Unit VIII
ATOMS AND NUCLEI

KEY POINTS

- Gieger-Marsden α-scattering experiment established the existence of nucleus in an atom.

  Bohr's atomic model

  (i) Electrons revolve round the nucleus in certain fixed orbits called stationary orbits.

  (ii) In stationary orbits, the angular momentum of electron is integral multiple of $h/2\pi$.

  (iii) While revolving in stationary orbits, electrons do not radiate energy. The energy is emitted (or absorbed) when electrons jump from higher to lower energy orbits, (or lower to higher energy orbits). The frequency of the emitted radiation is given by $h\nu = E_f - E_i$. An atom can absorb radiations of only those frequencies that it is capable of emitting.

- As a result of the quantisation condition of angular momentum, the electron orbits the nucleus in circular paths of specific radii. For a hydrogen atom it is given by

$$r_n = \left(\frac{n^2}{m}\right)\left(\frac{h}{2\pi}\right)^2 \frac{4\pi\varepsilon_0}{e^2} = \frac{n^2h^2\varepsilon_0}{\pi me^2}$$

$$\Rightarrow \quad r_n \propto n^2$$

  The total energy is also quantised : $E_n = \frac{-me^4}{8n^2\varepsilon_0^2h^2} = -13.6\text{eV}/n^2$

  The $n = 1$ state is called the ground state.

  In hydrogen atom, the ground state energy is – 13.6 eV.

- de Broglie's hypothesis that electron have a wavelength $\lambda = h/mv$ gave an explanation for the Bohr's quantised orbits.
- Neutrons and protons are bound in nucleus by short range strong nuclear force. Nuclear force does not distinguish between nucleons.
- The nuclear mass 'M' is always less than the total mass of its constituents. The difference in mass of a nucleus and its constituents is called the **mass defect.**

$$\Delta M = [Zm_p + (A - Z)m_n] - M$$

and $$\Delta E_b = (\Delta M)c^2$$

The energy ΔE_b represents the binding energy of the nucleus.

For the mass number ranging from A = 30 to 170 the binding energy per nucleon is nearly constant at about 8MeV per nucleon.

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. The photoelectric effect can be explained on the basis of

   (a) Wave theory (b) Electromagnetic theory

   (c) Quantum theory (d) Corpuscular theory

2. The wavelength of matter waves is independent of

   (a) Mass (b) Velocity

   (c) Momentum (d) Charge

3. If E_1, E_2, E_3 and E_4 are the respective kinetic energies of electron, deutron, proton and neutron having same de-Broglie wavelength, select the correct order in which those values would incrase:

   (a) E_1, E_3, E_4, E_2 (b) E_2, E_4, E_1, E_3

   (c) E_2, E_4, E_3, E_1 (d) E_3, E_1, E_2, E_4

4. Light of frequency $2.5v_0$ is incident on a metal surface of threshold frequency $2v_0$. If its frequency is halved and intensity is made doubled find the new value of photoelectric current.

   (a) 4 unit (b) 2.5. unit

   (c) zero (d) 1.05 unit

5. What is the momentum of photon of energy 3MeV in kg ms^{-1}?

   (a) 10^{12} kg ms^{-1} (b) 1.6×10^{-21} kg ms^{-1}

   (c) 3×10^{8} kg ms^{-1} (d) 1.6×10^{-19} kg ms^{-1}

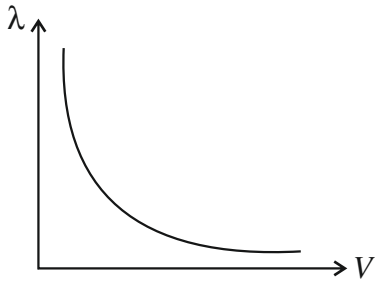
6. What is the momentum of an electron beam of wavelength 4Å?

   (h = 6.62×10^{-34}Js)

   (a) 1.65×10^{-24} kg ms^{-1} (b) 3×10^{5} kg ms^{-1}

   (c) 9.1×10^{-30} kg ms^{-1} (d) 3.9×10^{-24} kg ms^{-1}

7. The variation of the de-Broglie wavelength (λ) with the potential (V) through which an electron is accelerated from rest is shown in graph below



Choose the correct option:

(a) $\lambda \alpha V$ (b) $\lambda\alpha\sqrt{V}$

(c) $\lambda\alpha\frac{1}{\sqrt{V}}$ (d) $\lambda\alpha v^2$

8. A proton and electron have same velocity. Which one option is correct for deBroglie wavelength of Proton (λ_p) and electron (λ_e)?

