radioisotopes are used as fertilizer, insect control and as plant mutation breeding.

1. If a plants is given fertilizer tagged with radioactive carbon-14 then the plant releases beta radiation and thus by measuring radioactivity in different parts of plant, the uptake of fertilizer by plant can be determined.
2. They are used to kill bacteria and other harmful insects.
3. The process of photosynthesis and growth rate of plant roots is studied with the help of radioisotopes.
4. Different varieties of seeds are developed after mutation through radiation.

4. Medical Uses:

In medicines, the radioisotopes can be used for the following purposes.

1. They are used for the diagnosis and treatment of many diseases.
2. They can be injected in the body, inhaled or to enable imaging of internal organs and bodily processes.

3. Ionizing radiation has two very different use in medicine i.e. for diagnosis and radiation therapy.
4. High energy radiations can be used to destroy the selected tissues; such as cancerous tumor e.g. Cobalt-60 radioisotope is used for the treatment of cancer.
5. Iodine-131 radioisotope is used for the study of thyroid glands.
6. They are used for the cleaning of surgical instrument.

Uses in Industry:

1. Radioisotopes are used to improve productivity and to gain information which cannot be obtained in any other way.
2. They are used to find out the thickness of a material being produced.
3. They are used to trace out the cracks in welded joints.
4. They are used to trace out the leakages of pipes.
5. They are used to locate and remove faults in machines.

Q6. How is carbon-14 used to determine the ages of wood, bones and other artifacts?

Ans: Radioactive Dating:

Archaeologists and geologists use radioactive dating to estimate the age of ancient objects, i.e. wood, bones, etc. One common procedure uses carbon-14 which has a half-life of 5730 years. All biological organisms contain a given concentration of carbon-14. We can use this information to know about when the organism died. As long as the creature is alive, it will continue to absorb and collect carbon-14. Once the creature dies, no further carbon-14 will be ingested and proportion of carbon-14 will start to decline because carbon-14 is decaying way at a constant and predictable rate.

The proportion of the total amount of carbon that is carbon-14 is very small. Nevertheless, the amount is measureable. A measurement of the activity present can therefore be used to estimate the age of the specimen. Carbon-14 dating can be used for biological tissues as old as 50 or 60 thousand years, but is most accurate for younger samples, since the abundance of ^{14}C nuclei in them is greater. Very old biological materials contain no ^{14}C at all.

Materials with relatively longer half-lives can be used to determine the age of geologic formations. Uranium-238, for example, with a half-life of 4.53×10^9 years, can be used to date even the oldest deposits on earth.

Q7. What are fission and fusion?

Ans. **Nuclear Fission**:

The process of splitting of nuclei into intermediate size nuclei is called nuclear fission.

OR

The process of splitting of a heavy nucleus into two nuclei of nearly equal mass with the release of huge amount of energy is called nuclear fission.

Explanation:

The process of nuclear fission was first discovered by Otto Hahn and Fritz Stresemann in 1938.They found that the Uranium nucleus, after absorbing a low energy neutron, splits into two fragments of intermediate size. The splitting of a massive nucleus into two less massive fragments was termed as nuclear fission.

Mathematically:

It can be represented by the following nuclear reaction.

${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U^{*} \rightarrow$ X+Y+neutrons

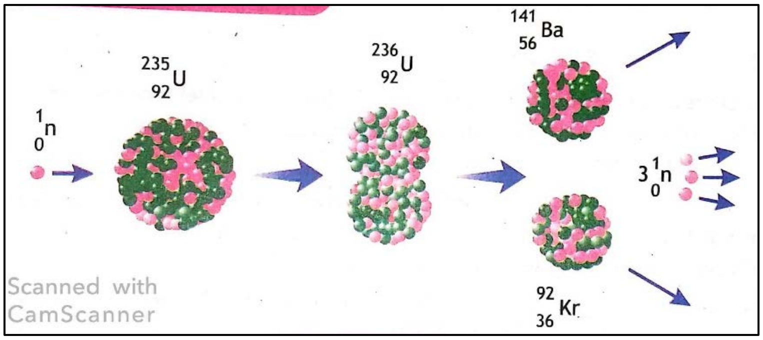
Where ${}^{236}U^{*}$ is an intermediate excited state that lasts for only about 10^{-12}s before splitting into X and Y. The resulting nuclei X and Y are called fission fragments.

