Nuclear Physics

Radio Activity:

The Phenomenon of nuclear decay of certain elements with the emission of radiations like alpha, beta, and gamma rays is called radioactivity and the elements which undergo this phenomenon are called radioactive elements.

Why?

The nucleus of some elements is unstable. Such nuclei undergo nuclear decay and get converted into more stable nuclei.

Natural Radioactivity:

The phenomenon of spontaneous emission of radiation from certain elements on their own is called natural radio activity.

Example: Uranium, Radium [Atomic Number > 82]
Technetium, Promethium [Atomic Number < 82]

43 61

There have been 29 radioactive substance discovered so far.

Artificial (or) Induced Radioactivity:

The Phenomenon by which even light elements are made radioactive, by artificial or induced methods is called artificial radioactivity.

In 1934 Irene Curie and F. Joliot discovered this kind of radioactivity.

Example:

$_4Be^9 + _2He^4 \rightarrow _6C^{13+}$

$_6C^{13+} \rightarrow _6C^{12} + _6n^1$

$_4Be^9 \rightarrow$ Parent Nucleus | $_2He^+ \rightarrow$ alpha (Projectile) Particle

$_6C^{12} \rightarrow$ Daughter Nucleus | $_0n^1 \rightarrow$ Ejected Particle

Units of Radioactivity:

Curie : 1 Curie = 3.7×10^{10} disintegrations per second

Rutherford: 1 Rd = 10^6 disintegrations Per second.

Becquerel: SI unit, quantity of one disintegration per second.

Roentgen (R): It is defined as the quantity of radio active substance which produces a charge of 2.58×10^{-4} C in 1 kg of air.

Alpha decay:

$_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}_{2}He^{4}$ (α - decay)

Beta decay:

$_{15}P^{32} \rightarrow {}_{16}S^{32} + {}_{-1}e^{0}$ (β - decay)

Gamma decay:

In this decay only the energy level of the nucleus changes. Atomic number and mass number remains the same.

Nuclear Fission:

The process of breaking up of a heavier nucleus into two smaller nuclei with the release of a large amount of energy and a few neutrons is called 'nuclear fission'.

$_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3{}_{0}n^{1} + Q$ (energy)

The average energy released in each fission process is about 3.2×10^{-11} J.

Fissionable Materials:

A Fissionable material is a radio active element, which undergoes fission in a sustained manner when it absorbs a neutron. It is also termed as 'fissile material'.

eg: U^{235}, Plutonium (Pu^{239} and Pu^{241})

Fertile Material: There are some radioactive elements, which can be converted into fissionable material. They are called as fertile material.

eg: U^{238}, Thorium – 232, Plutonium – 240

Chain Reaction:-

A chain reaction is a self-propagating Process in which the number of neutrons goes on multiplying rapidly almost in geometric progression.

i) Controlled chain reaction (Neutron absorber)

ii) Uncontrolled chain reaction (Atom Bomb)

Critical Mass:

The minimum mass of a fissile material necessary to sustain the chain reaction is called critical mass. It depends upon the nature, density and size of the fissile material.

Mass of the fissile material < Critical mass (sub critical)
Mass of the fissile material > Critical mass (super critical)
1ev = 1.602×10^{-19} joule.
1 million electron volt = 1 Mew = 10^6 eV
The energy released in a nuclear fission process is about 200 MeV.

Nuclear Fusion:

The process in which two lighter nuclei combine to form a heavier nucleus is termed as nuclear fusion.

eg: ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4 + Q$ (energy)
${}_1H^2$ – an isotope of hydrogen known as 'deuterium'.
The average energy released in each fusion reaction is about 3.84×10^{-12}J.

Mass Defect – Mass of the daughter nucleus is less than the sum of the masses of the two parent nuclei. This mass is converted into energy. This concept of mass-energy equivalence was proposed by Einstein in 1905.

$E = mc^2$ where C is the velocity of light.

Hiroshima Nuclear bomb – Little Boy (Uranium)

Nagasaki Nuclear bomb – Fat man (Plutonium)

Conditions necessary for Nuclear Fusion:-

i) 10^7 to 10^9 k High temperature
ii) High pressure to push the hydrogen nuclei closer to fuse with each other. Hence it is named as 'Thermonuclear reaction'.
iii) The repulsive force will be overcome by the kinetic energy of the nuclei at high temperature of the order of 10^7 to 10^9 K.

Stellar Energy:

The stars like our sun emit a large amount of energy in the form of light and heat. This energy is termed as the stellar energy. All stars contain a large amount of hydrogen.

Hydrogen Bomb : Atom Bomb + Nuclear Fusion.

Sun fuses about 620 million metric tons of hydrogen each second and radiates about 3.8×10^{26} joule of energy per second. When it reaches the earth its value is about 1.4 kilo joule per unit area in unit time.

Uses of Radio activity:

Agriculture: The radio isotope of phosphorus (P-32) helps to increase the productivity of crops

Medicine: Radio Sodium (Na^{24}) – used for effective functioning of heart.

