UNIT

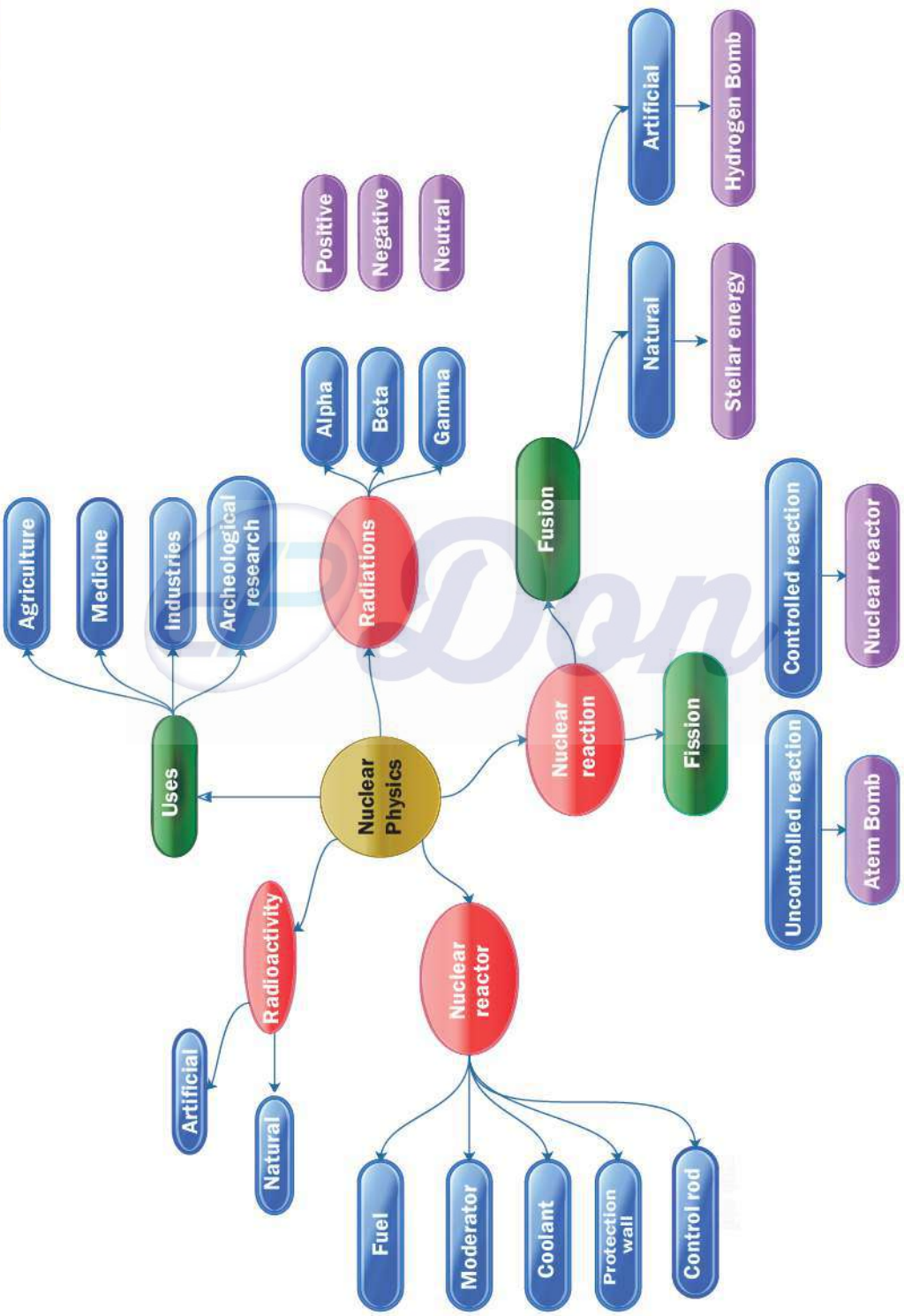
6

Nuclear Physics

POINTS TO REMEMBER

- Henry Becquerel discovered natural radioactivity.
- Radioactivity is the phenomenon of nuclear decay of certain elements with the emission of radiations like alpha, beta and gamma rays.
- Artificial radioactivity was discovered by Irene curie and F. Joliot.
- Artificial radioactivity occurs in lighter elements.
- Units of radioactivity are Curie, Rutherford, Becquerel and Rontgen.
- In Alpha decay, atomic number decreases by two and mass number decreases by four in parent nuclei.
- In Beta decay, atomic number increases by one.
- In gamma decays, both atomic and mass number do not change.
- The phenomenon of breaking the heavier nucleus into two smaller nuclei is called nuclear fission.
- A nuclear reactor is a device in which the nuclear fission reaction takes place in a self - sustained and controlled manner to produce electricity.
- Controlled chain reaction occurs in nuclear reactor.
- Uncontrolled chain reaction occurs in Atom bomb.
- The minimum mass of a fissile material necessary to sustain the chain reaction is called critical mass.
- The phenomenon of two lighter nuclei combine to form a heavier nucleus is called nuclear fusion.
- Atom bomb is based on the nuclear fission whereas stellar energy and hydrogen bomb is based on nuclear fusion.

MIND MAP



- Uses of Radioactivity

  In Agriculture - to increase the productivity and to increase the life span of agricultural products.

  In Medicine - to diagnosis and in therapy
  to sterilize the surgical devices.

  Industries - to detect the explosives in airlines luggages and to detect smoke leakage.

