Board Paper Questions on ' Dual Nature, Atoms, Nuclei...'

1. An electron and alpha particle have the same de Broglie wavelength associated with them. How are their kinetic energies related to each other ?

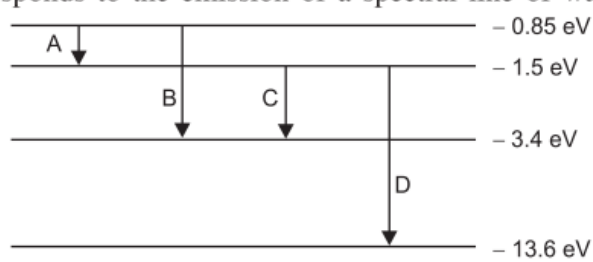
2. State the reason, why heavy water is generally used as a moderator in a nuclear reactor.

3. A nucleus $^{23}_{10}Ne$ undergoes β-decay and becomes $^{23}_{11}Na$. Calculate the maximum kinetic energy of electrons emitted assuming that the daughter nucleus and anti-neutrino carry negligible kinetic energy.

$$\left\{\begin{array}{l} \text{mass of } ^{23}_{10}Ne = 22\cdot994466 \text{ u} \\ \text{mass of } ^{23}_{11}Na = 22\cdot989770 \text{ u} \\ 1 \text{ u} = 931\cdot5 \text{ MeV}/c^2 \end{array}\right\}$$

4. An electromagnetic wave of wavelength λ is incident on a photosensitive surface of negligible work function. If the photo-electrons emitted from this surface have the de-Broglie wavelength λ_1, prove that $\lambda = \left(\frac{2mc}{h}\right)\lambda_1^2$.

The energy level diagram of an element is given below. Identify, by doing necessary calculations, which transition corresponds to the emission of a spectral line of wavelength 102·7 nm.



5. State the law of radioactive decay. If N_0 is the number of radioactive nuclei in the sample at some initial time, t_0, find out the relation to determine the number N present at a subsequent time. Draw a plot of N as a function of time.

OR

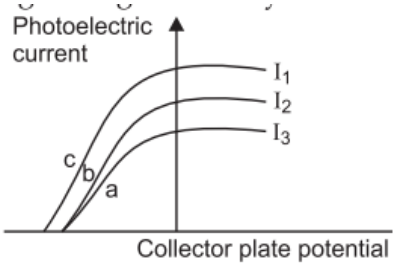
Draw a plot of the binding energy per nucleon as a function of mass number for a large number of nuclei.

Explain the energy release in the process of nuclear fission from the above plot. Write a typical nuclear reaction in which a large amount of energy is released in the process of nuclear fission.

6. Distinguish between isotopes and isobars. Give one example for each of the species. A radioactive isotope has a half-life of 5 years. How long will it take the activity to reduce to 3·125%?

7. Show that Bohr's second postulate, 'the electron revolves around the nucleus only in certain fixed orbits without radiating energy' can be explained on the basis of de-Broglie hypothesis of wave nature of electron.

8. The figure shows a plot of three curves *a, b, c* showing the variation of photocurrent vs. collector plate potential for three different intensities I_1, I_2 and I_3 having frequencies ν_1, ν_2 and ν_3 respectively incident on a photosenitive surface.



Point out the two curves for which the incident radiations have same frequency but different intensities. **1**

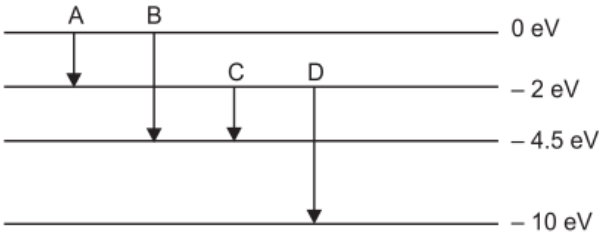
9. Two nuclei have mass numbers in the ratio 1 : 2. What is the ratio of their nuclei densities?

10. A radioactive nucleus '*A*' undergoes a series of decays according to the following scheme :

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

The mass number and atomic number of *A* are 180 and 72 respectively. What are these numbers for A_4?

11. (a) The energy levels of an atom are as shown below. Which of them will result in the transition of a photon of wavelength 275 nm?



