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NUCLEAR PHYSICS: Chapter 19

Nuclear Physics: Branch of physics that deals with the study of the nucleus is called nuclear physics.

THE NECLEUS:

The central part of an atom having positive charge is called nucleus. It contains protons and neutrons.

PROTON:

Proton is a positively charged particle present inside the nucleus. Its mass is 91.67x10-27 kg and its charge is +1.6x1019 kg.

NEUTRON:

Neutron is a neutral particle present inside the nucleus. Its mass is 1.67x1027 kg.

ELECTRON:

Electron is a negatively charged particle revolves around the nucleus in the orbits. Its mass is 9.1x10-31 kg and its charge is 1.6x10-19 C.

MASS NUMBER:

The total number of protons and neutrons present inside the nucleus is called mass number.

OR

The total number of neutrons present inside the nucleus is called mass number.

i.e. $A = Z + N$

A = mass number, Z = protons/electrons number, N = neutron number.

CHARGE NUMBER / ATOMIC NUMBER:

The number of protons or electrons present in the atom is called atomic number or charge number. It is denoted by Z.

NEUTRON NUMBER:

The number of neutrons present in the nucleus is called neutron number. It is denoted by N
Mathematically it is given as:

$$N = A - Z$$

Where N = neutron number, A = mass number.

NEUTRAL RADIOACTIVITY:

Definition:

The spontaneous emission of invisible rays from elements having atomic number greater than 82 is called radioactivity. The invisible rays are called radioactive rays and the elements which emit such rays are called radioactive element.

Examples:

Radioactive elements are polonium (z = 84), Radium (z = 88), thorium (z=90) , uranium (z=92) etc. As the phenomenon is natural, therefore it is termed as natural radioactivity. It was discovered by Henry Becquerel.

ALPHA, BETA AND GAMMA RAYS:

(Ruther ford's experiment.)

Ruther ford's performed an experiment to study the radiations emitted by radioactive element. A radioactive element for example radium is placed in a cavity made in the block of the lead. The radiation coming out of the whole in the cavity are allowed to enter into a vacuum chamber in which magnetic field is applied perpendicular to the plane of the paper and having direction toward. The charged radiations are deflected by the magnetic field. Three images are produced on the photographic plate which is placed in the vacuum chamber straight above the radiations bending towards left are positively charged radiations and are called Alpha (∝) rays. The radiations bending towards right are negatively charged and are called ß rays. The under acted radiations are neutral.

PROPERTIES OF RADIOACTIVE RAYS:

1. Alpha rays:

i. The are positively charged radiations.

ii. They consist of positively charged helium nuclei, called ? particle (2He4)

iii. Each ? particle consists of two protons and two neutrons.

iv. Mass of alpha particle is equal to mass of helium nuclei.

v. Charge of apha particle is equal to +2e.

vi. The speed of alpha particle is almost 100 times lesser than the speed of Light.

vii. ∝rays have low penetrating power.

viii. ∝ rays have high ioizing power.

ix. ∝ rays produce fluorescence in certain substance.

x. ∝ rays show relfection in electromagnetic field.

2. Beta rays:

i. They are negatively charged particles.

ii. They consist of negatively charged particle called electron.

iii. Mass of beta particle is equal to mass of electron.

iv. Charge of each ß particle is equal to –1e

v. ß rays (electrons) are emitted than the nucleus.

vi. The velocity of a ß particle is almost 10 times lesser than the velocity of Light. (Range: 19x109 m/s to 27x107 m/s)
vii. ß rays effect th photographic plate.
viii. ß rays have low ionization power.
ix. ß rays have high ionization power.
x. ß rays produce fluorescence.

3. Gamma rays:

i. γ – rays are neutral ionizations.
ii. γ – rays are electromagnetic waves like x-rays.
iii. γ – rays have wave length shorter than the wave length of x – rays.
iv. γ – rays have frequency greater than the frequency of x – rays.
v. γ – rays have negligible ionization power.
vi. γ – rays have very high penetrating power.
vii. γ – rays producer feeble flourensense.
viii. γ – rays eject electrons when fall on metal.
ix. γ – rays travel with the speed of light.

HALF LIFE OF AN ELEMENT:

Definition:

The deviation in which original number of atom becomes half is called half life of an element. OR The time in which half of the given number of radioactive atoms, decay into daughter, is called half life of an element.

Mathematical form:
Mathematically, it is given as:

$$T_{1/2} = 0.693/\lambda$$

Where **T½**= half life **λ** = decay constant

When an element decays by ∝ or ß emission if is converted into new element. The new element is called daughter element and the original element is called parent element.

RADIOACTIVE ISOTOPES:

Definition:

“Element having same atomic number but different atomic masses are called isotopes.” If one isotope is unstable and emits radioactive rays is called radio isotopes.

OR

“Elements having same proton number but different neutron number and emit ∝ , ß or γ rays are called radioactive isotope.”

EXAMPLE:

I. Carbon has two isotopes C_6^{12} and C_6^{14} . 6C_6^{14} is unstable are emit ß rays. Therefore it is considered as a radioactive isotope.
II. Hydrogen has three isotopes, H_1^1 , H_1^2 and H_1^3 . H_1^3 is radioactive isotopes and emits out ß particle.

EINSTEIN ENERGY MASS RELATION:

According to the special theory of relativity, "Energy and mass are interconvert able mass can be converted into energy and energy can be converted into mass." Einstein energy mass radiation is given as

E = mC2

Where, E = energy, m = mass, C = velocity of light.

NUCLEAR REACTION:

DEFINITION:

A reaction which produce certain changes to the nucleus is called nuclear reaction.

