

Class: 12th

Subject: Physics

Chapter 21: [NUCLEAR PHYSICS](#)

🔴 Important MCQs (From Summary)

1. Mass number (A) of a nucleus is the total number of:

(a) Protons only

(b) Neutrons only

(c) Protons and neutrons ✓

(d) Electrons

2. The particles inside the nucleus are called:

(a) Nucleons ✓

(b) Ions

(c) Isotopes

(d) Electrons



3. Neutron number (N) of an atom is:

(a) Number of protons

(b) Number of electrons

(c) Number of neutrons ✓

(d) Mass number

4. Atomic number (Z) of an element represents:

(a) Number of neutrons

(b) Number of protons

(c) Total nucleons

(d) Mass of atom

5. Isotopes are atoms of the same element with:

(a) Same mass number, different Z

(b) Same Z, different mass number

(c) Different Z and mass number

(d) Same number of neutrons

6. Radioactivity occurs in elements having Z greater than:

(a) 20

(b) 50

(c) 82

(d) 92

7. In radioactive decay, the original element is called:

(a) Daughter element

(b) Parent element

(c) Isotope

(d) Nucleon

8. Half-life is the time in which:

(a) All atoms decay

(b) Half of the parent atoms decay

(c) Daughter atoms form completely

(d) Radiation stops

9. A nuclear reaction where a heavy nucleus splits into smaller nuclei is called:

-
- (a) Fusion
- (b) Fission
- (c) Radioactive decay
- (d) Alpha emission

10. A nuclear reaction where two light nuclei combine to form a heavier nucleus is called:

- (a) Fusion
- (b) Fission
- (c) Radioactive decay
- (d) Beta emission



11. The unit of radioactive activity is:

- (a) Gray
- (b) Becquerel

(c) Sievert

(d) Curie

12. 1 Curie (Ci) equals:

(a) 1 disintegration/sec

(b) 3.7×10^{10} disintegrations/sec ✓

(c) 1 Gy

(d) 0.01 Sv



13. Absorbed dose of radiation (D) is defined as:

(a) Energy absorbed per atom

(b) Energy absorbed per unit mass ✓

(c) Number of disintegrations per second

(d) Energy released per nucleon

14. Which of the following is NOT a basic force of nature?

-
- (a) Gravitational
 - (b) Electromagnetic
 - (c) Weak nuclear
 - (d) Friction

15. Subatomic particles are classified into:

- (a) Protons, neutrons, electrons
- (b) Hadrons, leptons, gauge bosons, Higgs boson
- (c) Alpha, beta, gamma
- (d) Molecules and atoms

 **Important MCQs:**

1. According to Rutherford's atomic model, the positive charge of an atom is concentrated in:

- (a) Electrons

(b) Orbits

(c) Nucleus

(d) Entire atom

2. Who first suggested the existence of a neutral particle inside the nucleus?

(a) J.J. Thomson

(b) Niels Bohr

(c) Ernest Rutherford

(d) James Chadwick



3. The neutron was discovered by:

(a) Ernest Rutherford

(b) Niels Bohr

(c) J.J. Thomson

(d) James Chadwick

4. Nearly how much of the atomic mass is concentrated in the nucleus?

(a) 50%

(b) 75%

(c) 90%

(d) 99.9%

5. The radius of an atom is about how many times larger than the radius of its nucleus?

(a) 10^2

(b) 10^3

(c) 10^4

(d) 10^5

6. The nucleus of an atom consists of:

-
- (a) Electrons only
- (b) Protons only
- (c) Neutrons only
- (d) Protons and neutrons

7. The charge on a proton is:

- (a) -1.6×10^{-19} C
- (b) 0
- (c) $+1.6 \times 10^{-19}$ C
- (d) $+1.6 \times 10^{-27}$ C



8. The charge on a neutron is:

- (a) Positive
- (b) Negative
- (c) Zero

(d) Variable

9. The masses of proton and neutron are:

(a) Very different

(b) Equal to electron mass

(c) Almost equal

(d) Zero

10. Which unit is commonly used to express atomic masses?

(a) Kilogram

(b) Gram

(c) Joule

(d) Unified atomic mass unit (u)

11. One unified atomic mass unit (1 u) is defined as:

(a) Mass of a proton

(b) Mass of a neutron

(c) One-twelfth the mass of a carbon-12 atom

(d) Mass of an electron

12. An atom is electrically neutral because:

(a) Neutrons have no charge

(b) The number of protons equals the number of electrons

(c) Only electrons are present

(d) Only protons are present

13. The atomic number (Z) of an element represents the number of:

(a) Neutrons

(b) Protons

(c) Electrons and neutrons

(d) Nucleons

14. The mass number (A) of an atom is equal to:

(a) Number of protons only

(b) Number of neutrons only

(c) Number of protons + electrons

(d) Number of protons + neutrons ✓

15. The number of neutrons (N) in a nucleus is given by:

(a) $N = Z - A$

(b) $N = A + Z$

(c) $N = A - Z$ ✓

(d) $N = Z / A$

16. How many neutrons are present in Uranium-235?

(a) 92

(b) 143

(c) 235

(d) 327

17. Isotopes of an element have the same:

(a) Mass number

(b) Number of neutrons

(c) Atomic number

(d) Atomic mass



18. How many isotopes of hydrogen exist?

(a) One

(b) Two

(c) Three

(d) Four

19. The nucleus of tritium contains:

- (a) One proton and no neutron
- (b) One proton and one neutron
- (c) Two protons and one neutron
- (d) One proton and two neutrons