- The first nuclear reactor was built in 1942 at Chicago, USA.
- Dosimeter is a device used to detect levels of ionizing radiation
- Fuel, moderator, control rods, coolants and protection walls are important componenets of nucleur reactor.
- Tarapur Atomic power station is India's first power station
- Apsara was the first nuclear reactor in India and Asia

Scientists and Inventions:

400 BC	Democritus	- Atoms
1803	John Dalton	- Elements consists of atoms
	J.J. Thomson	- Cathode rays (electrons)
	Goldstein	- Protons
1932	Chadwick	- Neutrons
	Ernst Rutherford	- Nucleus (named)
	Henri Becquerel	- Natural radioactivity
	Marie Curie & Pierre curie	- Radium (named)
1934	Irene Curie & F. Joliot	- Artificial Radioactivity
	Soddy & Fajan	- Radioactive displacement law
	Otto Hahn & F. Strassman	- Nuclear fission
	Einstein	- Mass energy equivalence
	Dr. Henry Jahangir Bhaba	- Ist chairman of Indian Atomic energy commission
	Roentgen	- X-rays
	Martin Klaproth	- Uranium

UNITS	
Curie	The quantity of radioactive substance which undergoes 3.7×10^{10} disintegrations in one second. This is actually close to the activity of 1g of Radium^{226}. 1 curie = 3.7×10^{10} disintegration per second.
Rutherford (Rd)	The quantity of a radioactive substance, which produces 10^6 disintegrations in one second.
Becquerel	The SI unit of radioactivity is Becquerel. It is defined as the quantity of one disintegration per second.
Roentgen	The quantity of radioactive substance which produces a charge of 2.58×10^{-4} coulomb in 1 kg of air under standard conditions of pressure, temperature and humidity.

IMPORTANT ELEMENTS & THEIR USES	
U^{235}, Pu^{239}, P^{241}	Fissionable material
U^{238}, Pu^{240}, Th^{232}	Fertile material
$_2He^4$	α - particle
$-1e^B$	β - particle
Na^{24}	Effective functioning of heart
I^{131}	Cure goiter
Fe^{59}	Diagnose & treat anaemia
P^{32}	Cure skin disease
Co^{60}, Au^{79}	Treatment of skin cancer
Cf^{252}	Detect explosives
Am^{241}	Smoke detector
C^{14}	Archaeological research

COMPONENTS OF NUCLEAR REACTOR	
Fuel	Uranium
Moderator	Graphite, heavy water
Control rod	Boron & Cadmium
Coolant	Water, air & liquid sodium
Protection wall	Thick concrete lead wall

Textbook Evaluation

I. Choose the most suitable answer from the given four alternatives and write the option code and corresponding answer:

1. **Man-made radioactivity is also known as _____**
   a) Induced radioactivity
   b) Spontaneous radioactivity
   c) Artificial radioactivity
   d) a & c

2. **Unit of radioactivity is _____** ★★
   a) Roentgen
   b) Curie
   c) Becquerel
   d) All the above

3. **Artificial radioactivity was discovered by _____** ★★
   a) Becquerel
   b) Irene Curie
   c) Roentgen
   d) Neils Bohr

4. **In which of the following, no change in mass number of the daughter nuclei takes place**
   i) α decay ii) β decay iii) γ decay iv) neutron decay
   a) (i) is correct
   b) (ii) and (iii) are correct
   c) (i) & (iv) are correct
   d) (ii) & (iv) are correct

5. **_____ isotope is used for the treatment of cancer.** ★
   a) Radio Iodine
   b) Radio Cobalt
   c) Radio Carbon
   d) Radio Nickel

6. **Gamma radiations are dangerous because**
   a) it affects eyes & bones
   b) it affects tissues
   c) it produces genetic disorder
   d) it produces enormous amount of heat

7. **_____ aprons are used to protect us from gamma radiations**
   a) Lead oxide
   b) Iron
   c) Lead
   d) Aluminium

8. **Which of the following statements is/are correct?**
   i. α particles are photons
   ii. Penetrating power of γ radiation is very low
   iii. Ionization power is maximum for α rays
   iv. Penetrating power of γ radiation is very high
   a) (i) & (iii) are correct
   b) (ii) & (iii) are correct
   c) (iv) only correct
   d) (iii) & (iv) are correct

9. **Proton - Proton chain reaction is an example of _____**
   a) Nuclear fission
   b) α - decay
   c) Nuclear fusion
   d) β - decay

10. In the nuclear reaction ${}_6X^{12} \xrightarrow{\alpha \text{ decay}} {}_ZY^A$, the value of A & Z. ★★
    a) 8, 6 b) 8, 4
    c) 4, 8 d) cannot be determined with the given data
11. Kamini reactor is located at _____ ★★
    a) Kalpakkam b) Koodankulam
    c) Mumbai d) Rajasthan
12. Which of the following is/are correct?
    i. Chain reaction takes place in a nuclear reactor and an atomic bomb.
    ii. The chain reaction in a nuclear reactor is controlled
    iii. The chain reaction in a nuclear reactor is not controlled
    iv. No chain reaction takes place in an atom bomb
    a) (i) only correct b) (i) & (ii) are correct
    c) (iv) only correct d) (iii) & (iv) are correct

Ans:

1.	d)	(a) and (c)	2.	d)	All the above
3.	b)	Irene Curie	4.	b)	(ii) and (iii) are correct
5.	b)	Radio cobalt	6.	b)	it produces genetic disorder
7.	c)	lead	8.	d)	(iii) and (iv) are correct
9.	c)	Nuclear fusion	10.	b)	8,4
11.	a)	Kalpakkam	12.	b)	(i) and (ii) are correct

II. Fill in the blanks

1. One roentgen is equal to _____ disintegrations per second. ★★
2. Positron is an_____.
3. Anemia can be cured by _____ isotope. ★
4. Abbreviation of ICRP_____
5. _____is used to measure exposure rate of radiation in humans.
6. _____ has the greatest penetration power.
7. ${}_ZY^A \rightarrow {}_{Z+1}Y^A + X$; then X is _____.
8. ${}_ZX^A \rightarrow {}_ZY^A$. This reaction is possible in _____ decay.
9. The average energy released in each fusion reaction is about _____ J. ★
10. Nuclear fusion is possible only at an extremely high temperature of the order of _____ K. ★★
11. The radio isotope of _____ helps to increase the productivity of crops.
12. If the radiation exposure is 100 R, it may cause _____.