Radio – Iodine (I^{131}) is used to cure goiter.
Radio – Iron (Fe^{59}) is used to diagnose anemia.
Radio Phosphorus (P^{32}) is used in the treatment of skin diseases.

Radio Cobalt (Co^{60})
Radio Gold (Au^{1987}) } Skin cancer

Industries: An isotope of californium (cf^{252}) is used in the airlines to detect the explosives in the luggage.

An isotope of Americium (Am^{241}) is used as smoke detector.

Archeological Research – Radio Carbon dating, age of earth, fossils, old paintings and monuments.

NUCLEAR REACTOR

A Nuclear reactor is a device in which the nuclear fission reaction takes place in a self-sustained and controlled manner to produce electricity. The first nuclear reactor was built in 1942 at Chicago, USA.

Components of a nuclear reactors

The essential components of a nuclear reactor are (i) fuel, (ii) moderator, (iii) control rod, (iv) coolant and (v) protection wall.

Fuel:

A fissile material is used as the fuel. The commonly used fuel material is uranium.

Moderator:

A moderator is used to slow down the high energy neutrons to provide slow neutrons. Graphite and heavy water are the commonly used moderators.

Control rod:

Control rods are used to control the number of neutrons in order to have sustained chain reaction. Mostly boron or cadmium rods are used as control rods. They absorb the neutrons.

Coolant:

A coolant is used to remove the heat produced in the reactor core, to produce steam. This steam is used to run a turbine in order to produce electricity. Water, air and helium are some of the coolants.

Protection wall:

A thick concrete lead wall is built around the nuclear reactor in order to prevent the harmful radiations from escaping into the environment.

Uses of a nuclear reactor

1. Nuclear reactors are widely used in power generation.
2. They are also used to produce radio isotopes, which are used in a variety of applications.
3. Some reactors help us to do research in the field of nuclear physics.
4. Breeder reactors are used to convert non-fissionable materials into fissionable materials.

Nuclear power plants in India

Indian Atomic Energy Commission (AEC) was established in August 1948 by the Department of Indian Scientific Research committee at Bombay (now Mumbai) in Maharashtra. It is the nodal agency for all the research done in the field of atomic energy. Dr. Homi Jahangir Bhaba was the first chairman of Indian Atomic Energy Commission. Now, it is known as Bhaba Atomic Research Centre (BARC).

Nuclear power is the fifth largest source of power in India. Tarapur Atomic Power Station is India's first nuclear power station. Now, there are a total of seven power stations, one each in Maharashtra, Rajasthan, Gujarat, Uttar Pradesh and two in Tamilnadu. In Tamilnadu, we have nuclear power stations in Kalpakkam and Kudankulam. Apsara was the first nuclear reactor built in India and Asia. Now, there are 22 nuclear reactors which are operating in India. Some other operating reactors are

- Cirus
- Dhuruva
- Purnima

Previous Year Questions

1. Half-life of a radioactive substance with disintegration constant λ is
A. 0.6931/λ B. 0.6931 × λ C. λ /0.6931 D. $\lambda^2/0.6931$
சிதறல் மாறிலி கொண்ட ஒரு கதிர் வீச்சு பொருளின் அரை ஆயுட்காலம்
A. 0.6931 / λ B. 0.6931 × λ C. λ /0.6931 D. λ^2 /0.6931

2. The Name of the launching vehicle used to launch Chandrayan-2 is
a. PSLV **b. GSLV MKIII** c. GSLV III d. PSLV-C45
சந்திராயன்-2 ஐ செலுத்த பயன்படுத்தப்பட்ட செலுத்து வாகனத்தின் பெயர்
a. PSLV b. GSLV MKIII c. GSLV III d. PSLV-C45

3. The control rods is a nuclear reactor
a. absorb neutrons b. accelerate neutrons
c. slowdown neutrons d. absorb excess heat produced in the reactor
அணுகரு உலையில் உள்ள கட்டுப்பாட்டு கோல்கள்
a. நியுட்ரான்களை உறிஞ்சும்
b. நியுட்ரான்களின் வேகத்தை அதிகரிக்கும்
c. நியுட்ரான்களின் வேகத்தை குறைக்கும்
d. உலையில் வெளியாகும் அதிக அளவு வெப்பத்தை உறிஞ்சும்

4. The first ever satellite Sputnik 1 was launched in the year of
a. 1957 b. 1958 c. 1971 d. 1972
உலகின் முதல் செயற்கை கோள் ஸ்புட்னிக் 1 வின்னில் ஏவப்பட்ட ஆண்டு
a. 1957 b. 1958 c. 1971 d. 1972

5. A projectile is fired at angle to the vertical with a small velocity its horizontal range will be maximum when the angle to the vertical is
a. 120^0 b. 90^0 **c. 45^0** d. 30^0
குறிப்பிட்ட, கோணத்தில் குறைந்த திசைவேகத்தில் எறிபொருள் செங்குத்தாக மேல் நோக்கி எறியப்படுகிறது. கிடைத்தள வீச்சு பெருமமாக இருக்க எறிய வேண்டிய கோணம் என்ன?
a. 120^0 b. 90^0 c. 45^0 d. 30^0