

Radioactivity

Introduction

- Radioactivity was discovered by a French physicist **Henry Becquerel** in 1896.
- The term radioactivity was given by **Marie Curie**, the scientist who got Nobel Prize twice for physics and chemistry.
- The spontaneous emission of invisible radiation by some elements due to the splitting of their nucleus is called **radioactivity**.
- The invisible rays emitted by radioactive elements consist of
 - Alpha (α) particles** i.e., ${}^4_2\text{He}^{2+}$ (+2 unit charge and mass four units). They are deflected towards negative plate in electric field.
 - Beta (β) particles** i.e., electrons (-1 charge and mass zero). They are deflected towards positive plate in electric field.
 - Gamma (γ) rays** (no charge and no mass). They are not deflected from their path in electric or magnetic field. They are electromagnetic radiations. **Emission of γ -rays is the secondary effect of radioactive change.**
- Stable nuclei are those for which number of neutrons and protons are equal.
- Isotopes of all the known elements with $Z > 83$ are radioactive.
- Soddy and Fajan's group displacement law is used to determine group of the daughter element.**
- The time taken by half of the atoms of a radioactive element to disintegrate is called its **half-life**.
- The unit of half life period is time⁻¹.

Note X-rays were discovered by Roentgen in 1896. These are electromagnetic waves of very short wavelength and are used to detect cracks in fractured bones.

Nuclear Fission

The splitting of a heavy nucleus into two smaller almost equal nuclei along with the production of two or three neutrons and about 200 MeV of energy is called "nuclear fission". Nuclear fission was discovered by 'Hahn' and 'Strassmann' in 1939.

- Atom bomb** is the result of uncontrolled nuclear fission.

- The device in which controlled nuclear fission is carried out is called **nuclear reactor**. The fission is controlled by absorbing neutrons by using cadmium or boron rods. Heavy water (D_2O , mol. wt. 20) and graphite is used for slowing down the fast moving neutrons. U^{235} is used as a nuclear fuel.

Nuclear Fusion

The union of lighter nuclei to form a big nucleus is called the **nuclear fusion**. Nuclear fusion is also accompanied by release of energy because the total mass of products is lesser than total mass of reactants.

- Nuclear fusion occurs only at extremely high temperature ($> 10^6\text{K}$), so it is also called **thermo-nuclear reaction**.
- Hydrogen bomb** is the result of nuclear fusion. It contains a mixture of deuterium oxide (D_2O) and tritium oxide (T_2O) in a space surrounding an ordinary atom bomb.
- Source of solar and stellar energy is nuclear fusion.**

Applications of Radioisotopes

- Radio carbon dating is used to determine age of dead specimen with C^{14} content by comparing it with C^{12} content.

$$N = N_0 \left(\frac{1}{2} \right)^n$$

where, n = total time/ $t_{1/2}$.

- Rock dating or uranium dating is used to determine the age of rocks or earth. It is based on Pb and U ratio.

Uses of Radioisotopes

Radioisotope	Uses
${}^{131}_{53}\text{I}$ (Iodine-131)	(i) To study the structure and activity of thyroid gland. (ii) For the treatment of thyroid disease.
${}^{123}_{53}\text{I}$ (Iodine-123)	Brain imaging.
Co^{60} (Cobalt-60)	Treatment of cancer.
Na^{24} (Sodium-24)	To trace flow of blood.
P^{32} (Phosphorus-32)	For leukemia therapy.
C-14 (Carbon-14)	To study the kinetics of photosynthesis.

Exercise

1. Which one of the following is heavy water used in nuclear reactor? (CDS 2009 I)

(a) Water having molecular weight 18 u
(b) Water having molecular weight 20 u
(c) Water at 4°C but having molecular weight 19 u
(d) Water below the ice in a frozen sea

2. A nuclear reactor produce nuclear energy by
(a) nuclear fusion
(b) spontaneous fission
(c) uncontrolled chain reaction
(d) controlled chain reaction

3. The light emitted by firefly is due to (CDS 2009 II)
(a) a radioactive substance (b) chemiluminescence process
(c) a photoelectric process (d) burning of phosphorus

4. The α -particles are
(a) high energy electrons
(b) positively charged hydrogen ions
(c) high energy X-ray radiations
(d) double positively charged helium nuclei

5. In which categories did Marie Curie win her two different Nobel Prizes? (CDS 2007 I)
(a) Physics and Chemistry (b) Chemistry and Medicine
(c) Physics and Medicine (d) Chemistry and Peace

6. Which of the following isotopes of carbon is/are used in carbon dating? (CDS 2007 II)
(a) ${}^6\text{C}^{12}$ only (b) ${}^6\text{C}^{13}$ only
(c) ${}^6\text{C}^{14}$ only (d) ${}^6\text{C}^{12}$ and ${}^6\text{C}^{14}$

7. Consider the following statements.

- Gamma rays are not constituents of nuclei but they are emitted when a nucleus in an excited state returns to its normal state.
- The neutron to proton ratio for stable nuclei is always less than one.
- Beta rays consist of ordinary electrons which are of nuclear origin but do not revolve in orbits.
- X-rays and gamma rays are electromagnetic radiation.

Which of the above statements are correct?

