

Chapter	12 Nuclear and Particle Physics	Class	1 st Year	Subject	Physics
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Give Short Answers of the Following Questions

1. What Radioactivity?

Ans. The elements having charge number Z greater than 82 ($Z > 82$) are unstable. They emit invisible radiation (i.e. α , β , and γ) which effect the photographic plate. Such elements are called radioactive elements and this process called radioactivity.

2. Write the names of basic forces of nature.

Ans. • Gravitational force • Electric force • Magnetic force
• Weak nuclear force • Strong nuclear force

3. Define leptons and hadrons.

Ans. Hadrons:

These are particles that experiences strong nuclear force. In addition to protons, neutrons and mesons are hadrons.

Leptons:

These are the particles which do not experience strong nuclear force. Electrons, muons and neutrons are leptons.

4. Show that 1 a.m. u = 931 MeV

Ans. $E = m c^2$

$$E = (1.6606 \times 10^{-27}) (3 \times 10^8)^2$$

$$E = 1.5 \times 10^{10} \text{ J}$$

$$E = 1.5 \times 10^{10} / 1.6 \times 10^{-19} \text{ eV}$$

$$E = 931 \text{ M eV}$$

5. A particle which produces more ionization is less penetrating. Why?

Ans. Reason:

A particle which produces more ionization is less penetrating because it loses most of its energy in ionizing the atoms. So, it travels a very small distance in the medium before coming to rest.

6. What are baryons and mesons? How they are formed?

Ans. Baryons: The particles equal in mass or greater than protons are called baryons.

Mesons: The particles lighter than protons are called mesons.

According to quark theory

A pair of quark and anti-quark makes a meson and 3 quarks make a baryon.

7. Is meson a boson or fermion? Give reason.

Ans. Mesons are bosons:

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Reason:

Mesons are composed of one quark and one antiquark with integer spin values (0, 1 2, ...) which is a characteristic of bosons. So mesons are classified as bosons.

8. Why does an alpha emitter emit alpha particles instead of four separate nucleons?

Ans. An alpha particles is emitted from a nucleus during alpha decay instead of separate nucleons because they alpha particle have mainly greater nuclear stability along with high barrier tunneling ability as compare to individual nucleon.

9. Which is more energetic Alpha decay or Beta decay? Justify your answer.

Ans. Alpha decay is more energetic than beta decay.

Reason:

Alpha particle is much more massive than beta particle so its emission produces the greater mass difference between the parent and daughter nuclei.

10. A nucleus undergoes Gamma decay, emitting Gamma ray photon with energy 1.5 MeV. Calculate

- (i) Frequency of Gamma ray (ii) wave length of Gamma ray
(iii) Momentum of Gamma ray

Ans. As $E = 1.5 \text{ MeV} = 1.5 \times 10^6 \times 1.6 \times 10^{-19} \text{ J} = 2.4 \times 10^{-13} \text{ J}$

Frequency

$$E = hf$$

$$F = \frac{E}{h} = \frac{2.4 \times 10^{-13}}{6.63 \times 10^{-34}} = 3.63 \times 10^{20} \text{ Hz}$$

Wavelength

$$E = hf$$

$$E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{2.4 \times 10^{-13}} = 8.27 \times 10^{-16} \text{ m}$$

Momentum

$$E = cp$$

$$P = \frac{E}{c} = \frac{2.4 \times 10^{-13}}{3 \times 10^8} = 8.01 \times 10^{22} \text{ kgms}^{-1}$$

11. Why does the α -particles not make physical contact with the nucleus when headed directly toward it?

Ans. alpha particles do not make physical contact with the nucleus when headed directly toward it due to Coulomb's force of repulsion. As both alpha particles and the nucleus are positively charged and resulting in electromagnetic repulsion.

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12. What do different isotopes of a given element have in common? How are they different?

Ans. Isotopes

The nuclei of an element which have the same charge number (Z) but different mass number (A) are called isotopes.

Common Things and differences:

- They have same number of protons but different the number of neutrons.
- They have same chemical properties but different physical properties.

13. Identify the element that has 87 nucleons and 50 neutrons.

Ans. To calculate the number of protons

$$\text{Number of protons} = \text{Total number of nucleons} - \text{Number of neutrons}$$

$$\text{Number of protons} = 87 - 50$$

$$\text{Number of protons} = 37$$

So, the element with 37 protons is Rubidium (Rb)

14. What are the similarities and differences between the strong nuclear force and the electric force?

Ans. • The strong nuclear force is always attractive, while the electric force can be both attractive (between opposite charges) and repulsive (between like charges).

- The strong nuclear force has a very short range, typically on the order of a few femtometers (10^{-15} meters), while the electric force has an infinite range.
- The strong nuclear force is significantly stronger than the electric force at very small distances, but it decreases rapidly with increasing distance. The electric force, on the other hand, decreases with distance, but much more slowly.

