LONG QUESIONS

Q.1 Describe the structure of an atom. Differentiate between atomic number and atomic mass number? Write the symbol of atom.

Structure of Atom

There are two main parts of an atom.

(i) Central part (Nucleus)
(ii) Circular part (Orbits)

Rutherford's concept of structure of atom

Nucleus:

Rutherford discovered that the positive charge in an atom was concentrated in a small region called nucleus.

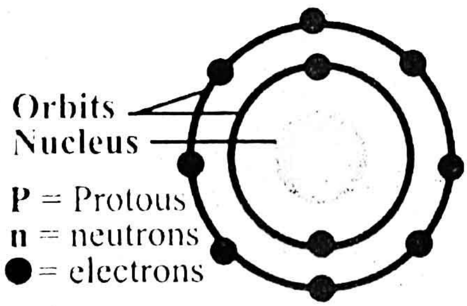
Nucleons:

"The nucleus contains protons and neutrons which are collectively called nucleons".

Circular Orbits:

Atom contains electrons which resolve in nearly circular orbits about nucleus.

Example: Simplest atom of hydrogen contain single proton.



Difference between atomic number and atomic mass number	
Atomic Number	**Atomic mass number**
1. The number of protons inside the nucleus is called the atomic number.	**1.** The sum of protons and neutrons present inside the nucleus of an atom is called its atomic mass number.
2. Atomic number depends upon the number of protons or electrons of atom.	**2.** Atomic mass number depends upon the number of neutrons.
3. Atomic number is represented by Z.	**3.** It is represented by 'A' which is written as: $A = Z + N$
4. It is written at the bottom left side of the symbol of an element. e.g. ${}^{4}_{2}He$	**4.** It is written at the top left side of the symbol of an element e.g ${}^{4}_{2}He$.

Comparison of the masses of the fundamental particles of atom

The mass neutron is nearly equal to the mass of proton. But proton is about 1836 times heaviour than an electron. Hence the mass of the atom is equal to the sum of the masses of protons and neutrons.

Symbol of atom (Nuclide)

Generally an atom is represented by the symbol ${}^{A}_{Z}X$, which is called nuclide.

Example:

Nuclide of hydrogen atom having only one proton is ${}^{1}_{1}H$.

Q.2 What is meant by isotopes? Give example.

Isotopes:

Isotopes are atom of an element which have same number of protons but different number of neutrons in their nuclei.

Example:

Hydrogen has three Isotopes.

(i) Protium $\left({}^{1}_{1}H\right)$

Protium contains one proton and one electron

(ii) Deuterium $\left({}^{2}_{1}H\right)$

Deuterium contain on proton, one neutron and one electron.

(iii) Tritium $\left({}^{3}_{1}H\right)$

Tritium contains one proton, two neutrons and one electron.

Fig.18.2: Three isotopes of hydrogen
Protium (${}^{1}_{1}H$), Deutrium (${}^{2}_{1}H$) and Tritium (${}^{3}_{1}H$)

Q.3 What is meant by natural radioactivity? Explain how it is discovered and how radiations are identified?

Natural Radioactivity

"The spontaneous emission of radiation by unstable nuclei is called natural radioactivity."

Radioactive elements

"The elements which emit radiations naturally are called radioactivity elements".

Explanation

In 1896, Becquerel accidentally discovered that uranium crystals emit an invisible radiation that can darken a photographic plate. He also observed that the radiation has the ability to ionize a gas.

Marie Curie

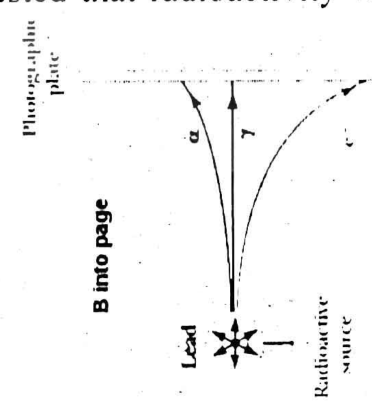
The most significant investigations of the process of radioactivity were done by Marie Curie and the husband Pierre.

They discovered two new elements which emitted radiations. These were named **polonium** and **radium**. This process of emission of radiations by some elements was called natural radioactivity by Marie Curie.