(a) 2, 3, 4 (b) 1, 3, 4
(c) 1, 2, 4 (d) 1, 2, 3

8. Consider the following statements.

In nuclear power reactors

- uranium-235 is used as the fission material.
- graphite is used as a moderator.
- rods of lead are used to control the rate of nuclear reaction.

Which of the above statements are correct?

(a) 1 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1, 2 and 3

9. Hydrogen bomb is based on the principle of
(a) nuclear fission (b) nuclear fusion
(c) natural radioactivity (d) artificial radioactivity

10. In nuclear reactors the speed of neutrons is slowed down by

(a) heavy water (b) ordinary water
(c) zinc rods (d) molten caustic soda

11. The fuel in atomic pile is
(a) carbon (b) sodium
(c) petroleum (d) uranium

12. In atomic reactors, graphite is used as
(a) lubricant (b) fuel
(c) linear of the reactor (d) moderator

13. In treatment of cancer, which of the following is used?
(a) ${}^{131}\text{I}_{53}$ (b) ${}^{32}\text{P}_{15}$ (c) ${}^{60}\text{Co}_{27}$ (d) ${}^2\text{H}_1$

14. In nuclear reactor, chain reaction is controlled by introducing
(a) cadmium rod (b) iron rod
(c) platinum rod (d) graphite rod

15. Which one among the following has been producing/can produce light by a chemical change? (CDS 2007 II)
(a) Sun (b) Moon
(c) Electric bulb (d) Lightning and thunder

16. Gamma rays have
(a) zero mass and no charge
(b) zero mass and positive charge
(c) unit mass and zero charge
(d) unit mass and negative charge

17. Which of the following particles cannot be accelerated?
(a) Electrons (b) α -particles
(c) Neutrons (d) Protons

18. Which one of the following is not needed in a nuclear fission reactor? (CDS 2010 II)
(a) Moderator (b) Coolant
(c) Accelerator (d) Control device

19. The energy generation in stars is
(a) mainly due to the fusion of heavy nuclei
(b) mainly due to the fusion of light nuclei
(c) solely due to the fusion of heavy nuclei
(d) due to both fission and fusion of light nuclei

20. Match the Column I and Column II and select the correct answer using the codes given below the Columns.

Column I (Nuclear reactor component)	Column II (Substance used)
A. Moderator	1. Uranium
B. Control rod	2. Graphite
C. Fuel rods	3. Boron
D. Coolant	4. Lead
	5. Sodium

Codes

A	B	C	D	A	B	C	D
(a) 2	1	3	5	(b) 2	3	1	5
(c) 3	2	1	5	(d) 3	4	1	2

21. 'Yellow cake' an item of smuggling across border is
(a) a crude form of heroin (b) a crude form of cocaine
(c) uranium oxide (d) unrefined gold

22. The difference between a nuclear reactor and atomic bomb is that
- no chain reaction takes place in nuclear reactor while in the atomic bomb there is a chain reaction
 - the chain reaction in nuclear reactor is controlled
 - the chain reaction in nuclear reactor, is not controlled
 - no chain reaction takes place in atomic bomb while it takes place in nuclear reactor

23. Match the Column I (radioisotope) with Column II, (medicinal use) and select the correct matching.

Column I	Column II
A. ^{60}Co	1. Leucaemia
B. ^{131}I	2. Anaemia
C. ^{59}Fe	3. Cancerous tumours
D. ^{32}P	4. Disorders of thyroid gland

Codes

A	B	C	D	A	B	C	D
(a) 3	4	1	2	(b) 1	2	3	4
(c) 3	4	2	1	(d) 4	3	2	1

24. Match Column I with Column II and select the correct answer using the codes given below the Columns.

Column I (Characteristics)	Column II (Particles)
A. Zero mass	1. Positron
B. Fractional charge	2. Neutrino
C. Fractional spin	3. Quark
D. Integral spin	4. Photon

Codes

A	B	C	D	A	B	C	D
(a) 2	3	1	4	(b) 3	2	4	1
(c) 2	3	4	1	(d) 3	2	1	4

25. An α -particle consists of which of the following?
(CDS 2007 II)

- 2 protons and 2 neutrons
- 1 protons and 1 electron
- 2 proton and 4 neutrons
- 1 protons and 1 neutron

Answers

- | | | | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1. (b) | 2. (d) | 3. (b) | 4. (d) | 5. (a) | 6. (d) | 7. (b) | 8. (b) | 9. (b) | 10. (a) |
| 11. (d) | 12. (d) | 13. (c) | 14. (a) | 15. (a) | 16. (a) | 17. (c) | 18. (c) | 19. (b) | 20. (b) |
| 21. (c) | 22. (b) | 23. (c) | 24. (a) | 25. (a) | | | | | |

Hints and Solutions

- Heavy water (D_2O) is used in nuclear reactor as a moderator. The molecular weight of heavy water is 20 u. It is an oxide of deuterium which is an isotope of hydrogen.
- The light emitted by firefly is due to the presence of a specific organ and this incident is known as bioluminescence i.e., luminescence produced by a living organism.
- Marie Curie win her two different Nobel Prizes in two different category i.e., physics and chemistry for the discovery of radium and polonium.

- The isotope of carbon ${}^6\text{C}^{14}$ and ${}^6\text{C}^{12}$ are used in radio carbon dating.

- In a chemical change a new substance is formed and it is also a permanent change. Sun has been producing light by nuclear fusion and it is a chemical change.