(a) $\lambda_p = \lambda_e \neq 0$ (b) $\lambda_p < \lambda_e$

(c) $\lambda_p > \lambda_e$ (d) $\lambda_p = \lambda_e = 0$

9. The threshold frequency of a certain metal is 3.3×10^{14} Hz. If light of frequency 8.2×10^{14} Hz is incidenet on the metal, predict the cut off voltage for photoelectric emission. ($h = 6.62 \times 10^{-34}$ Js)

(a) 202.74 V (b) 305.12V

(c) 531.5 V (d) 200 V

10. What is the momentum of an electron with K.E of 120 eV. (Given $h = 6.63 \times 10^{-34}$Js, Me $= 9.1 \times 10^{-31}$ Kg; 1 eV $= 1.6 \times 10^{-19}$J)

(a) 2×10^{-19} kg ms^{-1} (b) 5.88×10^{-24} kg ms^{-1}

(c) 9×10^{9} kg ms^{-1} (d) 5×10^{19} kg ms^{-1}

Answer

Q.	1	2	3	4	5	6	7	8	9	10
A.	(c)	(d)	(c)	(c)	(b)	(a)	(c)	(b)	(a)	(b)

QUESTIONS

Chapter-12 and 13 Atom & Nuclei
MCQ

1. α-particles are incident on a thin gold foil. For what angle of deviation will the number of α-particle be minimum?

   (a) 0° (b) 90°

   (c) 120° (d) 180°

2. Number of electrons and neutrons in $^{236}_{92}U$ atom will be-

   (a) electrons = 92
   Neutrons = 144

   (b) electrons = 144
   Neutrons = 92

   (c) electrons = 236
   Neutrons = 92

   (d) electrons = 92
   Neutrons = 236

3. After losing two electrons, to which particle does a helium atom get transformed into?

   (a) α-particle (b) β-particle

   (c) γ-particle (d) photon

4. The energy released in fusion reaction
   $^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + n$
   Where B.E of $^{2}_{1}H$ = 2.23 MeV and $^{3}_{2}He$ = 7.73 MeV

   (a) 4.5 MeV (b) 5.9 MeV

   (c) 6.2 MeV (d) 3.27 MeV

5. Two nuclei of mass numbers 1 and 27 have their radii ratio as—

   (a) 2 : 5 (b) 5 : 2

   (c) 1 : 5 (d) 1 : 3

6. The light energy emitted by a star is due to—

   (a) Joining of nuclei

   (b) Burning of nuclei

   (c) Breaking of nuclei

   (d) Reflection of solar light

7. Energy of an electron in nth orbit of hydrogen atom is—

(a) $\frac{-13.6}{n^2}eV$ (b) $\frac{n^2}{13.6}eV$

(c) $\frac{-n^2}{13.6}eV$ (d) $\frac{-13.6}{n}eV$

8. According to de-Broglie explanation of Bohr's second postulate of quantisation, the standing particle wave n a circular orbit for $n = 4$ is given by—

(a) $\frac{2\pi}{\lambda} = 2r_n$ $2\pi r_n = 3\lambda$

(c) $2\pi r_n = 4\lambda$ $\frac{\lambda}{2\pi} = 2r_n$

9. Angular momentum of an electron in the second orbit of an atom is—

(a) 5×10^{-31} Js 2.1×10^{-34} Js

(c) 5×10^{-9} Js 2.1×10^{-9} Js

10. According to the Bohr's atomic theory, what will be the energy of hydrogen atom for principal quantum number ∞?

(a) Infinite (b) –13.6 eV

(c) 13.6eV (d) Zero

11. The wavelength limits of Lymas, Balmer and Paschen series are λ_L, λ_B and λ_P respectively. Wavelengths in increasing order can be written as—

(a) $\lambda_P < \lambda_B < \lambda_L$ $\lambda_P > \lambda_B > \lambda_L$

(c) $\lambda_P = \lambda_B = \lambda_L$ $\lambda_L > \lambda_B > \lambda_P$

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

(a) 1 : 2 (b) 2 : 1

(c) 1 : 1 (d) 3 : 1

13. One milligram of matter is converted into energy, the energy released will be

(a) 9×10^{10} J (b) 7×10^{9} J

(c) 10 J (d) 900 J

14. If in a nuclear fusion process, the masses of the fusion nuclei are m_1 and m_2 and mass of the resultant nucleus is m_3, then

(a) $m_3=(m_1-m_2)$ (b) $m_3<(m_1+m_2)$

(c) $m_3=m_1+m_2$ (d) $m_3=m_2-m_1$

15. The biuding energy of deuteron is 2.2. MeV and that of $^4_2$He is 28MeV. If two deuteron are fused to form one $^4_2$He then energy released is —

(a) 30.5 MeV (b) 23.6 MeV

(c) 31.5 MeV (d) 19.5 MeV

Answers

1. (d)
2. (a)
3. (a)
4. (d)
5. (d)
6. (a)
7. (a)
8. (c)
9. (b)
10. (d)
11. (d)
12. (c)
13. (a)
14. (b)
15. (b)

Assertion - Reason Questions

Dual Nature

For question two statements are given one labelled assertion A and the other labelled Reason R. Select the correct answer to these questions from the codes a), b), c) and d) as given below.

a) Both A and R are true and R is correct explanation of A

b) Both A and R are true but R is not correct explanation of A

c) A is true but R is false

d) A is false and R is also false

1. Assertion : Photoelectric effect demonstrate the wave nature of light.

   Reason : The number of photoelectrons is proportional to the frequency of light.