Ans:

1.	3.7×10^{10}	2.	positive charge electron, $_{+1}e^{0}$
3.	Radio- Iron (Fe^{59})	4.	International Commision on Radiological production
5.	Dosimetre	6.	Gamma rays
7.	$_{-1}e^{0}$	8.	gamma
9.	3.84×10^{-12} J	10.	10^{7} to 10^{9}
11.	P-32	12.	Leukemia

III. State whether the following statements are true or false. If false, correct the false statement.

1. **Plutonium -239 is a fissionable material.** **True**

2. **Elements having atomic number greater than 83 can undergo nuclear fusion.** **False**

   Element having atomic number greater than 83 can undergo nuclear **fission.**

3. **Nuclear fusion is more dangerous than nuclear fission.** **False**

   Nuclear fission is more dangerous than nuclear **fusion.** (However fusion produces more heat energy than fission, fission reaction emits harmful radiation)

4. **Natural uranium U-238 is the core fuel used in a nuclear reactor.** **False**

   Natural uranium **U-235** is the core fuel used in a nuclear reactor.

5. **If a moderator is not present, then a nuclear reactor will behave as an atom bomb.** **False**

   If a **control rod** is not present, then a nuclear reactor will behave as an atom bomb.

6. **During one nuclear fission on an average, 2 to 3 neutrons are produced.** **True**

7. **Einstein's theory of mass energy equivalence is used in nuclear fission and fusion.** **True**

IV. Match the following

1. 1) BARC - a) Kalpakkam (c)
   2) India's first atomic power station - b) Apsara (d)
   3) IGCAR - c) Mumbai (a)
   4) First nuclear reactor in India - d) Tarapur (b)

2. 1) Fuel - a) Lead (d)
   2) Moderator - b) Heavywater (b)
   3) Coolant - c) Cadmium rods (e)
   4) Shield - d) Uranium (a)
   5) Control rods - e) Graphite (c)

3. 1) Soddy Fajan - a) Natural radioactivity (b)
   2) Irene Curie - b) Displacement Law (d)
   3) Henry bequerel - c) Mass energy equivalence (a)
   4) Albert Einstein - d) Artificial Radioactivity (c)

4. 1) Uncontrolled fission reaction - a) Hydrogen Bomb (d)
   2) Fertile material - b) Nuclear Reactor (c)
   3) Controlled fission reaction - c) Breeder reactor (b)
   4) Fusion reaction - d) Atom bomb (a)

5. 1) Co-60 - a) Age of fosil (c)
   2) I-131 - b) Function of heart (d)
   3) Na-24 - c) leukemia (b)
   4) C-14 - d) Thyroid disease (a)

V. Arrange the following in the correct sequence:

1. **Arrange in descending order, on the basis of their penetration power**
   Alpha rays, beta rays, gamma rays, cosmic rays
   Ans: Cosmic rays, gamma rays, beta rays, alpha rays.

2. **Arrange the following in the chronological order of discovery**
   Nuclear reactor, radioactivity, artificial radioactivity, discovery of radium.
   Ans: Radioactivity (1896), discovery of radium(1898), artificial radioactivity (1934), Nuclear reactor(1942)

VI. Use the analogy to fill in the blanks

1. Spontaneous process : Natural Radioactivity
   Induced process : _____

2. Nuclear fusion : Extreme temperature
   Nuclear fission : _____

3. Increasing crops : Radio phosphorous
   Effective functioning of heart : _____

4. Deflected by electric field : Alpha ray
   Null deflection : _____

Ans:

1.	Artificial radioactivity	2.	Room Temperature
3.	Radio Sodium	4.	Gamma rays

VII. Numerical problems:

1. $_{88}Ra^{226}$ experiences three α - decay. Find the number of neutrons in the daughter element.

Solution:

When an alpha particle emitted atomic number decreases by two, mass number decreases by four. Now three alpha particles emitted, atomic number decreases by six, mass number decreases by twelve.

$$_{88}Ra^{226} \longrightarrow {}_{82}X^{214} + 3\ {}_{2}He^{4}$$

A = 214 Z = 82

Number of neutrons in the daughter element N = A – Z

N = 214 – 82

N = 132

2. A cobalt specimen emits induced radiation of 75.6 millicurie per second. Convert this disintegration into becquerel (one curie = 3.7×10^{10} Bq)

Solution:

1 curie = 3.7×10^{10} Bq

1 milli curie = $3.7\times 10^{10}\times 10^{-3}$ Bq

75.6 milli curie = $75.6\times 3.7\times 10^{10-3}$ Bq

$= 279.72\times 10^{7}$ Bq

75.6 millicurie = **2.80×10^{9} Bq**

VIII. Assertion and reason type questions

Mark the correct choice as

a) If both the assertion and the reason are true and the reason is the correct explanation of the assertion.

b) If both the assertion and the reason are true, but the reason is not the correct explanation of the assertion.

c) Assertion is true, but the reason is false.

d) Assertion is false, but the reason is true.

1. **Assertion:** A neutron impinging on U^{235}, splits it to produce Barium and Krypton.
Reason: U - 235 is a fissile material.

Ans: a) If both the assertion and the reason are true and the reason is the correct explanation of the assertion.

2. **Assertion:** In a β - decay, the neutron number decreases by one.
Reason: In β - decay atomic number increases by one.

Ans: b) If both the assertion and the reason are true, but the reason is the correct explanation of the assertion.

3. **Assertion:** Extreme temperature is necessary to execute nuclear fusion.
Reason: In a nuclear fusion, the nuclei of the reactants combine releasing high energy.

Ans: b) If both the assertion and the reason are true, but the reason is not the correct explanation of the assertion.

4. **Assertion:** Control rods are known as neutron seeking rods.
Reason: Control rods are used to perform sustained nuclear fission reaction

Ans: a) If both the assertion and the reason are true and the reason is the correct explanation of the assertion.