Henry Becquerel performed some experiments and suggested that radioactivity was the result of the decay unstable nuclei.

How these radiations are identified?

Three types of radiation are usually emitted by a radioactive element (substance). e.g.



(i) Alpha (α) particles.

(ii) Beta (β) particles.

(iii) Gamma (γ) rays.

These three forms of radiations were studied by the following scheme. The radioactive source is placed inside the lead block. The radiations emitting from the source allow to pass through the magnetic field. These radiations split into three components. Alpha (α) and Beta (β) radiations bend in opposite direction in magnetic field but gamma (γ) radiation does not change direction.

Q.4 **What is meant by background radiations? Enlist some sources of background radiations.**

Background Radiations

"Radiations present in atmosphere due to different radioactive substances are called background radiations".

Sources of background radiations

Everywhere in rocks, soil, water and air of our planet (Earth) there are traces of radioactive elements. They emit the radiation every time, this natural radioactivity is called the background radiation. It is as much part of our environment as sunshine and rain. Fortunately, our bodies can tolerate it. Only those places can be injurious to health where radiations are very height in magnitude.

The earth and all living things on it also receive radiation from outer space. This radiation is called cosmic radiation which primarily consists of positively charged ions from protons to iron and large nuclei. The cosmic radiation interacts with atom in the atmosphere to create a shower of secondary radiation, including x-rays, muons, protons, alpha particles, electrons and neutrons.

Q.5 **Define nuclear transmutation? Explain the radioactive decay of nuclide.**

"The spontaneous process in which a parent unstable nuclide changes into a more stable daughter nuclide with the emission of radiations is called nuclear transmutation".

Examples of radioactive decay

There are three processes given as

(i) Beta (β) decay

General Equation

$$^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e + \text{Energy}$$

Parent nuclide	daughter nuclide	beta (β) -particle

Example

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e + \text{Energy}$$

carbon	nitrogen	beta (β) – particle

In (β) - decay, the parent nuclide has its proton number Z increased by 1 but is mass number or nucleon number a remains unchanged.

(iii) **Gamma (γ) – decay**

General Equation

$$^{A}_{Z}X \rightarrow {}^{A}_{Z}X + (\gamma)$$

parent nuclide	daughter nuclide	gamma rays

γ - rays are usually emitted at the same moment as either an alpha or a beta particle.

Q.6 Discuss the nature and properties of radiation.

There are three types of radiations which show different properties.

(1) Nature of Radiations

(i) Alpha (α) particles

Alpha particle is a helium nucleus comprising two protons and two neutrons with a charge of +2. Alpha particles are emitted by the decay of unstable heavy nucleus, i.e

$${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn \quad + \quad {}^{4}_{2}He \ + \ Energy$$

Radium radon Alpha particle

(ii) Beta (β) particles

Beta radiation is a stream of high-energy electrons. An unstable nuclei with excess of neutrons any eject beta radiations. i.e

$${}^{214}_{82}Pb \rightarrow {}^{214}_{83}Bi + {}^{0}_{-1}B$$

In above example one neutron is converted into proton with the emission of Beta particles

$${}^{1}_{0}n \rightarrow {}^{1}_{1}H \rightarrow {}^{0}_{-1}B$$

iii. Gamma (γ) rays

Gamma radiations are fast moving light photons. They are electromagnetic radiations of very high frequency and short wavelength. These radiations are emitted by the unstable excited nuclei.

(2) Ionizing Effect

"The phenomena by which radiations split matter into positive and negative ions is called ionization". All three kinds of radiations ionize the matter but in different extent.

i. Alpha (α) particles:

Alpha particles have the greatest power of ionization of all. It is due to large positive charge and large mass of alpha particles.

ii. Beta (β) particles:

Beta particles ionize a gas much less than alpha particles do. It is due to high speed and negligible mass.

iii. Gamma $((\gamma)$ rays:

The ionization of power of gamma rays is even less than that of beta particles.