20. Which instrument is used to separate isotopes and determine their masses?

- (a) Cyclotron
- (b) Spectrometer
- (c) Mass spectrograph
- (d) Microscope

21. The difference between the sum of the masses of nucleons and the actual mass of the nucleus is called:

- (a) Atomic mass

(b) Binding energy

(c) Mass defect

(d) Nuclear mass

22. Mass defect exists because the mass of a nucleus is:

(a) Greater than sum of nucleons

(b) Equal to sum of nucleons

(c) Less than sum of nucleons

(d) Independent of nucleons

23. The mass defect (Δm) of a nucleus is given by:

(a) $m_{\alpha} - (Z + A)$

(b) $Zm_{\alpha} - Am_{\alpha}$

(c) $Zm_{\alpha} + (A - Z)m_{\beta} - m_{\text{nucleus}}$

(d) $Am_{\alpha} - Zm_{\beta}$

24. The missing mass in a nucleus is converted into:

- (a) Momentum
- (b) Charge
- (c) Energy
- (d) Force

25. The relation connecting mass defect and binding energy is:

- (a) $E = mc$
- (b) $E = \Delta m / c^2$
- (c) $E = \Delta m c^2$
- (d) $E = m / c$

26. Binding energy of a nucleus is defined as the energy:

- (a) Released during radioactive decay

(b) Stored in electrons

(c) Required to break the nucleus into protons and neutrons



(d) Needed to remove electrons

27. For which element is the mass defect equal to zero?

(a) Helium

(b) Deuterium

(c) Hydrogen

(d) Uranium



28. The binding energy per nucleon is maximum for:

(a) Uranium

(b) Hydrogen

(c) Helium

(d) Iron

29. The approximate maximum value of binding energy per nucleon is:

(a) 2 MeV

(b) 5 MeV

(c) 8.8 MeV

(d) 15 MeV

30. One atomic mass unit (1 u) is equivalent to:

(a) 1.66×10^{-27} kg only

(b) 931 MeV only

(c) 1.66×10^{-27} kg and 931 MeV

(d) 9.11×10^{-31} kg

31. Elements having atomic number greater than which value are generally radioactive?

(a) 50

(b) 70

(c) 82

(d) 92

32. The phenomenon in which unstable nuclei emit radiations is called:

(a) Nuclear fusion

(b) Nuclear fission

(c) Radioactivity

(d) Ionization

33. Radioactivity was discovered by Henri Becquerel in the year:

(a) 1890

(b) 1896



(c) 1902

(d) 1911

34. Which element was used by Becquerel to discover radioactivity?

(a) Radium

(b) Polonium

(c) Thorium

(d) Uranium



35. Which of the following radiations is positively charged?

(a) Beta rays

(b) Gamma rays

(c) Alpha particles

(d) X-rays

36. Radiations that bend towards the positive plate are:

(a) Alpha particles

(b) Gamma rays

(c) Neutrons

(d) Beta particles

37. The radiations that are not deflected in an electric field are:

(a) Alpha rays

(b) Beta rays

(c) Gamma rays

(d) Protons

38. Alpha particles are actually:

(a) Electrons

(b) Protons

(c) Helium nuclei

(d) Photons

39. The charge and mass of an alpha particle are respectively:

(a) $+e$, $1u$

(b) $+2e$, $4u$

(c) $-e$, $1u$

(d) 0 , 0



40. Gamma rays are:

(a) Fast moving electrons

(b) Helium nuclei

(c) Protons

(d) Electromagnetic waves

41. When an alpha particle is emitted, the mass number of the nucleus:

(a) Increases by 4

(b) Decreases by 2

(c) Decreases by 4

(d) Remains unchanged

42. When a beta particle is emitted, the atomic number of the nucleus:

(a) Decreases by 1

(b) Increases by 1

(c) Decreases by 2

(d) Remains unchanged

43. Emission of gamma radiation causes the nucleus to:

-
- (a) Change mass number
 - (b) Change atomic number
 - (c) Change both A and Z
 - (d) Remain unchanged in A and Z

44. The time required for half of the radioactive atoms to decay is called:

- (a) Mean life
- (b) Decay constant
- (c) Half-life
- (d) Activity



45. After n half-lives, the fraction of radioactive atoms remaining is:

- (a) $(1/2)^n$
- (b) 2^n

(c) $n/2$

(d) $(1/2)^n$ ✓

46. The fixed distance travelled by an alpha particle in a medium before coming to rest is called:

(a) Penetration

(b) Path length

(c) Range ✓

(d) Track

47. The main mechanism by which charged particles lose energy in matter is:

(a) Reflection

(b) Diffraction

(c) Ionization ✓

(d) Polarization

48. Alpha particles produce intense ionization mainly because they:

- (a) Have no charge
- (b) Are very light
- (c) Are very massive compared to electrons
- (d) Travel in zigzag paths

49. Compared to alpha particles, beta particles have:

- (a) Greater ionizing power
- (b) Same range
- (c) About 100 times less ionizing power
- (d) No ionizing power

50. The path of beta particles in matter is:

- (a) Straight and continuous

-
- (b) Circular
 - (c) Erratic with frequent scattering
 - (d) Completely stationary

51. Gamma rays interact with matter at low energies mainly through:

- (a) Pair production
- (b) Compton scattering
- (c) Photoelectric effect
- (d) Nuclear fission



52. At photon energies greater than 1.02 MeV, the dominant interaction of gamma rays with matter is:

- (a) Photoelectric effect
- (b) Compton scattering
- (c) Fluorescence

(d) Pair production

53. Fluorescence is the property of a substance to:

(a) Emit high-frequency radiation

(b) Absorb low-frequency radiation

(c) Absorb high-frequency radiation and emit visible light

(d) Reflect radiation

54. Which radiation detector makes visible tracks of ionizing particles?

(a) Geiger counter

(b) Solid state detector

(c) Wilson cloud chamber

(d) Scintillation counter

55. In a Wilson cloud chamber, tracks are formed because vapours condense on:

-
- (a) Neutral atoms
 - (b) Electrons
 - (c) Ions produced along the particle path
 - (d) Nuclei