IX. Answer in one or two words (VSA)

1. **Who discovered natural radioactivity?** ✶ ✶
Ans: Henry Becquerel
2. **Which radioactive material is present in the ore of pitchblende?**
Ans: Radium.
3. **Write any two elements which are used for inducing radioactivity**
Ans: Boron,Aluminium
4. **Write the name of the electromagnetic radiation which is emitted during a natural radioactivity.**
Ans: gamma radiation
5. **If A is a radioactive element which emits an alpha particle and produces $_{104}Rf^{259}$ write the atomic number and mass number of the element A.** ✶ ✶
Ans: Atomic number:106 ; Mass number 263 [In alpha decay atomic number decrease by two and mass number decrease by four]
6. **What is the average energy released from a single fission process?**
Ans: The average energy released from a single process is 200MeV=3.2× 10^{-11} J
7. **Which hazardous radiation is the cause for the genetic disease?**
Ans: Gamma Radiation
8. **What is the amount of radiation that may cause death of a person when exposed to it?** ✶ ✶
Ans: 600 R.
9. **When and where was the first nuclear reactor built ?**
Ans: 1942, Chicago,USA; 1956, Mumbai.
10. **Give the SI unit of radioactivity**
Ans: Becquerel.
11. **Which material protects us from radiation?**
Ans: Lead

X. Answer the following questions in few sentences.

1. **Write any three features of natural and artificial radioactivity.** ✶ ✶

Natural radioactivity:

- Emission of radiation due to self-disintegration of a nucleus
- Exhibited by elements with atomic number more than 83
- This cannot be controlled

Artificial radioactivity:

- Emission of radiation due to disintegration of a nucleus through induced process.
- Exhibited by elements with atomic number less than 83
- This can be controlled

2. Define critical mass.

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

3. Define one roentgen. ✶ ✶

It is the quantity of radioactive substances which produces a charge of **2.58× 10^{-4} coulombs** in 1 kg of air under standard conditions of pressure, temperature and humidity.

4. State Soddy and Fajan's displacement law. ✶ ✶

- When a parent element emits an **alpha particle** the new element is formed with a decrease in atomic number by two and **mass number** by **four**.
- When a parent nucleus emits a **beta particle** the daughter nucleus is formed with an increase in **atomic number** by **one** and has **same mass number** of the parent nucleus.
- In gamma decay, the energy level of **nucleus only changes**. No new elements are formed.

5. Give the function of control rods in a nuclear reactor.

- The control rods are used to **control the chain reaction** as they are very good **absorbers of neutrons.**
- By pushing in and pulling out, the reaction rate can be controlled.

6. In Japan, some of the new born children are having congenital diseases. Why? ✶ ✶

- The nuclear bomb dropped during World War II emitted gamma radiation.
- Gamma rays caused injury to genes in the reproductive cells.
- This gives rise to mutations which pass on from generation to generation.

7. Mr. Ramu is working as an X - ray technician in a hospital. But, he does not wear the lead aprons. What suggestion will you give to Mr. Ramu?

- Radiation emitted by the X-ray machine can easily passes through our body and can cause genetic diseases.
- These have been passed by genetic diseases from generation to generation.
- When the emitted radiation is so high, it leads to death. So Mr. Ramu must wear the lead aprons.

8. What is stellar energy?

Fusion reaction that takes place in the cores of the Sun and other stars results in an **enormous** amount of **energy**, called stellar energy.

9. Give any two uses of radio isotopes in the field of agriculture. ✶ ✶

- To increase the productivity of crops
- Remains fresh beyond their normal life time

XI. Answer the following questions in detail:

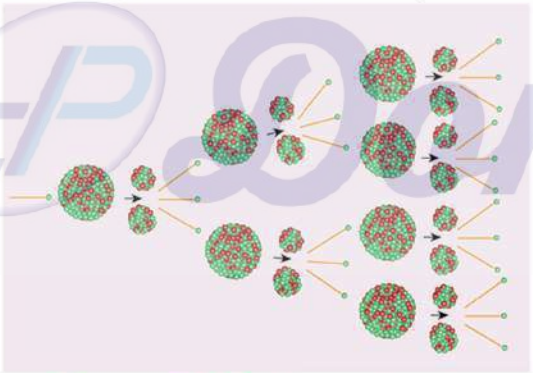
1. Explain the process of controlled and uncontrolled chain reactions.

(a) Controlled chain reaction:

- In the controlled chain reaction the number of **neutrons released is maintained** to be **one**.
- This is achieved by **absorbing** the **extra neutrons** with a **neutron absorber** leaving only one neutron to produce further fission.
- Thus, the reaction is sustained in a controlled manner.
- The energy released due to a controlled chain reaction can be utilized for constructive purposes.
- Controlled chain reaction is used in a nuclear reactor to produce energy in a sustained and controlled manner.

(b) Uncontrolled chain reaction:

- In the uncontrolled chain reaction the number of neutrons multiplies **indefinitely** and causes fission in a **large amount** of the fissile material.
- This results in the release of a **huge amount** of **energy** within a fraction of a second.
- This kind of chain reaction is used in the **atom bomb** to produce an explosion.



Uncontrolled chain reaction

2. Compare the properties of alpha, beta and gamma radiations. ★★★

Properties	α - ray	β - ray	γ - ray
What are they?	**Helium nucleus** ($_2He^4$) consisting of two protons and two neutrons.	They are **electrons** ($_{-1}e^0$), basic elementary particle in all atoms.	They are electromagnetic waves consisting of **photons**.
Charge	**Positively** charged particles. Charge of each alpha particle = +2e	**Negatively** charged particles. Charge of each beta particle = –e	**Neutral** particles. Charge of each gamma particle = zero
Ionising power	**100 times** greater than β rays and **10,000 times** greater than γ rays	Comparatively **low**	**Very less** ionization power

Properties	α - ray	β - ray	γ - ray
Penetrating power	**Low** penetrating power (even stopped by a thick paper)	Penetrating power is **greater** than that of α rays. They can penetrate through a thin metal foil.	They have a **very high** penetrating power greater than that of β rays. They can penetrate through thick metal blocks.
Effect of electric and magnetic field	Deflected by **both the fields.** (in accordance with Fleming's left hand rule)	Deflected by both the fields; but the direction of deflection is **opposite** to that for alpha rays. (in accordance with Fleming's left hand rule)	They are **not deflected** by both the fields.
Speed	Their speed ranges from **1/10 to 1/20** times the speed of light.	Their speed can go up to **9/10** times the speed of light.	They travel with the **speed of light .**

3. What is a nuclear reactor? Explain its essential parts with their functions. ★★★

- A nuclear reactor is a device in which the nuclear fission reaction takes place in a self sustained and controlled manner.