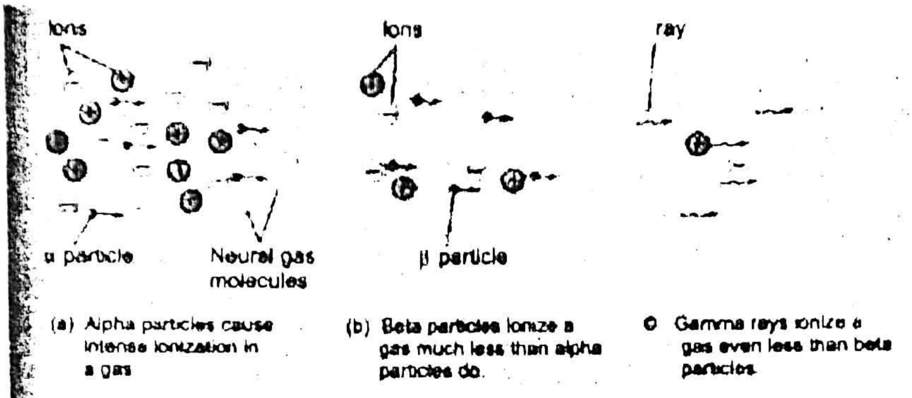


Fig. 18.5: Ionization effect of radiations in gas.

(3) **Penetrating ability**

"The strength of radiations to penetrate a certain material is called penetrating power".

All kind of radiations penetrate but penetrating range is different for each.

i. **Alpha (α) particles**

Alpha particles ahs the shortest range because of its strong interacting or ionizing power. Alpha particle has a rang of only a few centimetres in air.

ii. **Beta (β) p articles:**

Beta particle also penetrate to matter but their penetration is less than gamma rays and more than alpha particles. It is due to beta radiation strongly interacts with matter due to its charge. Beta particle has a range of several meters in air.

iii. **Gamma (γ) rays:**

The gamma ray can penetrate a considerable thickness of concrete. It is due to their large speed and neutral nature. Gamma radiations have a range of several hundred meters in air.

Fig. 18.6: Penetrating power of radiations in different materials

The three types of Radiation

Alpha particle	Beta particle	Gamma ray
Charge +2	Charge -1	No charge
Least penetration	Middle penetration	Highest penetration
Transmutes nucleus:		
$A \rightarrow A-4$	$A \rightarrow A$	$A \rightarrow A$
$Z \rightarrow Z-2$	$Z \rightarrow Z+1$	$Z \rightarrow Z$

Q.7 What do you understand by the half life of a radioactive elements? Explain with one example.

Half Life

"The time during which half of the unstable radioactive nuclei disintegrate is called the half life of the sample of radioactive element".

Explanation

Every radioactive element has its own characteristic half-life. For example, radium-226 has a half-life of 1620 years, which means that half of a radium-226 sample will be converted to other elements by the end of 1620 years (Fig. 18.7) In the next 1620 years, half of the remaining radium will decay, leaving only one-fourth the original amount of radium, and so on.

If the half-life of the radioactive element is $T_{1/2}$, then at the end of this time the number of atoms in the sample will become half i.e. 1/2. After a time $2T_{1/2}$. After second half-life period, the number of remaining atoms will become $1/2. 1/2 = 1/2^2 = 1/4$, after a time $3 T_{1/2}$, the number of remaining atoms will be $1/2. 1/2. 1/2 = 1/2^3 = 1/8$, and at the end of t half lives number of atoms that remain will be $1/2^t$.

ımount of radium, and so on.

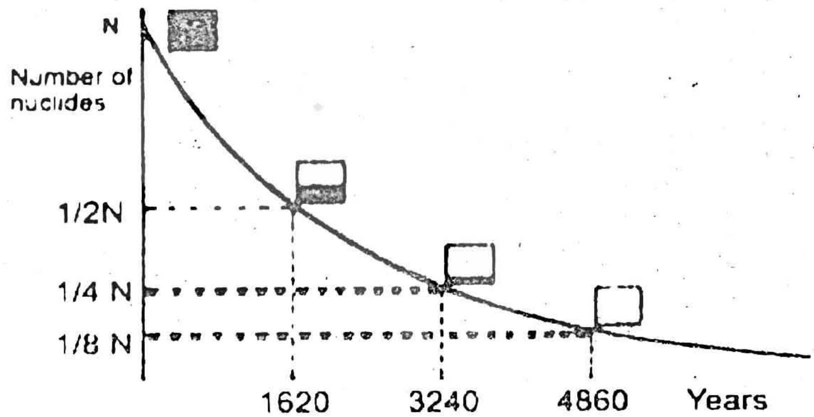


Fig.18.7 Radioactivity of radium

It means that if N_0 is the original number of atoms in the sample of radioactive element, then after t half lives number of atoms left in the sample can be determined by using the relation,

Remaining atoms = Original atoms 1/2

Or $N = N_0 \times 1/2^t$

Radioactivity is a nuclear process

Radioactivity is a nuclear process because radiations are emitted by the disintegration of nucleus.