(b) Which transition corresponds to emission of radiation of maximum wavelength?

12. A proton and an alpha particle are accelerated through the same potential. Which one of the two has (i) greater value of de-Broglie wavelength associated with it, and (ii) less kinetic enrgy? Justify your answers.

13. Two nuclei have mass numbers iin the ratio 1 : 8. What is the ratio of their nuclear radii?

14. (a) The mass of a nucleus in its ground state is always less than the total mass of its constituents – neutrons and protons. Explain.

(b) Plot a graph showing the variation of potential energy of a pair of nucleons as a function of their separtion. **2**

15. Draw a schematic arrangement of the Geiger-Marsden experiment. How did the scattering of α-particles of a thin foil of gold provide an important way to determine an upper limit on the size of the nucleus? Explain briefly. **3**

16. Draw a plot showing the variation of binding energy per nucleon versus the mass number *A*. Explain with the help of this plot the release of energy in the processes of nuclear fission and fusion. **3**

17. Define the activity of a radionuclide. Write its S.I. units. Give a plot of the activity of a radioactive species versus time.

How long will a radioactive isotope, whose half life is T years, take for its activity to reduce to 1/8th of its initial value? **3**

18. In the Rutherford scattering experiment the distance of closest approach for an α-particle is d_0. If α-particle is replaced by a proton, how much kinetic energy in comparison to α-particle will it require to have the same distance of closest approach d_0? **1**

19. The energy of the electron in the ground state of hydrogen atom is $-13 \cdot 6\,\text{eV}$.

(i) What does the negative sign signify?

ii) How much energy is required to take an electron in this atom from the ground state to the first excited state? **2**

20. (a) What is meant by half life of a radioactive element?

(b) The half life of a radioactive substance is 30 s. Calculate

(i) the decay constant, and

(ii) time taken for the sample to decay by 3/4th of the initial value. **3**

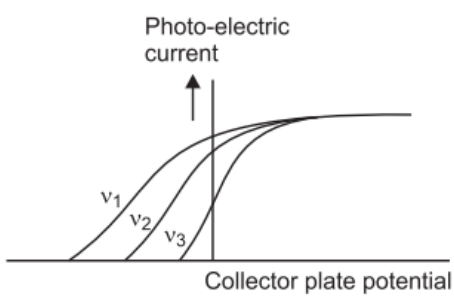
21. (a) What is meant by half life of a radioactive element?

(b) The half life of a radioactive substance is 20 s. Calculate:

(i) the decay constant and

(ii) time taken for the sample to decay by $7/8^{th}$ of the initial value. **3**

22. The graph below shows variation of photo-electric current with collector plate potential for different frequencies of incident radiations.



(i) Which physical parameter is kept constant for the three curves?

(ii) Which frequency (ν_1, ν_2 or ν_3) is the highest? **2**

23. (a) What is meant by half life of a radioactive element?

(b) The half life of a radioactive substance is 30 s. Calculate:

(i) the decay constant, and

(ii) time taken for the sample to decay by $3/4^{th}$ of the initial value. **3**

24. What is the ratio of radii of the orbits corresponding to first excited state and ground state in a hydrogen atom?

25. An electron is accelerated through a potential difference of 100 volts. What is the de-Broglie wavelength associated with it? To which part of the electromagnetic spectrum does this value of wavelength correspond?

26. A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy of nucleons in Y and Z is 8.5 MeV per nucleon. Calculate the energy Q released per fission in MeV.

27. (*i*) Define 'activity' of a radioactive material and write its S.I. unit.

(*ii*) Plot a graph showing variation of activity of a given radioactive sample with time.

(*iii*) The sequence of stepwise decay of a radioactive nucleus is

$$D \xrightarrow{\alpha} D_1 \xrightarrow{\beta^-} D_2$$

If the atomic number and mass number of D_2 are 71 and 176 respectively, what are their corresponding values for D ?

28. An electron is accelerated through a potential difference of 144 volts. What is the de-Broglie wavelength associated with it? To which part of the electromagnetic spectrum does this wavelength correspond?

29. An α-particle and a proton are accelerated from rest by the same potential. Find the ratio of their de-Broglie wavelengths.

30. Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions which you can draw regarding the nature of nuclear forces.

OR

Draw a plot of the binding energy per nucleon as a function of mass number for a large number of nuclei, $2 \le A \le 240$. How do you explain the constancy of binding energy per nucleon in the range $30 < A < 170$ using the property that nuclear force is short-ranged?

Nuclear forces are short ranged, so every nucleon interacts with their neighbours only; so binding energy per nucleon remains constant.]

30.

(*a*) Write symbolically the β^- decay process of $^{32}_{15}P$.

(*b*) Derive an expression for the average life of a radionuclide. Give its relationship with the half-life.

31. The ground state energy of hydrogen atom is $-13 \cdot 6$ eV. What are the kinetic and potential energies of electron in this state?

32. State Bohr's quantisation condition for defining stationary orbits.

33. If both the number of protons and the number of neutrons are conserved in a nuclear reaction like

$$^{12}_{6}C + ^{12}_{6}C \longrightarrow ^{20}_{10}Ne + ^{4}_{2}He,$$

in what way is mass converted into energy? Explain.

34. Draw a schematic arrangement of the Geiger – Marsden experiment for studying α-particle scattering by a thin foil of gold. Dsecribe briefly, by drawing trajectories of the scattered α-particles, how this study can be used to estimate the size of the nucleus.

35. Define the terms 'threshold frequency' and 'stopping potential' in the study of photoelectric emission.

Explain briefly the reasons why wave theory of light is not able to explain the observed features in photoelectric effect.

36. Show graphically, the variation of the de-Broglie wavelength (λ) with the potential (V) through which an electron is accelerated from rest.

37. State the law of radioactive decay.

Plot a graph showing the number (N) of undebased nuclei as a function of time (t) for a given radioactive sample having half life $T_{1/2}$. Depict in the plot the number of undecayed nuclei at (*i*) $t = 3T_{1/2}$ and (*ii*) $t = 5T_{1/2}$.

38. An electron and a photon each have a wavelength of 2 nm. Find

(*i*) their momenta

(*ii*) the energy of the photon

(*iii*) the kinetic energy of the electron.

39. Write any two characteristic properties of nuclear force.

40. Define the term 'stopping potential' in relation to photoelectric effect.

41. Using the curve for the binding energy per nucleon as a function of mass number A, state clearly how the release in energy in the processes of nuclear fission and nuclear fusion can be explained.

42. Draw a plot showing the variation of photoelectric current with collector plate potential for two different frequencies, $v_1 > v_2$, of incident radiation having the same intensity. In which case will the stopping potential be higher? Justify your answer.

43. (*a*) Using de Broglie's hypothesis, explain with the help of a suitable diagram, Bohr's second postulate of quantization of energy levels in a hydrogen atom.

(*b*) The ground state energy of hydrogen atom is –13.6 eV. What are the kinetic and potential energies of the electron in this state?

44. How is the mean life of a radioactive sample related to its half life?

45. When four hydrogen nuclei combine to form a helium nucleus, estimate the amount of energy in MeV released in this process of fusion (Neglect the masses of electrons and neutrinos) Given:

(*i*) mass of $^{1}_{1}H = 1.007825$ u

(*ii*) mass of helium nucleus = 4.002603 u, 1u = 931 MeV / c^2

46. Light of wavelength 2000 Å falls on a metal surface of work functions 4.2 eV. What is the kinetic energy (in eV) of the fastest electrons emitted from the surface?

(*i*) What will be the change in the energy of the emitted electrons if the intensity of light with same wavelength is doubled?

(*ii*) If the same light falls on another surface of work functions 6.5 eV, what will be the energy of emitted electrons?

47. Using the postulates of Bohr's model of hydrogen atom, obtain an expression for the frequency of radiation emitted when atom make a transition from the higher energy state with quantum number n_i to the lower energy state with quantum number n_f ($n_f < n_i$).

48. Light of wavelength 2500 Å falls on a metal surface of work function 3.5 V. What is the kinetic energy (in eV) of (*i*) the fastest and (*ii*) the slowest electronic emitted from the surface?

If the same light falls on another surface of work function 5.5 eV, what will be the energy of emitted electrons?

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