Example of Fission:

Consider a slow neutron is allowed to fall on uranium ${}^{235}_{92}U$ as shown in figure. When the neutron enters into the nucleus of ${}^{235}_{92}U$ a compound nucleus is formed. This compound nucleus is unstable and again disintegrates into two fragments "Ba" and "Kr" with the release of energy.

${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U^{*} \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$

Where "Q" is nuclear reaction energy which is very high. It is found that 1kg of uranium delivers as much energy as 3000 tons of coal.

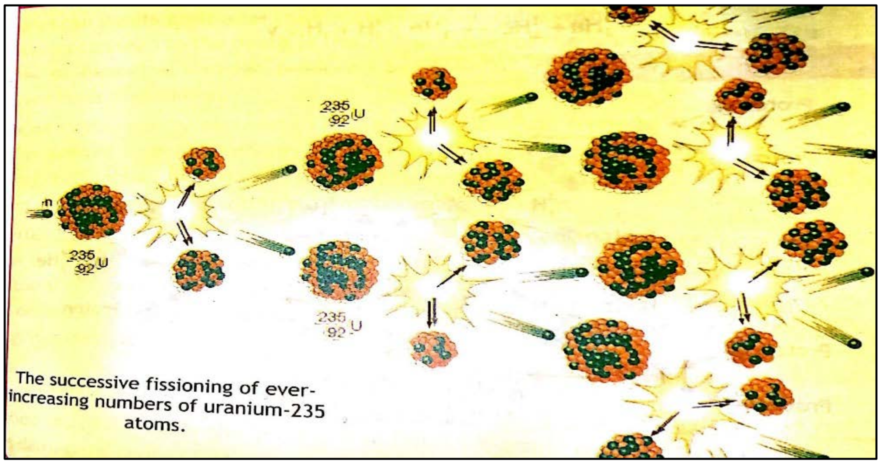


Fission Chain Reaction:

When one nuclear reaction causes an average of one or more nuclear reactions, thus a self-propagating series of these reactions is achieved and is called Fission Chain Reaction.

Explanation:

In a fission process, each nucleus emits about two to three neutrons. These neutrons may collide with the other uranium nuclei and cause fission in them. The nuclei which undergo the fission reaction will emit neutrons. These neutrons will produce further fission on other nuclei. If this process



continues, more and more neutrons are produced. So the number of fission grows with time as shown in figure. And a large amount of energy is released. This is called Nuclear Chain Reaction. If it is not controlled, it may produce a huge amount of energy in very short time. In explosion of atomic bomb, we produce such an uncontrolled fission chain reaction.

Nuclear Fusion:

When two nuclei combine to form a heavy nucleus, the process is called nuclear fusion.

Explanation:

It is reverse process of nuclear fission. In nuclear fusion, when two nuclei form a large nucleus, the mass of larger nucleus is less than the mass of nuclei that formed it. This loss in the mass appears in the form of energy. A self-sustaining fusion reaction is also possible but the energy required is possible only in the environments of stars including sun.

Example of Nuclear Fusion:

One of the two cycles of fusion reaction is Proton-Proton cycle.

Proton-Proton Cycle:

In this process, the direct collision of protons results in the formation of heavier nuclei whose collision in turn produces helium nuclei as shown in figure. But the combination of four protons in a single step is not possible due to coulombs force of repulsion. The initial reaction in proton-proton cycle is:

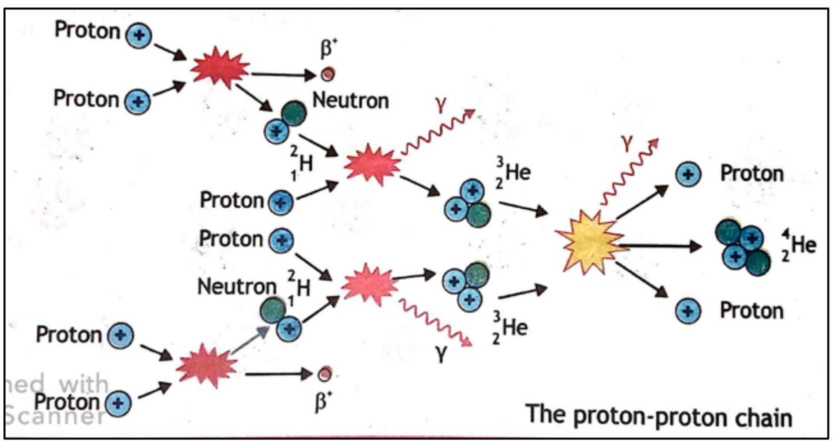
$^1_1H + ^1_1H \rightarrow ^2_1H + \beta^+$