56. Thick, straight and continuous tracks in a cloud chamber are produced by:

- (a) Beta particles
- (b) Gamma rays
- (c) Alpha particles
- (d) Neutrons



57. The detector that produces identical output pulses irrespective of the particle energy is:

- (a) Solid state detector
- (b) Wilson cloud chamber

(c) Scintillation counter

(d) Geiger–Muller counter

58. The time during which a Geiger counter cannot record another particle is called:

(a) Response time

(b) Relaxation time

(c) Dead time

(d) Life time

59. The main function of quenching gas in a Geiger–Muller tube is to:

(a) Increase ionization

(b) Cool the tube

(c) Prevent spurious secondary pulses

(d) Increase sensitivity

60. In a solid state detector, the electric signal is produced due to:

- (a) Gas ionization
- (b) Nuclear fission
- (c) Creation of electron–hole pairs
- (d) Fluorescence

61. A nuclear reaction in which radium-226 changes into radon-222 by emitting an alpha particle is an example of:

- (a) Artificial nuclear reaction
- (b) Chemical reaction
- (c) Natural nuclear reaction
- (d) Fusion reaction

62. Rutherford was the first scientist who suggested that nuclear reactions can also be produced by:

- (a) Heat energy

(b) Chemical processes

(c) Bombarding nuclei with particles

(d) Electric current

63. The general form of a nuclear reaction is represented as:

(a) $X \rightarrow Y + \text{energy}$

(b) $X + x \rightarrow Y + y$

(c) $X - x \rightarrow Y - y$

(d) $X + Y \rightarrow x + y$



64. In Rutherford's nuclear reaction, nitrogen was bombarded with alpha particles to produce:

(a) Carbon and neutron

(b) Oxygen and proton

(c) Boron and electron

(d) Helium and neutron

65. Which particle was emitted during Rutherford's nuclear reaction of nitrogen?

(a) Neutron

(b) Electron

(c) Proton

(d) Gamma ray

66. In a nuclear reaction, the total number of protons and neutrons before and after the reaction remains:

(a) Increased

(b) Decreased

(c) The same

(d) Zero

67. A nuclear reaction can take place only when the total energy of reactants is:

-
- (a) Less than the products
 - (b) Greater than the products
 - (c) Equal to the total energy of products
 - (d) Zero

68. The minimum kinetic energy required by an alpha particle to make Rutherford's nitrogen reaction possible is approximately:

- (a) 0.13 MeV
- (b) 1.13 MeV
- (c) 7.7 MeV
- (d) 931 MeV

69. The discovery of neutron was made by James Chadwick by bombarding which element with alpha particles?

- (a) Carbon
- (b) Nitrogen

(c) Beryllium

(d) Oxygen

70. Neutrons were identified in Chadwick's experiment by observing the ejection of:

(a) Electrons from metal

(b) Alpha particles

(c) Fast moving protons from paraffin

(d) Gamma rays

71. Nuclear fission was first discovered by:

(a) Rutherford and Chadwick

(b) Bohr and Einstein

(c) Otto Hahn and Fritz Strassmann

(d) Marie and Pierre Curie

72. Nuclear fission of uranium is initiated mainly by bombarding it with:

- (a) Fast protons
- (b) Alpha particles
- (c) Slow neutrons
- (d) Gamma rays

73. In the fission of uranium-235, the nucleus splits into:

- (a) One heavy nucleus
- (b) Two very light nuclei
- (c) Two nuclei of nearly equal masses
- (d) Three identical nuclei

74. The average number of neutrons released in one fission reaction of uranium-235 is:

- (a) One

(b) Two

(c) Three

(d) Five

75. The approximate energy released in the fission of one uranium nucleus is:

(a) 20 MeV

(b) 50 MeV

(c) 100 MeV

(d) 200 MeV



76. The binding energy per nucleon of fission products like barium and krypton is:

(a) Less than uranium

(b) Equal to uranium

(c) Greater than uranium

(d) Zero

77. A self-sustaining series of nuclear fission reactions is called:

(a) Nuclear decay

(b) Fusion process

(c) Fission chain reaction

(d) Artificial transmutation

78. The minimum mass of uranium required to sustain a chain reaction is called:

(a) Atomic mass

(b) Nuclear mass

(c) Critical mass

(d) Binding mass

79. If the mass of uranium is greater than the critical mass, the result is:

-
- (a) No reaction
 - (b) Controlled energy production
 - (c) Slow reaction
 - (d) Violent explosion

80. Control of chain reaction in a nuclear reactor is achieved by using rods made of:

- (a) Aluminium
- (b) Iron
- (c) Cadmium or boron
- (d) Copper

81. The main function of control rods in a nuclear reactor is to:

- (a) Increase temperature
- (b) Absorb neutrons



- (c) Slow down protons
- (d) Reflect gamma rays

82. The substance used in a reactor to slow down fast neutrons is called:

- (a) Coolant
- (b) Fuel
- (c) Moderator
- (d) Shield



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83. Which of the following is commonly used as a moderator in nuclear reactors?