Conclusion

The process of radioactivity does not depend upon the chemical combinations or reactions. It also not affected by any change in physical conditions like temperature, pressure, electric or magnetic fields.

Q.8 Define stable and unstable nuclei? How radioisotopes are produced?

Stable nuclei:

Nuclei which do not emit radiations naturally are called stable nuclei. The elements with atomic number 1 to 82 are stable nuclei. E.g. Sodium; $^{23}_{11}Na$, $^{40}_{20}Ca$ etc.

Unstable nuclei

The elements whose atomic number is greater than 82 are naturally radiating all the time called unstable nuclei. They emit different types of radiations and hence continuously change one type of element to another.

How radioisotopes are formed?

The stable and non-radioactive elements can also be change into radioactive elements by bombarding them with protons, neutrons or alpha particles are called radioactive isotopes or radio-isotopes.

Examples:

(1) $^{1}_{0}n$ +

$$^{1}_{0}n + {}^{23}_{11}Na \rightarrow {}^{24}_{11}Na + gamma(\gamma)$$

neutron stable sodium nuclide sodium radio isotope

(2)

$$^{4}_{2}He + {}^{27}_{13}Al \rightarrow {}^{30}_{15}Na + {}^{1}_{0}n$$

particle aluminium nuclide a phosphorous radioisotope

Q.9 Describe the uses of radioisotopes in different fields?

Radioisotopes are frequently used in medicine, industry and agriculture for variety of useful purpose.

Important applications of radioisotopes

(1) Traces:

Radioactive tracers are chemical compounds containing some quantity of radioisotope.

Radioactive traces are used to explore the metabolism of chemical reactions inside the human body, animal or plant.

i. Tracers in medicine (Medical field)

Radio isotopes are used for the diagnosis and treatment of diseases in hospitals.

(a) Iodine - 131

Radio iodine – 131 is used in treating cancer of thyroid glands.

Iodine – 131 readily accumulates in the thyroid gland and can be used for the monitoring of thyroid functioning.

(b) Phosphorous -32

P-32 is used to diagnose the brain tumour and for the treatment of leukaemia. The malignant part of the body absorbs more quantity of isotopes and this helps in tracing the affected part of the body.

(c) Cobalt – 60

The gamma-rays from cobalt – 60 are used for treatment of cancer because this powerful radiation kills the cancerous cells.

(d) **Gallium - 67**

Ga-67 is used to identify tumours in the lymph region of the throat and neck.

ii. **Tracers is industry**

In industry tracers can be used to locate wear and tear of the moving parts of the machinery, e.g. Co-60. They can be used for the location of leaks in underground pipes. By introducing a suitable radioactivity tracer into the pipe, the leak can be conveniently traced from higher activity in the region of crack in the pipe.

γ -rays radiography is used in metals. It shows any flaw in metal castings any welded joints.

Traces of radio isotopes are used to monitor the flow of oil and gas through pipe. They are used to check and control the thickness or density of finished products.

iii. **Tracers in agriculture:**

In agriculture radio phosphorus – 32 is used as a tracer to find out how well the plants are absorbing the phosphate fertilizers which are crucial to their growth.

(2) **Medical Treatment**

Radio isotopes are also used in nuclear medicines for curing various diseases. For example, radioactive cobalt – 60 is used for curing cancerous tumors and cells. The radiations kill the cells of the malignant tumor in the patient.

(3) **Carbon Dating**

Radioactive carbon – 14 is present in small amount in the atmosphere. Live plants use carbon dioxide and therefore become slightly radioactive.