NUCLEAR FISSION:

DEFINITION:

The process in which heavy decomposed into lighter nuclei is called nuclear fission or the phenomenon in which heavy nucleus is broken into two middle order nuclei with the release of energy is called nuclear fission.

EXAMPLE:

The nuclear fission is given as

$$\mathbf{U_{92}^{235}} + \mathbf{O_0^1} \rightarrow B_{a36}^{144} + K_{r36}^{90} + \mathbf{O_{30}^1} + \textbf{Energy}$$

The energy is released because mass on the right hand is less than the mass on the left hand side. The difference in mass (loss of mass) is converted into energy.

NUCLEAR CHAIN REACTION:

DEFINITION:

A reaction which once starts repeat itself in the same manner is called nuclear chains reaction.

EXAMPLE:

When 92U235 is bombarded by slow reaction, fission is produced. The three neutrons released in this fission can be employed to produce fission in three other nuclei of $\mathbf{U_{92}^{235}}$ and a chain reaction can be developed as shown in figure. If this process is allowed to continue, then more and more nuclei undergo fission and larger amount of energy is released. This is called nuclear chain reaction.

TYPES OF CHAIN REACTION:

There are two types of chain reaction:

i. Controlled chain reaction.

ii. Uncontrolled chain reaction.

NUCLEAR REACTORS:

DEFINITION:

A device which is used to perform nuclear chain reaction in controlled manner is called nuclear reactor.

OR

"A system used to obtain controlled amount of head from nuclear fission is called nuclear reactor."

The nuclear chain reaction in uranium releases energy in the form of heart. If the chain reaction is controlled a constant. How of heat is obtained this heat can be used to run generator for producing electricity.

The fissionable material 92U235 is fission element. The three neutrons released in each fission are fast moving. These neutrons must be slowed down because only neutrons produced fission in 92U235 the process of slowing down of neutrons is called moderation. In the reactor heavy water is such as moderator.

The chain reaction is controlled by using neutron absorbing rods. Two out of the three neutrons are absorbed by control rods. The heat produced in the nuclear reactor is carried away by the circulation of carbon dioxide is the core of reactor. It is used to produce steam and this steam is used to run the generator for producing electricity.

NUCLEAR FUSSION:

DEFINITION:

The phenomenon in which two light nuclei are combined with the release of energy, is called nuclear fussion or fussion reaction.

OR

"The process in which two lighter nuclei combines together to heavy. Heavy nucleus is called nuclear fussion."

EXAMPLE:

$$H_1^2 + H_1^3 \rightarrow H_{e_2}^{+} + O_0^1 + \text{energy}$$

$$H_1^2 + H_1^2 \rightarrow H_{e_2}^{4} + \text{energy.}$$

ENERGY OF THE SUN:

Solar energy from the sun is due to the fusion of hydrogen into helium. This fusion is possible because the temperature in the sun is about 1.5x106 ?C. The fusion reaction that happens in the sun is given as::

$$H_1^2 + H_1^2 \rightarrow H_{e_2}^{4} + \text{energy.}$$

THE ATOMIC BOMB:

The atomic bomb is based on nuclear fission. The maximum amount of mass required to start the nuclear fission is called critical mass. If the mass is slightly greater than the critical mass, the chain reaction will develop at a faster rate and in a very short time tremendous amount of energy will be released. This producer is adopted in atomic bomb.

THE HYDROGEN BOMB:

The hydrogen bomb is based on the principle of nuclear fission. To start fission reaction, a very high temperature is nucleated. This high temperature is obtained from fission chain reaction.

The energy released in the explosion of hydrogen bomb is far greater than that released from the explosion of an atom.

USES OF RADIO ISOTOPES:

The isotopes of an element which emits out radiation is called radio isotope. Radio isotopes are widely used in

i. Agriculture

ii. Medicine etc.

I INDUSTRY:

A Radio isotopes are used to check the thickness of the material being produced.

B Radio isotopes are used to detect cracks in welded joints.

C Radio isotopes are used to detect the leakages in pipes.

II AGRICULTURE:

A Varieties of seeds for various agriculture commodities which show resistance against the attacks of pets have been produced after imitation through radiations from radio isotopes.

B Radiation from radio isotopes are used to kill bacteria and preserve food stuff.

C It is used to determine the optimum amount of fertilizers and other nutrient intake by plants. Its count rate is used to determine the amount of chemicals absorbed by various parts of the plants.

III MEDICINE:

A Radio isotopes iodine 131, is used to study thyroid glands.

B Radio isotopes phosphorus 32 is used to locate the position of tumor in the brain.

C Radio isotope strontium is used in the treatment of internal wounds.

D Radio isotope sodium is used tracing the blood circulation in the body.

E Radio isotope phosphorus has found effective for heating leukemia as radiation emitted by Hood cancer if destroys the excess production of white blood corpuscles (cells).

F Radio isotope cobalt – 60 is used to treat cancerous tumors inside the body RADIATION HAZARDS:

In contrast to good use in industry, agree culture medicine etc. nuclear radiations are very dangerous to the human body. They can damage the body cells due to the ionization which they produce. A body, if strongly heated suffers the following diseases.

i. Anemia (a decrease in red blood corpuscles).

ii. Leukemia (an increase in white blood corpuscles)

iii. Malignant tumors.

iv. Cataracts (eye lens becomes opaque).

RADIATION SAFETY:

(Precautions to minimize radiation danger)

i. One should be at a safe distance from radio isotopes.

ii. The time for radiation exposure should be short.

iii. The radiations from nuclear reactor are shielded by the thick concrete walls.

iv. The radioactive material should be kept in lead box with the lid made of lead.