- (a) Lead
- (b) Heavy water
- (c) Mercury
- (d) Uranium

84. The central part of a nuclear reactor where fission takes place is called:

- (a) Turbine
- (b) Generator
- (c) Core
- (d) Condenser

85. Fast reactors mainly utilize which isotope to produce plutonium-239?

- (a) Uranium-235
- (b) Uranium-233
- (c) Uranium-238
- (d) Plutonium-240

86. A nuclear reaction in which two light nuclei combine to form a heavier nucleus is called:

- (a) Fission

(b) Radioactive decay

(c) Fusion

(d) Chain reaction

87. Energy is released in a nuclear reaction when the binding energy per nucleon of the products is:

(a) Less than reactants

(b) Equal to reactants

(c) Zero

(d) Greater than reactants



88. Compared to fission, fusion reactions produce:

(a) Less energy per nucleon

(b) Same energy per nucleon

(c) More energy per nucleon

(d) No energy

89. Fusion reactions are difficult to start mainly because:

(a) Neutrons are unstable

(b) Electrons interfere

(c) Positively charged nuclei repel each other

(d) Binding energy decreases

90. To initiate a fusion reaction, nuclei must be brought together by overcoming:

(a) Gravitational force

(b) Magnetic force

(c) Electrostatic repulsive force

(d) Nuclear attractive force

91. The minimum temperature required to start a thermonuclear fusion reaction is about:

-
- (a) 6000 °C
 - (b) 1 million °C
 - (c) 5 million °C
 - (d) 10 million °C

92. Fusion reactions occurring at extremely high temperatures are called:

- (a) Artificial reactions
- (b) Radioactive reactions
- (c) Thermo-nuclear reactions
- (d) Chain reactions

93. At present, controlled fusion reactions are:

- (a) Used in nuclear reactors
- (b) Used to generate electricity

(c) Fully controlled in laboratories

(d) Not yet practically controlled

94. The enormous energy of the Sun is produced due to:

(a) Nuclear fission

(b) Chemical reactions

(c) Fusion of hydrogen nuclei

(d) Radioactive decay

95. In the proton–proton (p–p) chain reaction in the Sun, the total energy released is approximately:

(a) 1 MeV

(b) 10 MeV

(c) 17.6 MeV

(d) 25.7 MeV

96. Radiation detected by a Geiger tube even when no source is nearby is called:

- (a) Artificial radiation
- (b) Thermal radiation
- (c) Background radiation
- (d) Nuclear radiation

97. Background radiation mainly comes from:

- (a) Medical X-rays only
- (b) Nuclear reactors
- (c) Cosmic rays and Earth's crust
- (d) Radioactive waste

98. Depletion of the ozone layer mainly increases exposure to:

- (a) Gamma rays

(b) Alpha particles

(c) Infrared rays

(d) Ultraviolet rays

99. The radioactive gas that increases indoor radiation levels is:

(a) Carbon dioxide

(b) Helium

(c) Radon

(d) Neon



100. The SI unit of activity of a radioactive source is:

(a) Curie

(b) Gray

(c) Sievert

(d) Becquerel

101. One becquerel (Bq) is equal to:

(a) One joule per kilogram

(b) One disintegration per second

(c) 3.7×10^{10} disintegrations per second

(d) One rad

102. The SI unit of absorbed dose of radiation is:

(a) Rad

(b) Curie

(c) Gray (Gy)

(d) Sievert

103. Which radiation is about 20 times more damaging than X-rays for the same absorbed dose?

- (a) Beta particles
- (b) Gamma rays
- (c) Alpha particles
- (d) Neutrons

104. The SI unit of equivalent dose of radiation is:

- (a) Gray
- (b) Rad
- (c) Curie
- (d) Sievert (Sv)



105. Which radioisotope is commonly used to treat cancer by radiotherapy?

- (a) Carbon-14
- (b) Sodium-24

(c) Cobalt-60

(d) Potassium-40

106. Which of the following is NOT a fundamental force of nature?

(a) Gravitational force

(b) Electromagnetic force

(c) Magnetic force

(d) Strong nuclear force

107. Which forces are long-range in nature?

(a) Gravitational and weak nuclear forces

(b) Electromagnetic and gravitational forces

(c) Strong and weak nuclear forces

(d) Strong nuclear and electromagnetic forces

108. The force responsible for keeping neutrons and protons confined inside the nucleus is:

- (a) Electromagnetic force
- (b) Gravitational force
- (c) Strong nuclear force
- (d) Weak nuclear force

109. The weak nuclear force is responsible for:

- (a) Binding atoms together
- (b) Chemical reactions
- (c) Spontaneous decay of radioactive elements
- (d) Keeping planets in orbit

110. Which two forces were unified to form the electroweak force?

- (a) Strong and gravitational forces

(b) Electromagnetic and weak nuclear forces

(c) Weak nuclear and strong nuclear forces

(d) Gravitational and electromagnetic forces

111. According to the standard model, elementary particles include:

(a) Hadrons only

(b) Leptons only

(c) Gauge bosons only

(d) Leptons, gauge bosons, and Higgs boson

112. Hadrons are particles that:

(a) Experience strong nuclear force

(b) Do not experience strong nuclear force

(c) Are always lighter than protons

(d) Include only leptons

113. Baryons are:

(a) Particles lighter than protons

(b) Made of quark-antiquark pairs

(c) Particles equal to or heavier than protons

(d) Leptons

114. Mesons are made up of:

(a) Three quarks

(b) Quark-antiquark pair

(c) Only leptons

(d) Gauge bosons

115. How many types of quarks are there in the standard model?

- (a) 3
- (b) 4
- (c) 5
- (d) 6

116. A proton is composed of:

- (a) Two down quarks and one up quark
- (b) Two up quarks and one down quark
- (c) One up quark and two strange quarks
- (d) Three down quarks

117. Leptons do NOT:

- (a) Experience electromagnetic force
- (b) Experience gravitational force
- (c) Experience strong nuclear force

(d) Have mass

118. The carrier particle of electromagnetic force is:

(a) Gluon

(b) W boson

(c) Photon

(d) Higgs boson

119. Gluons are responsible for:

(a) Weak nuclear force

(b) Strong nuclear force and holding quarks together

(c) Electromagnetic force

(d) Gravitational force

120. The Higgs boson is important because it:


(a) Carries electromagnetic force

- (b) Holds quarks in nucleus
- (c) Provides mass to other particles
- (d) Causes gravitational attraction

Important Short Questions (From Summary)

1. Define mass number of a nucleus.

Answer:

 Mass number is the total number of protons and neutrons present in a nucleus of an atom, denoted by A.