When a tree dies, the radio carbon – 14 present inside the plant starts decaying. Since the half-life of carbon – 14 – 5730 year, the age of dead tree can be calculated by comparing the activity of carbon-14 in the live and dead tree. The activity of the live tree remains almost constant as the carbon-14 is being replenished while the carbon 14 in the dead trees in no more replenished. Therefore, by measuring the activity in the ancient relic, scientists can estimate its age.

Other radio isotopes are also used to estimate the age of geological specimens. For example, some rocks contain the unstable potassium isotope K-40. This decays to the stable argon nuclide Ar-40 with half life of 2.4×10^8 years. The age of rock sample can be estimated by comparing the concentrations of K-40 and Ar-40.

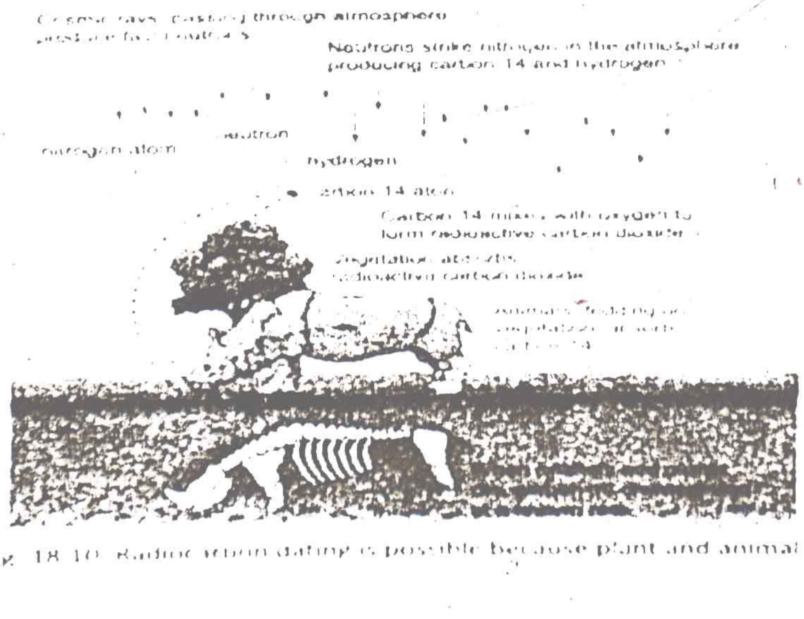


Fig. 18.10 Radiocarbon dating is possible because plant and animal life

Q.10 Define and explain the phenomenon of nuclear fission?

Nuclear fission

"The process of splitting of heavy nuclei into lighter nuclei is called fission reaction".

Natural Nuclear Transmutation

A nuclear transmutation in which an unstable nucleus changes into more stable nucleus is called natural nuclear transmutation.

Example

$${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}C$$

Artificial Transmutation

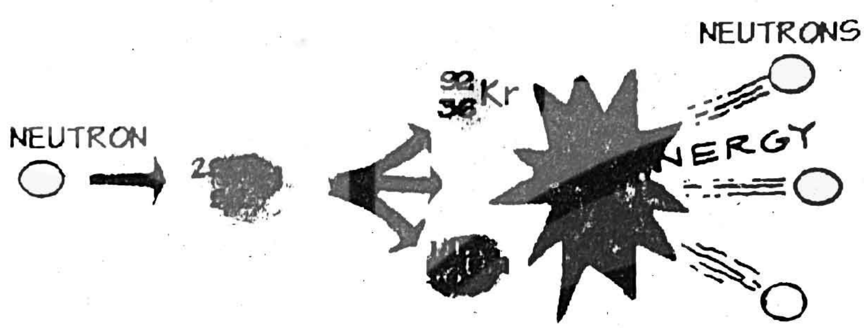
A nuclear transmutation reaction in which an unstable nucleus changes into more stable nucleus when it is bombarded with particle like neutron is called artificial transmutation.

Example:

Famous example of artificial transmutation is the nuclear fission reaction.

Nuclear fission

Nuclear fission takes place when a heavy nucleus, such as U-235, splits or fissions, into two smaller nuclear by bombarding a slow moving (low- energy) neutron represent in equation;



$${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow X + Y + \text{neutron} + \text{energy}$$

U-236 in an intermediate state that lasts only for few seconds before splitting into nuclei X and Y, called fission fragments.