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:

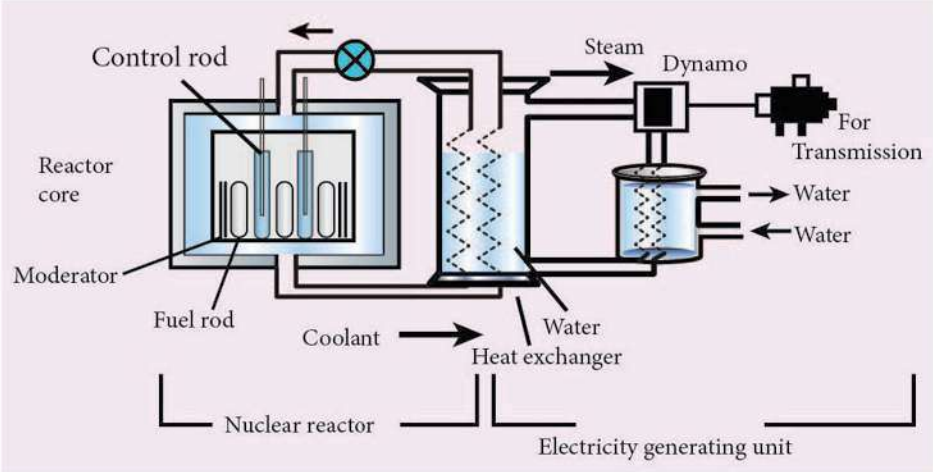
- Control rods are used to control the number of neutrons in order to have sustained chain reaction.
- Mostly boron or cadmium rods are used as control rods. They absorb the neutrons.

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.



Schematic diagram of a nuclear reactor

XII. Higher Order Thinking Skills (HOTS)

1. Mass number of a radioactive element is 232 and its atomic number is 90. When this element undergoes certain nuclear reactions, it transforms into an isotope of lead with a mass number 208 and an atomic number 82. Determine the number of alpha and beta decay that can occur.

In alpha decay atomic number decreases by two and mass number decreases by four. So

$232 - 208 = 24$

Mass number decreased by 24. So 6 alpha particle would come out.

$${}_{90}X^{232} \rightarrow {}_{78}Y^{208} + 6\ {}_{2}He^{4}$$

In beta decay atomic number increases by one

$78 + 4 = 82$

So, 4 beta particle would come out.

$${}_{78}Y^{208} \rightarrow {}_{82}Z^{208} + 4\ {}_{-1}e^{o}$$

So, six alpha particle and four beta particles would come out.

2. 'X – rays should not be taken often'. Give the reason.

- The intensity of radiation used in X-ray machine is small , so the chance that X-ray will cause severe problems is very low.
- X-ray posses almost equal energy like gamma radiation.
- So, if we take often, it may destructive living cell present in our body.
- It may leads to cancer.

3. Cell phone towers should be placed far away from the residential area – why?

- Cell phone companies are used non-ionised radiations.
- It is not harmful like X-ray or gamma radiation.
- In 2006 report issued by the WHO, human body absorbs energy from cell phone towers which is almost five times more than FM and Television.
- Signals from each mobile towers travels few miles from there.
- The closer we are the greater the danger.

Additional Questions

I. Choose the most suitable answer from the given four alternatives and write the option code and corresponding answer:

1. **Cathode rays contains**
   a) proton b) electron c) neutron d) positron

2. **Pitch blende is an ore of**
   a) Uranium b) Radium c) Plutonium d) Alumium

3. **$_4Be^9 + _2He^4 \rightarrow _6C^{12} + _0n^1$ Which is a projectile in above equation?** ✶
   a) $_4Be^9$ b) $_6C^{12}$ c) $_0n^1$ d) $_2He^4$

4. **Arrange the following rays in ascending order according to the ionizing power**
   i) Alpha ii) Beta iii) Gamma
   a) Gamma, Beta, Alpha b) Alpha, Beta, Gamma
   c) Gamma, Alpha, Beta d) Alpha, Gamma, Beta

5. **Which of the following is the heaviest one?**
   a) Hydrogen b) Alpha
   c) Beta d) Gamma

6. **New elements do not formed in**
   a) Alpha decay b) Beta decay
   c) Gamma decay d) All of these

7. **Reason for nuclear fission to be a chain reaction is**
   a) 200 MeV energy is produced
   b) two smaller nuclei formed
   c) 2 or 3 neutron are formed for further reaction
   d) all of these

8. **In a chain reaction, rate of production of neutrons must be more than the rate of its loss is a**
   a) Critical level b) Supercritical level
   c) Subcritical level d) both (a) and (c)

9. **eV is a unit of**
   a) radioactivity b) critical mass
   c) energy released in nuclear fission d) radiation

10. **Positrons are** ✶
    a) electron charge but proton mass b) electron charge but neutron mass
    c) proton charge but neutron mass d) proton charge but electron mass

11. **Isotope of _____ element is used to age of old oil painting**
    a) Carbon b) Californium b) Americium d) Phosphorous

12. **The safe limit of receiving the radiation is about**
    a) 1 R b) 0.1 R c) 100 R d) 10 R

13. **In a nuclear reactor, boron is used as**
    a) fuel b) moderator
    c) control rod d) protection wall

14. **Nuclear reactor is used for** ★
    a) to generate electricity b) to produce radio isotopes
    c) to do research in nuclear physics d) all the above

15. **$_{Z}X^{A}$, is a atom which releases two alpha rays and followed by two beta rays, now atomic number and mass number of daughter nucleus**
    a) Z – 8, A–8 b) Z – 4, A–8 c) Z – 2, A–8 d) Z – 4, A–6

Ans:

1.	b)	electron	2.	b)	Radium
3.	d)	$_{2}He^{4}$	4.	a)	gamma,beta, alpha
5.	b)	alpha	6.	c)	gamma decay
7.	c)	2 (or) 3 neutron are formed for further reaction	8.	b)	supercritical level
9.	c)	Energy released in nuclear fission	10.	c)	Proton charge but electron mass
11.	a)	Carbon	12.	b)	0.1 R
13.	c)	Control rod	14.	d)	All the above
15.	c)	Z - 2, A - 8			