A deuteron produced in the above reaction may combine with other proton as

$$^1_1H + ^2_1H \rightarrow ^3_2He + \gamma$$

Finally, two such reactions can combine to form helium-4 with the release of two protons as

$^3_2He + ^3_2He \rightarrow ^4_2He + ^1_1H + ^1_1H + \gamma$



The proton-proton chain

Q9. What are background radiations? What are its major sources?

Ans. **Background Radiations:**

Radiations that come from environmental sources including earth's crust, the atmosphere, cosmic rays and radio isotopes are called as background radiations or naturally occurring radiations.

Explanation:

Radiations are something that cannot be avoided in our world, like the food that we eat, the air we breathe, the ground beneath us and the star above us all expose us to radiations. These sources of radiations are called background of radiations. So all living things are exposed to natural ionizing radiations from the environment. A radiation detector can be used to record these radiations.

Sources of Background Radiation:

Background radiations originate from variety of sources. The major sources of background radiations are discussed below:

1. Cosmic radiation
2. Terrestrial radiation
3. Internal radiation

1. **Cosmic Radiation:**

   Cosmic rays are those radiations which reaches the earth from space. Outer space is a sea of radiation. Stars including our Sun emit many forms of radiations including gamma radiation. Much of the gamma radiation is unable to get through our atmosphere, but some of it does reach the earth's surface. So the earth and all living things on it are constantly bombarded by radiations from space. The dose from cosmic radiation varies in different parts of the world.

2. **Terrestrial Radiation:**

   Radioactive material is also found throughout nature. As earth contains all sorts of radioactive materials. It is in the soil, water, vegetation. Low levels of uranium, thorium, and their decay products are found everywhere. The dose from terrestrial sources also varies in different parts of the world.

3. **Internal Radiation:**

   All people also have radioactive Potassium-40, Carbon-14, lead-210 and other isotopes inside their bodies from birth.

Q10. What are radiation hazards? How can we safeguard ourselves from the radiation?

Ans. Radiation Hazards:

The hazards (harmful effects) because of nuclear radiations are called radiation hazards.

Explanation:

Nuclear radiations are dangerous to human health because of its ionizing power which can alter the structure of molecules within a living cell leading to different diseases and finally death of the cell and even of the organism itself. The amount of biological damage produced by ionizing radiation is different for different kinds of radiations. Almost every person is exposed to background nuclear radiations.

Effects of radiations:

The effects of radiations on human can be grouped into two categories:

1. **Acute effects of radiations:**

Acute effects are short term effects that appear within a matter of minutes, days or weeks when a person is exposed to nuclear radiations.

A person with radiation sickness (acute effects) can exhibit nausea, vomiting, fever, diarrhea and loss of hair, depending on the severity of the dose.

2.**Latent effects of radiations**:

Latent effects are long-term effects that appear within a matter of years, decades or even generations, when a person is exposed to nuclear radiations.

Latent effects of radiations may appear as a result of high-level or low-level exposure over a long period of time. Some long-term effects are hair loss, eye cataracts and various kinds of cancer.

Damage to human health:

Damage to human health can be further divided into two categories.

1. **Damage by Irradiation**:

When the nuclear radiations from the material damage the cells of a person directly. Such damage is called damage by Irradiation

2. **Damage by Contamination**:

When some radioactive material is swallowed or breathed in, it emits radiations inside the body, which produces damage. Such damage is called damage by contamination.

Safety Measures (Precautions from radiation hazard):

The following precautions must be taken to minimize the radiation hazards.