When and who nuclear fission discovered

Nuclear fission was first observed in 1939 by Otto Han and Fritz Strassman.

How fission take place?

The uranium nucleus was split into two nearly equal fragments after absorbing a slow moving (low-energy) neutron. The process also resulted in the production of typically two or three neutrons per fission event. On average, 2.47 neutrons are released per event such as given below

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

Enormous energy released

In nuclear fission, the total mass of the products is less than the original mass of the heavy nucleo|us. From measurements it is showed that about 200 MeV of energy is released in each fission event. This is large amount of energy relative to the energy released in chemical processes.

Example:

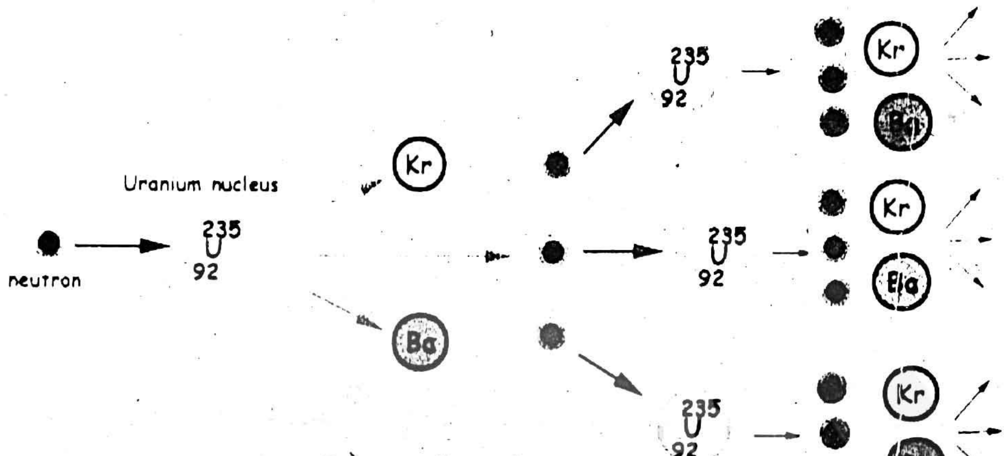
If we born one tonne of coal then about 36×10^9J of energy is released.

Chain Reaction

"A fission reaction where the neutrons from a previous step continue to propagate and repeat the reaction, tem as chain reaction".

Explanation of chain reaction

During fission reaction neutrons are emitted. These neutrons can in turn trigger other uranium nuclei to undergo fission with the possibility of a chain reaction.



Fission Chain Reaction in Uranium 235

Explosion

Calculations show that if the chain reaction is controlled, it will proceed too rapidly and possibility result in the sudden release of an enormous amount of energy which is considered as an explosion.

How chain reaction in controlled?

The fission chain reaction is controlled in nuclear reactor. In nuclear reactor the extra neutrons liberated in fission reactions are absorbed using some material to stop chain reaction. e.g.

$$^{10}_{5}B \quad + \quad ^{1}_{0}n \quad \rightarrow \quad ^{7}_{3}Li \quad + \quad ^{4}_{2}He$$

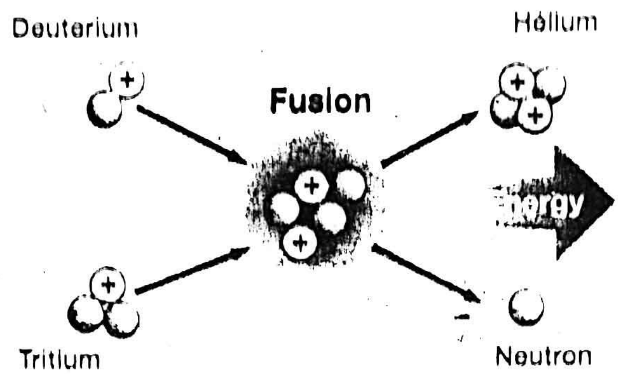
Thus chain reaction is prevented from going too fast. Hence their energy is controlled, so nuclear reactor provides energy for useful purposes.