II. Fill in the blanks

1. **Proton is discovered by _____.**
2. **When alpha particle is bombarded with Beryllium _____ isthe ejected particle we get.** ★
3. **1 million Becquerel is called as _____.**
4. **Charge of an alpha particle is _____ times of charge of a Beta particle.**
5. **In a gamma decay _____ of the parent nucleus changes.**
6. **In natural uranium, _____ % of uranium is fissile material.**
7. **Nuclear chain reaction is controlled by _____.**
8. **In atom bomb, the mass of fuel is kept in _____ level.**
9. **The energy released in a nuclear fission process is about _____ MeV.**
10. **The ejected particle in nuclear fission is _____.** ★
11. **_____ radio isotope used to increase the productivity of crops as well as in treatment of skin diseases.** ★
12. **Helium is used as _____ in nuclear reactor.**

13. First reactor in Tamilnadu was built in _____.
14. 1 kg mass converted in to _____ J in a nuclear reactions.
15. Nucleus of Helium is also known as _____ rays. ✱

Ans:

1.	Goldstein	2.	Neutron
3.	Rutherford	4.	two
5.	Energy level	6.	0.72
7.	Absorbing the extra neutrons	8.	Sub-critical
9.	200	10.	Neutron
11.	Phosphorous	12.	Coolant
13.	Kalpakkam	14.	9×10^{16}
15.	Alpha		

III. State whether the following statements are true or false. If false, correct the false statement.

1. **The charge of an atom is concentrated in its central part** — **False**
   The **mass** of an atom is concentrated in its central part.
2. **In a radioactivity, only harmful radiations emitted.** — **False**
   In a radioactivity, harmful **radiations and elementary particles** are emitted.
3. **In a natural radioactivity, spontaneous emission of radiation takes place** — **True**
4. **1 g of radium – 226 gives 37×10^{10} disintegrations per second** — **False**
   1 g of radium – 226 gives **3.7×10^{10}** disintegrations per second
5. **Gamma rays are electromagnetic radiation** — **True**
6. **Hydrogen has only one isotopes called deuterium.** — **False**
   Hydrogen has two isotopes called **deuterium and tritium**.
7. **Uranium core nuclear bomb was used in Nagasaki.** ✱ — **False**
   Plutonium core nuclear bomb was used in Nagasaki.
8. **Heavier nuclei participation in nuclear fission** — **True**
9. **Radio – Iodine (I^{131}) is used to cure goiter.** — **True**
10. **Fission materials changed into fertile materials in breeder reactors.** ✱ — **False**
    Fertile materials changed into **fission** materials in breeder reactors

IV. Match the following

1. 1) J.J.Thomson - a) neutrons (b)
   2) Goldstein - b) electrons (d)
   3) Chadwick - c) nucleus (a)
   4) Rutherford - d) protons (c)

2. 1) Alpha rays - a) negative particles ★ (d)
   2) Beta rays - b) electromagnetic radiation (a)
   3) Gamma rays - c) positive electron (b)
   4) Positron - d) nucleus of Helium (c)

V. Arrange the following in the correct sequence:

1. **Arrange the following nuclear power plants in the chronological order of constructed**
   Kalpakkam power station, Chicogo power station, Kudankulam power station, Tarapur power station.
   Ans: Chicogo power station, Tarapur power station, Kalpakkam power station, Kudankulam power station

2. **Arrange the following process in an atom bomb in explosion.**
   supercritical mass, radiation emitted , subcritical mass, Conventional explosive used
   Ans: Subcritical mass, Conventional explosive used, supercritical mass, radiation emitted.

VI. Use the analogy to fill in the blanks:

1. Traditional unit of radioactivity : Curie
   SI unit of radioactivity : _____
2. Nuclear fission : Splitting of heavier nucleus
3. Detect the explosives in the luggage : Californium
   Smoke 0detector : _____
4. Unit of charge : coulomb
   Unit of energy in atomic level : _____

Ans:

1.	Becquerel	2.	Adding the smaller nuclei
3.	Americium	4.	eV

VII. Assertion and reason type questions

Mark the correct choice as

a) If both the assertion and the reason are true and the reason is the correct explanation of the assertion.
b) If both the assertion and the reason are true, but the reason is not the correct explanation of the assertion.
c) Assertion is true, but the reason is false.
d) Assertion is false, but the reason is true.

1. **Assertion:** Natural radioactivity radiates alpha, beta and gamma rays.
   Reason: They can be controlled.
   Ans: c)Assertion is true, but the reason is false.

2 **Assertion:** Gamma rays are not deflected by electric field.
Reason: Charge of gamma rays is zero.

Ans: a) If both the assertion and the reason are true and the reason is the correct explanation of the assertion.

3. **Assertion**: In supercritical mass, nuclear fission does not take place.
Reason: In atom bombs, fuel is kept at subcritical mass.

Ans: d) Assertion is false, but the reason is true.

4. **Assertion:** Hydrogen bomb itself contains a small atom bomb to start fusion reaction.
Reason: Extremely high temperature and pressure is needed for fusion reaction.

Ans: a) If both the assertion and the reason are true and the reason is the correct explanation of the assertion

VIII. Answer in one or two words (VSA)

1. **Name some elementary particles in atom.**
Ans: Photon, Meson, Positron and Nutrino

2. **Name the two elements of natural radioactive elements with atomic number less than 83.**
Ans: Technetium -43, promethium -61

3. **Which particle is used to bombard radioactive lighter elements for artificial radioactivity?**
Ans: Alpha particles

4. **What are the ejected particles in artificial radioactivity?**
Ans: Neutron, Positron.