2. What are nucleons?

Answer:

 Nucleons are the protons and neutrons present in the nucleus of an atom.

3. Define neutron number (N) of an atom.

Answer:

👉 Neutron number (N) is the number of neutrons present in the nucleus of an atom.

4. What is the atomic number (Z) of an element?

Answer:

👉 Atomic number (Z) is the number of protons in the nucleus of an atom or the number of electrons in a neutral atom.

5. What are isotopes?

Answer:

👉 Isotopes are nuclei of the same element that have the same atomic number (Z) but different mass numbers (A).

6. Define radioactivity.

Answer:

👉 Radioactivity is the spontaneous emission of radiations (α , β , γ) from elements having atomic number $Z > 82$.

7. What is radioactive decay?

Answer:

👉 Radioactive decay is the transformation of a radioactive element into a new element due to the emission of radiation.

8. Differentiate between parent and daughter elements.

Answer:

👉 Parent element is the original radioactive element before decay, while daughter element is the new element formed after radioactive decay.

9. Define half-life of a radioactive element.

Answer:

👉 Half-life is the time required for half of the atoms of a radioactive element to decay into daughter elements.

10. What is a fission reaction?

Answer:

👉 Fission reaction is a nuclear reaction in which a heavy nucleus splits into two nuclei of almost equal size, releasing energy.

11. What is a fusion reaction?

Answer:

👉 Fusion reaction is a nuclear reaction in which two light nuclei combine to form a heavy nucleus, releasing energy.

12. Which unit is used to measure the activity of a radioactive source?

Answer:

👉 Activity of a radioactive source is measured in Becquerel (Bq); 1 Bq = 1 disintegration per second. A larger unit is Curie (Ci); 1 Ci = 3.7×10^{10} disintegrations per second.

13. Define absorbed dose of radiation.

Answer:

👉 Absorbed dose (D) is the energy absorbed from ionizing radiation per unit mass of the absorbing body, $D = E/m$. Its SI unit is Gray (Gy).

14. Name the four basic forces of nature.

Answer:

👉 i. Gravitational force

ii. Electromagnetic force

iii. Weak nuclear force

iv. Strong nuclear force

15. Classify subatomic particles into four groups.

Answer:

👉 i. Hadrons

ii. Leptons

iii. Gauge bosons

iv. Higgs boson

 **Important long Questions**

☀ Q.1: Explain nuclear fission. How does a fission chain reaction occur and how is it controlled in a nuclear reactor?

❖ Answer:

1. Nuclear Fission:

- Nuclear fission is a reaction in which a heavy nucleus, such as uranium-235 or plutonium-239, splits into two smaller nuclei of roughly equal mass, along with the release of energy and neutrons.

Example:

- Uranium-235 + neutron \rightarrow Barium + Krypton + 3 neutrons + energy
- The mass of the fission products is slightly less than the original mass. The lost mass is converted into energy according to Einstein's equation $E = mc^2$.

2. Characteristics of Fission:

- Produces a large amount of energy, about 200 MeV per nucleus of uranium-235.
- Emission of neutrons allows further fission reactions.
- Produces radioactive fission fragments.

3. Fission Chain Reaction:

-
- When a neutron causes fission of one uranium-235 nucleus, it releases two or three neutrons.
 - These emitted neutrons can induce fission in other uranium nuclei, producing more neutrons and energy.
 - This repeating process is called a chain reaction.
 - If uncontrolled, it leads to an explosive release of energy, as in an atomic bomb.

4. Control in a Nuclear Reactor:

- A nuclear reactor is designed to maintain a controlled chain reaction to produce energy safely.
- Fuel rods containing uranium or plutonium are placed in the reactor core.
- **Moderator:** Substances like water or heavy water slow down neutrons to increase the probability of fission.
- **Control rods:** Made of cadmium or boron, these rods absorb excess neutrons to regulate the chain reaction. By inserting or withdrawing control rods, the reaction rate and energy output are controlled.
- Heat generated from fission is used to produce steam, which rotates turbines to generate electricity.

◆ Summary:

- Nuclear fission is the splitting of a heavy nucleus into smaller nuclei with energy and neutrons release.

- Chain reaction occurs when emitted neutrons cause further fission.
- In reactors, moderators slow neutrons and control rods regulate the reaction for safe energy production.

🌟 **Q2. Describe nuclear fusion and compare it with fission.**

Explain how energy is produced in the Sun.

❖ **Answer:**

1. Nuclear Fusion:

Nuclear fusion is a reaction in which two light nuclei combine to form a heavier nucleus, releasing energy. In fusion, a mass defect occurs, meaning the total mass of the products is less than the mass of the reactants, and the lost mass is released as energy.

Example:



Fusion requires extremely high temperature and pressure to overcome the electrostatic repulsion between positively charged nuclei.

2. Comparison with Fission:

- **In fission**, heavy nuclei such as Uranium-235 split into smaller nuclei and release energy, while in fusion, light nuclei merge to form a heavier nucleus.