Q.11 Nuclear Fusion

When two light nuclei combine to form a heavier nucleus, the process is called nuclear fusion. The mass of the final nucleus is always less than the masses of the original nuclei. According to mass energy relation this loss of mass converts into energy. If an atom of Deuterium is fused with an atom of Tritium, the a Helium nucleus or alpha particle is formed as given by

$$^{2}_{1}H \quad + \quad ^{3}_{1}H \quad \rightarrow \quad ^{4}_{2}He \quad + \quad ^{1}_{0}n \quad + \quad \text{energy}$$

Pictorially fusion reaction is shown in the following figure.



Source of Energy

Energy coming from the Sun and stars is supposed to be the result of fussion of hydrogen nuclei into Helium nucleus with release of energy. The temperature at the centre of the sum is nearly 20 million kelvin which makes the fusion favourable. According to this reaction four hydrogen nuclei fuse together to form a helium nucleus along with two positrons, three alpha particles and 25.7 MeV of energy.

Q.12 Differences between nuclear fission and nuclear fusion.

Nuclear Fission	Nuclear Fusion
1. A bigger heavier nucleus splits into smaller (lighter) nuclei.	1. Lighter nuclei fuse together to form the heavier nucleus.
2. It does not require temperature.	2. Extremely high temperature is require for fusion to take place.
3. A chain reaction sets in.	3. It is not a chain reaction.
4. It can be controlled and energy released can be used for peaceful purpose.	4. It cannot be controlled and energy released cannot be used properly.
5.The products of the reaction are radioactive in nature.	5. The products of a fusion reaction are non-radioactive in nature.
6. At the end of the reaction nuclear waste is left behind.	No nuclear waste is left at the end of fusions reaction.

Q.13 Describe the half-lives of some important isotopes? Also write the radiation produced by this decay process.

Element	Isotope	Half-Life	Radiation Produced
Hydrogen	$^{3}_{1}H$	12.3 years	β
Carbon	$^{14}_{6}C$	5730 years	β
Cobalt	$^{60}_{27}Co$	30 years	$\beta - \gamma$
Iodine	$^{131}_{53}I$	8.07 days	$\beta - \gamma$

Lead	$^{212}_{82}Pb$	10.6 hours	β
Polonium	$^{194}_{84}Po$	0.7 seconds	α
Polonium	$^{210}_{84}Po$	138 days	$\alpha-\gamma$
Uranium	$^{235}_{92}U$	7.1 x 10^8 years	$\alpha-\gamma$
Uranium	$^{238}_{92}U$	4.51 x 10^8 years	$\alpha-\gamma$
Plutonium	$^{236}_{94}Pu$	2.85 years	α
Plutonium	$^{242}_{94}Pu$	3.79 x 10^5 years	$\alpha-\gamma$

Q.14 Discuss uses and the hazards of radiations? Describe the precaution to minimize radiations dangers (safety measures)

Important fields where radiations are uses as follow

Radiations are very useful in medicine, agriculture and industry, they can also cause considerable damage if not used with precautions. Radioactive, nuclear materials are now widely used in nuclear power plants, nuclear – powered submarines, intercontinental ballistic missiles etc.

Radiations Hazards

Some of harmful effects on human beings due to large doses or prolonged small doses of radiations.

6. Radiation burns, mainly due to beta and gamma radiations, which may cause redness and sores on the skin.
7. Sterility (i.e. inability to produce children).
8. Genetic mutations in both human and plants. Some children are born with serious deformities.
9. Leukernia (Cancer of the blood cells)
10. Blindness or formation of cataract in the eye.

Explosion of nuclear reactor at Chernogyl

During the nuclear accident at Chernobyl, Russia the explosion of the nuclear reactors melted through a few meters thick concrete housing. This caused a massive destruction of local community and also contaminated vegetation and livestock in the large surrounding area. Millions of dollars were lost as the contaminated vegetable and livestock had to be destroyed.

Precautions to minimize radiation dangers

Because we cannot detect radiations directly, we should strictly follow safety precautions, even when the radioactive sources are very weak.

6. Sources should not be handled with tongs and forceps.
7. The user should use rubber gloves and hand should be washed carefully after the experiment.
8. All radioactive sources should be stored in thick lead containers.
9. Never point radioactive source towards a person.
10. Frequent visits to the radiation sensitive areas should be avoided.