5. **What is the relation between units Becquerel and Rutherford?**
Ans: 10^6 Becquerel =1 Rutherford

6. **Who discovered Uranium?**
Ans: Martin klaproth

7. **What is the maximum speed of beta particle?** ★
Ans: 2.7×10^8m/s [Hint: $\frac{9}{10}\times 3\times 10^8 = \frac{27}{10}\times 10^8 = 2.7\times 10^8$m/s]

8. **Write the average energy released in each fission process?**
Ans: 200meV $=3.2\times10^{-11}$ J.

9. **What causes the most destruction during the explosion of Atom bomb?**
Ans: Very high pressure produced during the time of explosion.

10. **Names the nuclear bombs used in Hiroshima and Nagasaki during World War II.**
Ans: Hiroshima –Little boy
Nagasaki –FAT man .

11. Principle of hydrogen bomb and atom bomb

Ans: Principle of hydrogen bomb-nuclear fusion reaction.

Principle of Atom bomb –controlled nuclear fission reaction.

12. Which isotope is used in the treatment of skin diseases ?

Ans: Radio Phosphorous -32

13. What is the safe limit of overall exposure to radiation of human body over a year?

Ans: 20 milli sievert

14. What is the use of helium in a nuclear reactor? ★

Ans: Coolant.

15. What happens to the atomic number of a parent nucleus when it undergoes an alpha and beta decay successively ?

Ans: Atomic number decrease by one

IX. Answer the following questions in few sentences.

1. Why does not natural radioactivity take place elements which have atomic number less than 83?

- Lighter elements have greater nuclear force.
- This force holds nucleons within the nucleus. So no radiation comes out from lighter elements.

2. Why does mean $_{13}Al^{27}$ (α ,n) $_{15}P^{30}$? ★

Alpha particle is used as projectile towards $_{13}Al^{27}$ and we get $_{15}P^{30*}$ and a neutron (i.e)

$$_{13}Al^{27} + {}_2He^4 \rightarrow {}_{15}P^{30*} + {}_0n^1$$

3. What is mass defect?

- In a nuclear reaction, there is a difference in total mass of reactants and total mass of products.
- This difference in mass is called mass defect.

4. A radioactive nucleus 'A' undergo a series of given below.

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

- The atomic number and mass number of A_2 are 71 and 176 respectively.
- Determine the mass and atomic numbers of A_4 and A.
- In **α – decay atomic number decreases** by **two** and **mass number decreases** by **four**.
- In **β – decay atomic number alone increases** by **one**.
- In **gamma decay, no changes in both atomic and mass number.** So,

$$A \xrightarrow{\alpha} {}_{70}A_1^{176} \xrightarrow{\beta} {}_{71}A_2^{176} \xrightarrow{\alpha} {}_{69}A_3^{172} \xrightarrow{\gamma} A_4$$

$$_{72}A^{180} \xrightarrow{\alpha} {}_{70}A_1^{176} \xrightarrow{\beta} {}_{71}A_2^{176} \xrightarrow{\alpha} {}_{69}A_3^{172} \xrightarrow{\gamma} {}_{69}A_4^{172}$$

A_4 mass number 172

A_4 atomic number 69

A mass number 180

A atomic number 72

5. What is dosimeter? ✶

- It is a device used to **detect the levels of exposure** to an ionizing radiation.
- It is available in pocket size too.

6. How can you say nuclear energy is good source of energy?

- It **doesn't produce** any **harmful gases.**
- The fuel is **not a seasonal** one like windmill, hydro power station, etc.
- We can build nuclear reactors **near the sea/ocean.**

X. Answer the following questions in detail:

1. Differentiate natural radioactivity and artificial radioactivity. ✶

S.No	Natural Radioactivity	Artificial radioactivity
1	Emission of radiation due to **self disintegration** of a nucleus.	Emission of radiation due to **disintegration** of a nucleus through induced process.
2	**Alpha, beta and gamma** radiations are emitted.	**Mostly elementary particles such as neutron, positron,** etc. are emitted
3	It is a **spontaneous** process	It is an **induced** process.
4	Exhibited by elements with atomic number **more than 83.**	Exhibited by elements with atomic number **less than 83.**
5	This **cannot be controlled.**	This **can be controlled.**

2. Explain Alpha decay, beta decay and gamma decay with one suitable example for each.

Alpha decay:

- A nuclear reaction in which an unstable parent nucleus emits an alpha particle and forms a stable daughter nucleus, is called **'alpha decay'.**
- E.g.: Decay of **uranium (U^{238})** to **thorium (Th^{234})** with the emission of an alpha particle.
- $_{92}U^{238} \longrightarrow {}_{90}Th^{234} + {}_{2}He^{4}$ (α - decay)
- In α - decay, the parent nucleus emits an **α particle** and so it is clear that for the daughter nucleus, the mass number decreases by four and the atomic number decreases by two.

Beta decay:

- A nuclear reaction, in which an unstable parent nucleus emits a beta particle and forms a stable daughter nucleus, is called **'beta decay'.** E.g.: Beta decay of phosphorous. $_{15}P^{32} \longrightarrow {}_{16}S^{32} + {}_{-1}e^{0}$
- In β - decay there is **no change** in the mass number of the daughter nucleus but the atomic number increases by one.
- In a nuclear reaction, the element formed as the product nucleus is identified by the atomic number of the resulting nucleus and not by its mass number.

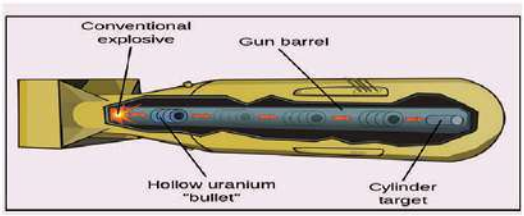
Gamma decay:

- In a γ - decay, only the energy level of the nucleus changes.
- The atomic number and mass number of the radioactive nucleus **remain the same.**
- $_{86}Rn^{222^{*}} \rightarrow {}_{86}Rn^{222} + \gamma$ – ray (0.187 MeV)

3. Explain structure and working of atom bomb with neat diagram. ★★

Structure:

- An atom bomb consists of a piece of **fissile material** whose mass is subcritical.
- This piece has a cylindrical void. It has a cylindrical fissile material which can fit into this void and its mass is also subcritical.
- When the bomb has to be exploded, this cylinder is injected into the void using a conventional explosive.
- The two pieces of fissile material join to form the supercritical mass, which leads to an explosion.