- Fission is easier to start because neutrons are neutral and can easily reach the nucleus, whereas fusion is harder to start due to repulsion between positively charged nuclei.
- Energy per nucleon released in fusion is greater than in fission.
- Fission produces radioactive fragments, while fusion typically produces stable nuclei like helium.
- Fission can be controlled in nuclear reactors to produce electricity, but controlled fusion on a large scale is still under development.

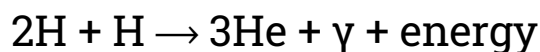
3. Energy Production in the Sun:

- The Sun is mainly composed of hydrogen, and its core temperature is about 20 million °C.
- Energy in the Sun is produced through the proton-proton (p-p) chain reaction.

Step 1: Two protons fuse → deuteron + positron + neutrino + energy



Step 2: Deuteron fuses with another proton → Helium-3 + gamma ray + energy



Step 3: Two Helium-3 nuclei combine \rightarrow Helium-4 + 2 protons + energy



- In this process, four protons are converted into one helium nucleus, releasing about 25.7 MeV of energy.
- The energy is initially in the form of gamma rays, which gradually reach the Sun's surface and are emitted as sunlight.

◆ **Summary:**

- Fusion involves merging light nuclei to release energy, while fission involves splitting heavy nuclei.
- Fusion releases more energy per nucleon but is harder to control than fission.
- The Sun's energy is produced by the fusion of protons in its core.

✨ **Q3. Define radioactivity. Explain different types of radiations (α , β , γ) and their properties.**

❖ **Answer:**

1. Definition of Radioactivity:

Radioactivity is the spontaneous emission of radiations from the nuclei of certain unstable elements. Elements with atomic

number greater than 82, such as uranium and thorium, are naturally radioactive.

2. Types of Radiations:

There are three main types of radioactive radiations: alpha (α), beta (β), and gamma (γ).

(a) Alpha (α) Radiation:

- Consists of two protons and two neutrons (helium nucleus).
- Has a positive charge (+2).
- Mass is relatively large compared to β and γ .
- Travels a few centimeters in air and can be stopped by a sheet of paper.
- Highly ionizing but low penetration power.

Example: Emitted by Uranium-238 during decay.

(b) Beta (β) Radiation:

- Consists of fast-moving electrons (β^-) or positrons (β^+).
- Charge is negative for β^- and positive for β^+ .
- Mass is very small compared to α .
- Travels several meters in air and can be stopped by a thin sheet of aluminum.
- Moderately ionizing and moderately penetrating.

Example: Emitted in the decay of Carbon-14.

(c) Gamma (γ) Radiation:

- Consists of high-energy electromagnetic waves.
- Has no charge and no mass.
- Travels several kilometers in air and requires thick lead or concrete to stop.
- Weakly ionizing but highly penetrating.
- Often emitted along with α or β radiation to remove excess energy from the nucleus.

Example: Emitted by Cobalt-60 and Uranium-238.

◆ Summary:

- α : Heavy, positive, low penetration, highly ionizing.
- β : Light, negative or positive, moderate penetration, moderately ionizing.
- γ : No mass, no charge, high penetration, weakly ionizing.

☀ **Q4. What is radioactive decay? Explain the terms parent element, daughter element, and half-life with examples.**

❖ Answer:

1. Radioactive Decay:

Radioactive decay is the process in which an unstable atomic nucleus loses energy by emitting radiation. During this process, the original element transforms into a different element or isotope.

2. Parent Element:

The parent element is the original radioactive element that undergoes decay.

- **Example:** Uranium-238 (U-238) is a parent element.

3. Daughter Element:

The daughter element is the new element or isotope formed as a result of the decay of the parent element.

- **Example:** When U-238 decays by alpha emission, it forms Thorium-234 (Th-234) as the daughter element.

4. Half-Life:

The half-life of a radioactive element is the time required for half of the atoms of the parent element to decay into daughter elements.

- **Example:** The half-life of U-238 is about 4.5 billion years. This means that in 4.5 billion years, half of a sample of U-238 will have decayed into Th-234.

5. Example of Radioactive Decay:

Uranium-238 \rightarrow Thorium-234 + α -particle

Here, U-238 is the parent element, Th-234 is the daughter element, and α -particle is the emitted radiation.

◆ **Summary:**

- **Radioactive decay:** Transformation of unstable nucleus with emission of radiation.
- **Parent element:** Original radioactive element.
- **Daughter element:** New element formed after decay.
- **Half-life:** Time in which half of the parent atoms decay.

☀ **Q5. Explain the biological effects of radiation. Discuss both low-level and high-level radiation exposure.**

❖ **Answer:**

1. Biological Effects of Radiation:

- Radiation can interact with living tissues and cause damage to cells, tissues, and organs. The effects depend on the type of radiation, its intensity, duration of exposure, and the part of the body exposed.

2. Low-Level Radiation Exposure:

- Low-level radiation usually comes from background sources like cosmic rays, naturally occurring radioactive materials, and medical X-rays.
- It is generally considered harmless but can cause minor effects if exposure is prolonged.
- Possible effects include temporary redness of skin, mild hair loss, slight drop in white blood cells, or minor cellular damage.

-
- Chronic low-level exposure over many years may slightly increase the risk of cancer or genetic mutations.

3. High-Level Radiation Exposure:

- High doses of radiation can be extremely harmful and even lethal.
- Immediate effects include radiation burns, severe damage to skin and internal tissues, nausea, vomiting, diarrhea, and hair loss.
- It can disrupt blood cell production, causing anaemia or lowering immunity.
- High exposure may lead to long-term effects like cancer, genetic mutations, chromosome abnormalities, and eye cataracts.