1. We should stay away from radioactive source because these radiations spread in all directions.
2. The less time that people are exposed to a radiation source, the less they absorbed dose.
3. We can prevent by shielding ourselves from the radiation source. i.e. barriers of lead or concrete can stop or reduce radiation intensity.
4. The persons working in the laboratories should wear lab coats, shoes and safety glasses.
5. An inventory of radioactive sources used in the laboratory must be maintained and updated.
6. The nuclear waste should be buried far away from the residential areas.
7. The radioactive material must be placed in a box of lead.
8. The doctors should use the radiations for minimum possible time during the treatment.
9. Overdose of radiations should be avoided.
10. Food items must not be stored or consumed inside the laboratory.

CONCEPTUAL QUESTIONS:

Give a brief response to the following questions.

Q1. The atomic number of one particular isotope is equal to its mass number. Which isotope is it?

Ans. As we know that isotopes have same numbers of protons (Z) but different numbers of neutrons or mass number (A). In periodic table, hydrogen is the first element having three isotopes i.e., Protium (^1_1H), Deutrium (^2_1H) and Tritium ($^3_1$H). The only known isotope which has the same atomic number and mass number is Protium(^1_1H). Protium is stable form of hydrogen that has only one proton in the nucleus, one electron revolving around the nucleus and no neutron. Therefore, its atomic number as well as mass number is equal to 1.

Q2. Which is more likely to expose, a film kept in a cardboard box, α- particles or β-particles? Explain.

Ans. β-particles is more likely to expose a film kept in a cardboard box than α-particles. Because penetration power of β-particles is greater than that of α-particles. β-particles can travel several feet in air when emitted from a radioactive source where as α-particles a can penetrate only a few centimeters in air. So, α-particles cannot penetrate cardboard but β-particles may go deep in certain substances due to its less mass and less charge. Therefore, β-particles can easily penetrate through a cardboard.

Q3. It is possible for a form of heavy hydrogen to decay by emitting an alpha particle? Explain.

Ans. No, it is not possible for any form of hydrogen to decay by emitting alpha particles. As we know that Deuterium ($^2_1$H) is also known as heavy hydrogen which has one of the two stable isotopes of hydrogen. The nucleus of deuterium contains 1 proton and 1 neutron. In α-decay, a nucleus emits anα-particle ($^4_2$He) that is doubly ionized helium nucleus. The α-particle contains 2 protons and 2 neutrons i.e. a combination of 4 nucleons. As the heavy hydrogen ($^2_1$H) has only 1 proton and 1 neutron in its nucleus. So, it is not possible for a heavy hydrogen to emit an α-particle because the emission of an α-particle occurs most often in massive nuclei that is having large number of neutrons and protons.

Q4. Different isotopes of a given element have different masses but they have the same chemical properties. Explain why chemical properties are unaffected by a change of isotope.

Ans. Each atomic number identifies a specific element but not the isotope. Thus, different isotopes of a given element have the same number of electrons and share a similar electronic configuration. Chemical properties are determined by the valence electrons of an atom and not by the neutrons in the nucleus. Thus, because of this electronic structure, all isotopes of a given element have the same chemical properties. However, due to different mass number they have different physical properties such as boiling point, melting point etc.

Q5. What fraction of a radioactive sample has decayed after two half-lives have elapsed?

Ans. After two half-lives, ¾ of a radioactive sample has been decayed.

Let original number of atoms = N_o

Then number of under decayed atoms after n-half-lives is given by,

$N = \left(\frac{1}{2}\right)^n N_o$ ---------- (i)

Hence we have two half lives, i.e.

n=2

So, Equation (i) becomes

$N = \left(\frac{1}{2}\right)^2 N_o$

$N = \frac{1}{4} N_o$

N= $\frac{No}{4}$

Now, the number of decayed atoms = original atoms – under decayed atoms

$N^{/} = N_o - N$

Putting value of "N" in eq.(ii), we get

$N^{/} = N_o - \frac{N_o}{4}$

$N^{/} = \frac{4N_o - N_o}{4}$

$N^{/} = \frac{3N_o}{4}$

Hence number of atoms decayed after two half lives is equal to ($\frac{3N_o}{4}$).

Q6. Can Carbon-14 dating give the age of fossil dinosaur skeletons? Explain.