15. Fill in the missing particle or nucleus:

a. ${}^{45}_{20}\text{Ca} \rightarrow ? + e^- + \bar{\nu}$

b. ${}^{58}_{29}\text{Cu}^* \rightarrow ? + \gamma$

Ans. ${}^{45}_{20}\text{Ca} \rightarrow {}^{A+1}_{Z}X + e^- + \bar{\nu}$

$${}^{45}_{20}\text{Ca} \rightarrow {}^{46}_{20}\text{X} + e^- + \bar{\nu}$$

Since charge number remain the same, so daughter nucleus is isotope of calcium ${}^{46}_{20}\text{Ca}$

$${}^{58}_{29}\text{Cu}^* \rightarrow ? + \gamma$$

$${}^{58}_{29}\text{Cu}^* \rightarrow {}^{58}_{29}\text{Cu} + \gamma$$

Since emission of gamma ray photon neither change its charge number nor mass number so only the energy state will change (i.e. ${}^{58}_{29}\text{Cu}$)

16. Why neutrino must be released in the positron emission?

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Ans. Both the neutrino and the anti-neutrino have zero charge and very small mass. The neutrino carries away some of the energy and momentum released during the positron emission process. This ensures that energy and momentum are conserved.

17. Distinguish between fermions and bosons.

Ans. Fermions:

- Fermions are matter particles with half-integer spin, obeying Pauli's Exclusion Principle.

Bosons:

- Bosons are force carriers with integer spin, obeying Bose-Einstein statistics.

18. How does strong force hold the nucleus?

Ans. The strong force, also known as the strong nuclear force, holds the nucleus together by binding protons and neutrons into a compact, stable unit.

The strong force is due to particles called gluons, which are exchanged between quarks. Quarks are the building blocks of protons and neutrons.

19. Can there be pair production for photons having energy 20 keV? Explain briefly.

Ans. No, pair production is not possible for photons with energy 20 keV.

Reason:

The minimum energy required for pair production is 1.02 MeV, which is the sum of rest-mass energies of an electron-positron pair. Since 20 keV is less than 1.022 MeV, pair production cannot occur.

20. What is the difference between beta particle and electron?

Ans. Electron:

- An electron is a fundamental subatomic particle with a negative charge.
- It is a constituent of an atom, orbiting the nucleus.
- Electrons are emitted or absorbed during various atomic processes, such as chemical reactions or photon interactions.

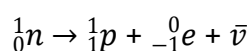
Beta Particle:

- A beta particle is an electron that is emitted from the nucleus of an atom during certain types of radioactive decay (beta decay).
- Beta particles are created when a neutron in the nucleus is converted into a proton, an electron, and a neutrino.
- Beta particles have the same properties as electrons, but they originate from the nucleus rather than being part of the atom's electrons.

21. How do a proton and a neutron convert to each other?

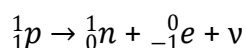
Ans. A proton and a neutron convert to each other during positive and negative beta decay.

During negative beta decay:



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During positive beta decay:



22. Why does beta-decay have a continuous energy spectrum and alpha-decay have a discrete energy spectrum?

Ans. Beta decay has continuous energy spectrum because the energy released is shared between β -particle and neutrino/anti-neutrino. As neutrino/anti-neutrino carry away some amount of energy of β -particle varies and hence β -particle has continuous energy spectrum.

Alpha decay has discrete energy spectrum because energy released is fixed and determined by difference of binding energies of parent and daughter nuclei.

23. Differentiate between hadron and leptons with examples.

Ans. Hadrons and Leptons:

Particles can be broadly classified based on whether they interact via the strong force. Those that experience the strong force are known as hadrons, while those that do not experience strong force are called leptons. Examples of hadrons include protons, neutrons, and pions, whereas electrons and neutrinos are classified as leptons.

24. Why electron-positron pair cannot decay into a single photon?

Ans. It is not possible to create a single photon by electron-positron pair. Because it became the violation of law of conservation of momentum. The decay would violate conservation of linear momentum. As total linear momentum before conversion is zero. So at least two photons should form to move in opposite direction with equal magnitude of momentum to conserve the momentum.

25. State the role of Higgs Boson in the generation of mass in modern physics theories.

Ans. Role of Higg's Bosons

The particles that interact strongly with Higg's field get more mass such as carriers of electroweak interaction i.e., W^+ , W^- and Z bosons whereas the particles like photons do not interact with Higg's field and hence, their rest mass is considered zero. Higgs boson has a mass of around 125 giga-electron-volts (GeV) and decays rapidly into other particles. The Higgs boson gets its mass from its interactions with its associated Higg's field.

26. What are Mesons? Give example.

Ans. Mesons

Mesons belong to subatomic particles composed of one quark and one antiquark. They are: They are formed by combination of pair of quark and antiquark.

Example:

Pion (π): Composed of up and down quarks and their antiquarks. e.g. π^+ , π^- , π^0