Example: Accidents in nuclear plants or exposure to atomic bombs can produce high-level radiation effects.

◆ **Summary:**

- Radiation damages living cells by ionization, breaking chemical bonds, or altering DNA.
- **Low-level exposure:** Minor, often reversible effects; mostly safe.
- **High-level exposure:** Severe damage to body systems, potentially fatal, with long-term genetic effects.

☀ Q6. Discuss the medical, agricultural, and industrial uses of radiation. Explain the use of tracers in medicine and agriculture.

❖ Answer:

1. Uses of Radiation:

a) Medical Uses:

- Radiation is widely used for diagnosis and treatment of diseases.
- **Diagnosis:** Radioactive isotopes act as tracers to locate diseased organs. For example, radioactive iodine-131 is used to examine the thyroid gland.
- **Treatment:** Radiotherapy uses gamma rays or beta particles to destroy cancerous cells. Cobalt-60 is commonly used in cancer treatment.
- Radiation is carefully controlled to minimize harm to healthy tissues.

b) Agricultural Uses:

- Radiation helps in studying the uptake of fertilizers in plants. By mixing a small amount of radioactive isotope with fertilizer, scientists can track how much the plant absorbs.

-
- Radiation-induced mutations are used to develop improved crop varieties, which are more resistant to diseases and pests and provide better yields.

Example: Mutated varieties of rice, wheat, cotton, and chickpea have been developed using radiation.

c) Industrial Uses:

- Radiation is used for quality control in industries, such as detecting cracks or cavities in pipelines, machinery, and metal castings.
- Gamma radiography allows inspection of internal structures without damaging the materials.
- Radioactive tracers are used to monitor fluid flow, detect leaks, and study chemical processes in industries.

2. Tracer Techniques:

- **Definition:** A tracer is a radioactive isotope that behaves chemically like a normal element but emits radiation, making it detectable.
- **In Medicine:** Tracers help follow the movement of substances in the body. For example, sodium-24 can trace blood circulation, and iodine-131 tracks thyroid function.
- **In Agriculture:** Tracers track the uptake and distribution of fertilizers or nutrients in plants, helping farmers optimize fertilizer use.

◆ **Summary:**

- Radiation is a versatile tool in medicine, agriculture, and industry.
- Tracers allow observation of processes without altering them, making it easier to study biological and industrial systems.
- Careful use of radiation ensures maximum benefit while minimizing risks.

✨ **Q7. Describe the structure of a nuclear power reactor. Explain the function of fuel, moderator, and control rods.**

❖ **Answer:**

A nuclear power reactor is a device used to produce energy through controlled nuclear fission reactions. Its structure is similar to a furnace in a thermal power station, but instead of burning coal or oil, the reactor produces heat via nuclear reactions.

1. Structure of a Nuclear Reactor:

- The reactor consists of a core, moderator, control rods, coolant, and a heat exchanger.
- **Core:** This is the central part where nuclear fuel is kept, usually in the form of cylindrical rods. It contains fissile materials like uranium-235, plutonium-239, or

uranium-233. In natural uranium, the concentration of U-235 is increased from 0.7% to 2–4% for effective fission.

- **Coolant/Heat Transport:** Water, heavy water, or other liquids transport heat from the core to the heat exchanger, where steam is produced to rotate turbines and generate electricity.

2. Functions of Key Components:

a) Fuel:

- The fuel rods contain fissile material like U-235 or Pu-239.
- When neutrons strike the fuel, the nuclei undergo fission, releasing a large amount of energy (about 200 MeV per fission of uranium).
- This energy appears as the kinetic energy of fission fragments, which is converted into heat for electricity generation.

b) Moderator:

- Moderators are substances like ordinary water, heavy water, or carbon that slow down fast neutrons produced during fission.
- Slow neutrons are more effective in sustaining a chain reaction in fissile materials.

- Heavy water (D₂O) is often used in reactors like the Karachi Nuclear Power Plant (KANUP) for moderation and heat transport.

c) Control Rods:

- Control rods are made of materials like cadmium or boron, which can absorb neutrons.
- By inserting or withdrawing control rods, the number of neutrons available for fission can be controlled, regulating the speed of the chain reaction.
- **In emergencies**, the rods are fully inserted to stop the reaction completely, shutting down the reactor.

3. Working Principle:

- A neutron strikes a uranium nucleus, causing it to split (fission) into smaller nuclei, releasing energy and more neutrons.
- These neutrons can strike other nuclei, sustaining a controlled chain reaction.
- Heat produced in the core is transferred via coolant to the heat exchanger, producing steam, which drives turbines to generate electricity.

◆ Summary:

- **Fuel:** Provides fissile material for energy production.
- **Moderator:** Slows down neutrons to sustain the chain reaction efficiently.

- **Control Rods:** Regulate or stop the nuclear reaction for safety and control.
- The reactor converts nuclear energy into electrical energy safely and continuously.

☀ **Q8. List the basic forces of nature and explain their characteristics and significance. Discuss the unification of electromagnetic and weak forces.**

❖ **Answer:**

1. Basic Forces of Nature:

There are four fundamental forces that govern all interactions in the universe:

a) Gravitational Force:

- **Nature:** Attractive force between masses.
- **Range:** Infinite, acts over long distances.
- **Significance:** Holds planets in orbit, keeps atmosphere and oceans bound to Earth, causes tides.

b) Electromagnetic Force:

- **Nature:** Acts between charged particles; includes electric and magnetic forces.
- **Range:** Long-range, acts over large distances.
- **Significance:** Responsible for chemical reactions, bonding of atoms and molecules, friction, cohesion, and adhesion.

c) Strong Nuclear Force:

- **Nature:** Very strong attractive force acting between nucleons (protons and neutrons).
- **Range:** Extremely short, confined to the nucleus ($\sim 10^{-15}$ m).
- **Significance:** Binds protons and neutrons together, overcoming electrostatic repulsion between protons.

d) Weak Nuclear Force:

- **Nature:** Responsible for certain types of radioactive decay, like beta decay.
- **Range:** Very short ($\sim 10^{-18}$ m).
- **Significance:** Causes spontaneous breaking of unstable nuclei, important in nuclear reactions in stars.