Ans. Carbon-14 dating is technique used to find the age of fossils and organic matter. As we know, the half-life of Carbon-14 is only 5730 years. But this method is only useful for organic matter which is less than 50,000 years old. On the other hand, the age of dinosaurs bones are millions of years' old which is greater than the half life of Carbon-14. Therefore, is not possible to determine the age of dinosaur's fossils using C-14 dating. In order to determine the ages of dinosaur's fossils, scientist need an isotope with a very long half-life.

Q7. Some food is treated with gamma radiation to kill bacteria. Why is there not a concern that people who eat such food might be consuming food containing gamma radiation?

Ans. The food is exposed to ionizing radiations, either from γ-rays, x-rays or high energy electrons. This technique is used to extend the shelf life of food produces and make them safe. Treating foods with γ-rays does not make it radioactive. Therefore, irradiated foods are safe because the radiation does not strike the food directly. Irradiation makes food safer by killing harmful bacteria. The radiations that are used do not have sufficient energy to make changes in the food and making them radioactive.

Q8. Radioactive α - emitters are relatively harmless outside the body, but can be dangerous if ingested or inhaled. Explain.

Ans: Among the ionizing radiations, α -particles are the least dangerous in terms of external effects. They are the heaviest and having a high ionizing power than β and γ-rays. Due to this, α-particles do not penetrate very deeply into the body. Infact, clothing can stop alpha particles. However, if these particles are ingested or inhaled usually in the form of radon gas, it may cause more several effects and damage to our body due to its high ionizing power. For example, it may cause lung cancer.

Q9. If nuclear radiation is harmful, how it can be used for treatment of diseases?

Ans. The nuclear radiations are used for the treatment of various diseases. But when these radiations are exposed to human body, they may cause severe burns and other diseases. To avoid such harmful effects, these radiations should be used carefully by expert doctors. Like very small amount of radiations are used for imaging scans. The radiation disappears (decays) in a very short time due to which it is not harmful for humans. So, the radiations should be focused on the germs of affected area (i.e. cancer cells) in order to kill them and other healthy parts of the body should keep safe from falling of radioactive radiations.

ASSIGNMENTS

Assignments 18.1

Find the daughter nucleus when radium-224 undergoes alpha decay.

Data:

Parent nucleus=Radium-224=^{224}Ra

Mass number of radium-A=224

Atomic number of radium=Z=88

Find:

Daughter nucleus=?

Solution:

As we know that,

$^{A}_{Z}X = ^{A-4}_{Z-2}Y + \alpha$+Q

By putting values

$^{224}_{88}Ra = ^{224-4}_{88-2}Y$ +He(α) + Q

Or

$^{224}_{88}Ra = ^{224-4}_{88-2}Y$ +He(α) + Q -------(i)

Now, the element with Z=86 and A=220 in periodic table is Radon$^{220}_{86}Ra$, so eq.(i) becomes

$^{224}_{88}Ra = ^{220}_{86}YRn + ^{4}_{2}$He($\alpha$) + Q -------(i)

So, when Radium-224 undergoes α-decay, it converts into Radon-220.

Q2. An atom of sodium-24 can transmute into an atom of some other element by emitting a beta particle. Represent this reaction in symbols, and identity the daughter element.

Ans: Data:

Parent nucleus= sodium-24=^{24}Na

Mass number of sodium =A=24

Atomic number of sodium=Z=11

Find:

Daughter nucleus=?

Solution:

The general equation for β-decay is given by,

$^{A}_{Z}X = {}_{Z+1}^{A}Y + \beta^{-}$+Q

By putting values

$^{24}_{11}Na = ^{24}_{12}Y + \beta^{-}$+Q --- (i)

Now the element with Z=12 and A=24 in periodic table is magnesium ($^{24}_{12}Mg$), so eq (i) becomes

$^{24}_{11}Na = ^{24}_{12}Mg + \beta^{-}$+Q

So, when Na-24 undergoes β-decay, it converts unto Magnesium-24.

Q3. Lead-210 has a half-life of 22.3 years. How much of the 80mg of lead will be left after 66.9 years?

Ans: Data:

Half-life of lead-210=$T_{1/2}$=22.3 years

Total quantity of lead-210=N_o=80mg

Total elapsed time=Δt=66.9 years

Find:

Quantity left=N=?