Atom bomb

- During this explosion tremendous amount of energy in the form of heat, light and radiation is released.
- A region of very high temperature and pressure is formed in a fraction of a second along with the emission of hazardous radiation like γ rays, which adversely affect the living creatures.
- This type of atom bombs were exploded in 1945 at Hiroshima and Nagasaki in Japan during the World War II.

4. Write the uses of radioactivity in the following fields.

i) Agriculture ii) Medicine

Agriculture :

- The radio isotope of **phosphorous (P-32)** helps to increase the **productivity of crops.**
- The radiations from the radio isotopes can be used to **kill the insects and parasites** and **prevent the wastage** of agricultural products.
- Certain perishable cereals exposed to radiations remain fresh beyond their normal life, **enhancing** the **storage time.**
- Very small doses of radiation **prevent sprouting and spoilage of** onions, potatoes and gram.

Medicine:

- Radio sodium (Na^{24}) is used for the effective **functioning of heart.**
- Radio – Iodine (I^{131}) is used to **cure goiter.**
- Radio-iron is (Fe^{59}) is used to **diagnose anaemia** and also to provide treatment for the same.
- Radio phosphorous (P^{32}) is used in the treatment of **skin diseases.**
- Radio cobalt (Co^{60}) and radio-gold (Au^{198}) are used in the treatment of **skin cancer.**
- Radiations are used to **sterilize the surgical devices** as they can kill the germs and microbes.

XI. Numerical problems:

1. The isotope of $_{92}U^{238}$ successively undergo two alpha decays and two beta decays. What is the atomic number and mass number of resulting daughter nuclei.

When an alpha decay, atomic number and mass number decreases by two and four respectively. In a beta decay, atomic number increases by one.

$$_{92}U^{238} \longrightarrow {}_{88}X^{230} + 2\ {}_{2}He^{4}$$

$$_{88}X^{230} \longrightarrow {}_{90}Y^{230} + 2\ {}_{-1}\beta^{0}$$

Atomic number of resulting daughter nucleus: **90**

Mass number of resulting daughter nucleus: **230**

2. A substances undergo disintegration of two α decays and 3 β decays and formed $_{83}X^{206}$. Find the atomic number and mass number of parent nucleus.

In beta decay atomic number decreases by one

$$_{83}X^{206} + 3\ {}_{-1}e^{0} = {}_{80}Y^{206}$$

In alpha decay atomic number increases by two and mass number decreases by four

$$_{80}Y^{206} + 2\ {}_{2}He^{4} \longrightarrow {}_{84}T^{214}$$

Atomic number of parent nucleus is **84**

Mass number of parent nucleus is **214**

XII. Higher Order Thinking Skills (HOTS)

1. Why do we need very high temperature to start nuclear fusion reaction?

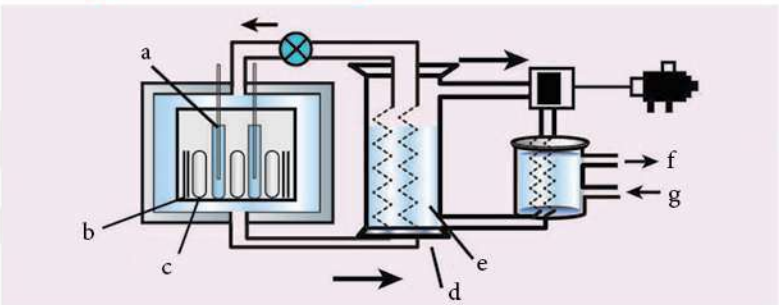
- When two lighter nuclei comes closer, they repel due to electrostatic force (force between two charges).
- We need high energy to overcome this force, so that two lighter nuclei fuse together and form a single nucleus.

2. How can you say artificial radioactivity is controlled?

- Artificial radioactivity occurs only when a projectile particle is bombarded with some lighter elements.
- So when we stop projectile particle, radioactivity stops.

XIII. Label the parts

1. Redraw the diagram and label the parts.



Unit Test - 6

Nuclear Physics

Time : 1 hr **Marks : 30**

I. Choose the most suitable answer and write the code with the corresponding answer. 5 × 1 = 5

1. Unit of radioactivity is _____
   a) Roentgen b) Curie c) Becquerel d) All the above
2. Artificial radioactivity was discovered by _____
   a) Becquerel b) Irene Curie c) Roentgen d) Neils Bohr
3. Proton - Proton chain reaction is an example of _____
   a) Nuclear fission b) α - decay c) Nuclear fusion d) β - decay
4. ${}_4Be^9 + {}_2He^4 \rightarrow {}_6C^{12} + {}_0n^1$ Which is a projectile in above equation?
   a) ${}_4Be^9$ b) ${}_6C^{12}$ c) ${}_0n^1$ d) ${}_2He^4$
5. ${}_ZX^A$, is a atom which releases two alpha rays and followed by two beta rays, now atomic number and mass number of daughter nucleus
   a) Z – 8, A–8 b) Z – 4, A–8 c) Z – 2, A–8 d) Z – 4, A–6

II. Answer the following questions in one or two lines. 5 × 2 = 10

1. ${}_{88}Ra^{226}$ experiences three α - decay. Find the number of neutrons in the daughter element.
2. A cobalt specimen emits induced radiation of 75.6 millicurie per second. Convert this disintegration into becquerel (one curie = 3.7×10^{10} Bq)
3. Define one roentgen.
4. Give the function of control rods in a nuclear reactor.
5. Give any two uses of radio isotopes in the field of agriculture.

III. Answer the following questions in brief: 2 × 4 = 8

1. Differentiate natural radioactivity and artificial radioactivity.
2. i) Give the function of control rods in a nuclear reactor.
   ii) What is dosimeter?

IV. Answer the following questions in detail: 1 × 7 = 7

1. i) What is thermonuclear reaction? Why is nuclear fusion reaction called as thermonuclear reaction?
   ii) Write the uses of radio activity in agriculture.