2. Unification of Forces:

- **In the 20th century**, scientists discovered that electric and magnetic forces are two aspects of a single force called the electromagnetic force.
- **In 1979, Glashow, Weinberg, and Abdus Salam** were awarded the Nobel Prize for the unification of electromagnetic and weak nuclear forces into a single electroweak force.
- This unification showed that forces which seemed different at low energies are actually manifestations of the same fundamental interaction at high energies.

3. Significance of Unification:

- Helps physicists understand fundamental interactions in a simpler framework.
- Paves the way for the search for a Grand Unified Theory (GUT), which aims to unite the strong, weak, and electromagnetic forces into one single force.

◆ Summary:

- **Gravitational Force:** Long-range, attracts masses.
- **Electromagnetic Force:** Long-range, acts on charges.
- **Strong Nuclear Force:** Short-range, binds nucleons.
- **Weak Nuclear Force:** Short-range, causes radioactive decay.
- **Electroweak Unification:** Combines electromagnetic and weak forces into a single framework, simplifying our understanding of fundamental interactions.

✨ Q9. Explain the classification of subatomic particles. Describe hadrons, leptons, gauge bosons, and Higgs boson with examples.

❖ Answer:

Subatomic particles are the fundamental constituents of matter and can be classified into four main groups according to the Standard Model of Particle Physics:

1. Hadrons:

- **Definition:** Particles that experience the strong nuclear force.
- **Composition:** Made of quarks (not elementary).

Types:

- **Baryons:** Composed of three quarks (e.g., proton = 2 up quarks + 1 down quark, neutron = 1 up quark + 2 down quarks).
- **Mesons:** Composed of a quark and an antiquark (e.g., pion, kaon).
- **Significance:** Protons and neutrons are baryons and form the nuclei of atoms.

2. Leptons:

Definition: Particles that do not experience the strong nuclear force.

Types:

- Electron (e^-), Muon (μ^-), Tau (τ^-) and their corresponding neutrinos (ν_e, ν_μ, ν_τ).
- **Significance:** Electrons are essential for chemical bonding, and neutrinos are important in nuclear reactions like those in the Sun.

3. Gauge Bosons:

Definition: Particles that act as carriers of the fundamental forces.

Examples and Forces:

- **Photon (γ):** Carrier of electromagnetic force.
- **Gluon (g):** Binds quarks inside hadrons, strong nuclear force.
- **W^+ , W^- , Z^0 bosons:** Mediators of weak nuclear force.

Significance: Responsible for the interaction between other particles.

4. Higgs Boson:

- **Definition:** A particle discovered in 2012 that explains how other particles acquire mass.
- **Significance:** Interaction with the Higgs field gives mass to elementary particles like quarks and leptons.

◆ **Summary:**

- **Hadrons:** Quark-based, feel strong force (protons, neutrons).
- **Leptons:** Elementary, no strong force (electron, neutrinos).
- **Gauge Bosons:** Force carriers (photon, gluon, W/Z bosons).
- **Higgs Boson:** Gives mass to particles via Higgs field.

☀ Q10. Define mass number, atomic number, neutron number, and isotopes. Explain the relationship between these terms and their significance in nuclear physics.

❖ Answer:

1. Mass Number (A):

- The mass number of a nucleus is the total number of protons and neutrons in the nucleus.
- **Symbol:** A
- **Significance:** Determines the total mass of the nucleus and helps identify the isotope of an element.

2. Atomic Number (Z):

- The atomic number is the number of protons in the nucleus of an atom.
- **Symbol:** Z
- **Significance:** Determines the chemical properties of the element and its position in the periodic table.

3. Neutron Number (N):

- The neutron number is the number of neutrons present in the nucleus.
- **Symbol:** N
- **Significance:** Affects the stability of the nucleus and plays a key role in nuclear reactions.

Relationship between A, Z, and N:

- Mass number is the sum of protons and neutrons:

$$A = Z + N$$

- Knowing any two of these quantities allows calculation of the third.

4. Isotopes:

- **Definition:** Isotopes are atoms of the same element (same Z) that have different mass numbers (A) due to a different number of neutrons.

Example: Carbon-12 and Carbon-14 both have 6 protons, but Carbon-12 has 6 neutrons and Carbon-14 has 8 neutrons.

Significance in Nuclear Physics:

- **Understanding mass number**, atomic number, and neutron number is essential for nuclear reactions, stability analysis, and radioactive decay.
- **Isotopes** are important in **radioactivity** studies, medical imaging, radiotherapy, and nuclear energy applications.

◆ Summary:

- A (Mass number) = Z (Protons) + N (Neutrons)
- Z defines the element, N affects nuclear stability, isotopes are variants of elements with different neutron numbers but identical chemical behavior.

Note:

This chapter is designed to provide a solid foundation of knowledge, with the goal of deepening understanding and encouraging further exploration of the subject. The content has been carefully selected to support effective learning and inspire students to engage with the topic more deeply.

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Purpose: To contribute to education by offering insightful, valuable content that enhances learning and understanding.

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