Solution:

As we know that,

$N=\left(\frac{1}{2}\right)^n N_o$ ---- (i)

For finding "n", we have

$n=\frac{\Delta t}{T_{1/2}}$

$n=\frac{66.9}{22.3}$

n=3

Now, putting values of "n" and "N_o" in eq.(i)

$N=\left(\frac{1}{2}\right)^3 \times 80$

$=\frac{1}{8}\times 80$

N=10mg

So, 10mg of lead-210 will be present after 66-9 years.

Q4. Suppose the fossil of bone you are examining has ¼ of the carbon-14 deposits as composed to the bone of the living animal per gram. The half-life of ^{14}C is 5730 years, what is the approximate age of the fossil?

Ans: Data:

Half-life of carbon-14=$T_{1/2}$=5730 years

Quantity lift of carbon-14=$N=\frac{1}{4}N_o$

Find:

Total elapsed time=Δt=?

Solution:

We know that,

$N=\frac{\Delta t}{T_{1/2}}$

Or

$\Delta t=n\,T_{1/2}$ ---- (i)

For finding "n", we have

$N=\left(\frac{1}{2}\right)^n N_o$ ---- (ii)

As $N=\frac{1}{4}N_o$, So eq. (ii) becomes

$\frac{1}{4}N_o=\left(\frac{1}{2}\right)^n N_o$

$\frac{1}{4}=\left(\frac{1}{2}\right)^n$

$\left(\frac{1}{2}\right)^2=\left(\frac{1}{2}\right)^n$

By comparing the powers on the both sides of equation, we get

2=n

Or

N=2

Now, putting the values of "n" and "$T_{1/2}$" in eq.(i)

$\Delta t=nT_{1/2}$

Δt=2x5730

Δt=11,460 years

So, the fossil bone is 11460 years old.

NUMERICAL QUESTIONS:

Q1. How many neutrons are contained in a gold nucleus $^{197}_{79}Au$?

Ans: Data:

Gold nucleus=$^{197}_{79}Au$

Mass number of gold=A=197

Atomic number of gold=Z=79

Find:

Number of Neutrons-N=?

Solution:

As we know that,

N=A-Z

By putting values,

N=197-79

N=118

Q2. $^{220}_{86}Rn$decays via alpha decay. Identify the daughter nuclide.

Ans: Data:

Parent (unstable) nuclide=$^{220}_{86}Rn$

Mass number of radon=A=220

Atomic number of Radon-Z=86

Find:

Daughter (stable) nuclide =?

Solution:

The general equation for **α**-decay is given by

${}^{A}_{Z}X = {}^{A-4}_{Z-2}Y$ + **α**+Q

By putting values

${}^{220}_{86}Rn = {}^{220-4}_{86-2}Y + {}^{4}_{2}He$(**α**) +Q

Or

${}^{220}_{86}Rn = {}^{216}_{84}Y + {}^{4}_{2}He$(**α**)+Q ------- (i)

Now, in periodic table, the element with Z=84 and A=216 is polonium ${}^{216}_{84}Po$, so eq.(i) becomes

${}^{220}_{86}Rn = {}^{216}_{84}Po + {}^{4}_{2}He$(**α**)+Q

So, when ${}^{220}_{86}Rn$undergoes **α**-decay, it converts into Polonium-216.

Q3. Write the nuclear equations for the beta decry of ${}^{210}_{82}Pb$ and ${}^{234}_{90}Th$.

Ans: **Data:**

Lead nucleus = ${}^{210}_{82}Pb$

Thorium nucleus = ${}^{234}_{90}Th$

Find:

(a) Nuclear equation for ${}^{210}_{82}Pb$=?

(b) Nuclear equation for ${}^{234}_{90}Th$=?

Solution:

(a) **Nuclear equation for ${}^{210}_{82}Pb$:**

In case of B-decay, the general equation is given by,

${}^{A}_{Z}X = {}_{Z+1}{}^{A}Y + \beta^{-}$+Q

By putting values

${}^{210}_{82}Pb = {}_{82+1}{}^{210}Y + \beta^{-}$+Q

Or

${}^{210}_{82}Pb = {}^{210}_{83}Y + \beta^{-}$+Q ------(i)

Now, the element with Z=83 and A=210 in periodic table is bismuth (${}^{210}_{83}Bi$), so eq. (i)

Becomes

${}^{210}_{82}Pb = {}_{82+1}{}^{210}Y + \beta^{-}$+Q

Thus, when lead-210 undergoes β-decay, it converts into bismuth-210.

(b) **Nuclear equation for ${}^{234}_{90}Th$:**

In case of β-decay, the general equation is given by

${}^{A}_{Z}X = {}_{Z+1}{}^{A}Y + \beta^{-}$+Q

By putting values

${}^{234}_{90}Th = {}_{90+1}{}^{234}Y + \beta^{-}$+Q

Or

${}^{234}_{90}Th = {}_{91+1}{}^{234}Y + \beta^{-}$+Q-(ii)

Now the element with Z=91 and A=234 in the periodic table is protactinium${}^{234}_{91}Pa$,

So, eq. (ii) becomes

${}^{234}_{90}Th = {}^{234}_{91}Pa + \beta^{-}$+Q

Thus, when thorium-234 undergoes β-decay, it converts into protactinium-234.

Q4. Iodic-131 is an important radioisotope for medical diagnostic and treatment procedures. The half life of ^{131}I is 8.02 days. Out of 100g of the sample how much will be left after 24 days?

Ans: **<u>Data:</u>**

Half-life of iodine-131=$T_{1/2}$=8.02 days

Total quantity of iodine-131=N_o=100g

Total elapsed time=Δt=24days

<u>Find:</u>

Quantity left=N=?

<u>Solution:</u>

We know that,

$N=\left(\frac{1}{2}\right)^n N_o$---- (i)

For finding "n", we have

$N=\frac{\Delta t}{T_{1/2}}$

$n=\frac{24}{8.02}$

n=2.99

Or

n=3

Now, putting values of "n" and "No" in eq.(i)

$N=\left(\frac{1}{2}\right)^3 x100$

$N=\frac{1}{8}x100$

N=12.5g

So, 12.5g of iodine-131 will be present after 24 days.

Q5. Phosphorus-32 used in plant sciences for tracking a plant's uptake of fertilizer from the roots to the leaves. The half-life of ^{32}P is 15 days. Out of 800 μg of the activity given as fertilizer how much will be left after one month?

Ans: **<u>Data:</u>**

Half-life of phosphorus-32 = $T_{1/2}$=15 days

Total quantity=N_o=800 μg

Total elapsed time=Δt=1month

Δt=30 days

<u>Find:</u>

Quantity left=N=?

Solution:

We know that,

$N = \left(\frac{1}{2}\right)^2 N_o$ – (i)

For finding "n", we have

$n = \frac{\Delta t}{T_{1/2}}$

$n = \frac{30}{15}$

n=2

Now, putting values of n and N_o in eq.(i)

$N = \left(\frac{1}{2}\right)^2 x800\ \mu g$

$N = \frac{1}{4} x800\ \mu g$

$N = 200\ \mu g$

So, 200 μg of phosphorous-32 will be present after one month.

Q6. ^{12}C to ^{14}C ratio in an animal is found to be one fourth of the ratio in the bone of living animal. The half-life ^{14}C is 5730 years, how old is the fossil?

Ans: <u>Data:</u>

Half-life of carbon-14 = $T_{1/2}$ = 5730 years

Quantity left of carbon-14 = $N = \frac{1}{4} N_o$

<u>Find:</u>

Total elapsed time = Δt = ?

<u>Solution:</u>

We know that,

$n = \frac{\Delta t}{T_{1/2}}$

Or

$\Delta t = nT_{1/2}$----(i)

For finding "n", we have

$N = \left(\frac{1}{2}\right)^n N_o$-----(ii)

As $N = \frac{1}{4} N_o$, so eq (ii) becomes

$\frac{1}{4} N_o = \left(\frac{1}{2}\right)^n N_o$

$\frac{1}{4} = \left(\frac{1}{2}\right)^n$

$\left(\frac{1}{2}\right)^2 = \left(\frac{1}{2}\right)^n$

By comparing the powers on both sides of equation, we get

2=n

Or

n=2

Now, putting the values of "n" and "$T_{1/2}$" in eq.(i)

$\Delta t = n\, T_{1/2}$

$= 2 \times 5730$

$\Delta t = 11460$ years

So, fossil bone is 11460 years old.