2. Assertion : The energy of X-ray photon is greater than that of visible light photon.

   Reason : X-ray photon in vacuum travels faster than light photon.

3. Assertion : A partial of mass mat rest decays into two particles of masses m_1 and m_2 having non-zero velocities, will have ratio of de-Broglie wavelengths unity.

   Reason : Here we cannot apply conservation of linear momentum.

4. Assertion : Light of frequency 1.5 times the threshold frequency is incident on a photo sensitive material of the frequency is halved and intensity is doubled, the photo electric current remains unchanged.

   Reason : The photo electric current varies diversity with the intensity of light and frequency of light.

5. Assertion : A photon has no rest mass, yet it carries definite momentum.

   Reason : Momentum of photon is due to its energy and hence its equivalent mass.

   Answers :

   1. a) 2. c) 3. c) 4. d) 5. a)

Assertion - Reason Question (Atom & Nuclei)

1 Assertion : Balmer series lie in the visible region of electro magnetic spectrum

Reason : Wavelength of photon emitted when electron jumps from higher energy state to lower energy

Stable is given $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$

n=3 to 00

2. Assertion : Total energy of an electron in hydrogen atom is negative.

   Reason : Electron is bounded to the nucleus.

3. Assertion : In a radioactive decay an electron is emitted by the nucleus.

   Reason : Electron are present inside the nucleus.

4. Assertion : Force acting between proton-proton (f_{pp}) is less than fine acting between proton-proton (f_{pn}) inside a nucleus.

   Reason : Protons being positively charged, repel each other by coulombian free.

5. Assertion : Unlike gravitational and electro-static forces, nuclear force has limited range.

   Reason : Nuclear forces do not obey inverse square law.

Case Study Questions

DUAL NATURE OF MATTER & RADIATION

I. Photocell is usually a vacuum tube having two electrodes. One is a cathode made of a photo sensitive material, which units electrons when exposed to light of sufficient frequency and the other is an anode. Which is maintained at a positive potential with respect to cathode. When light of suitable frequency strikes on cathode, electrons are inutted from cathode and are attracted to the anode and a current flows. This current can be used to open a door, ring a bell

Attempt any 4 sub-parts from each question.

Each question carries one mark.

1. Photocell is based on the phenomenon of

   a) Compton effect b) Photo electric effect

   c) Magnetic effect of current d) Photo electric effect

2. If the wavelength of evident radiation is greater than the threshold wave length for a metal surface then

   a) Kinetic energy of photoelectron will be higher

   b) Photoelectric current will be higher

   c) Photoelectric effect will not take place

   d) None of the above

3. A photocell units electrons when exposed to the light of the frequency of incident light is increased keeping intensity constant then

   a) Magnitude of cut-off voltage will increase

   b) Photo electric current will decrease

   c) No photoelectron will unit

   d) Photoelectrons will unit but their kinetic energy will be zero

4. Photoelectric effect is used in

   a) Cyclotron b) Moving coil galvanometer

   c) Van de Graaff Generator d) Photocell

5. Light radiations of suitable frequency incident on a photosensitive surface. How will the kinetic energy of photoelectrons vary if the intensity of incident radiations increased.

   a) Remains same b) Increase

   c) Decrease d) None of the above

Answers :

1. (b) 2. (c) 3. (a) 4. (d) 5. (a)

II **de Broglie Hyper thesis**

de Broglie in 1924 proposed that matter should also exhibit dual behaviour like properties. It means that just the photon has momentum as well as wavelength, de-Broglie gave the following relation between wavelength and momentum (p) of a material particles.

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

When in is mars of the particles and *v* its velocity.

Electron micros cope is mad on wave like behaviour of electron just as ordinary microscope utilize the wave nature of light. An electron microscope is a powerful tool in modern scientific research because it achieves a magnification of about 15 million times that of ordinary optical microscope.

Attempt any 4 sub parts from each question.

Each question carries 1 mark.

1. An electron, have same moments, which one has greater de-Bringlie wavelength?

   a) Electron b) Proton

   c) X-particle d) All have same de-Bringlie wavelength

2. An electron, a proton a electron and an alpha particle are moving with speed. which one has greater de-Bronglie wavelength?

   a) Electron b) Proton

   c) Decetron d) Alpha particle

3. de-Broglie waves are :

   a) Light waves b) Micro waves

   c) Waves d) All of the above

4. The magnification produced by electron microscope is

   a) Greater than ordinary optical microscope

   b) Less than ordinary optical microscope

   c) Same as that of ordinary optical microscope

   d) none of the above

Answers :

1. (d) 2. (a) 3. (c) 4. (a) 5. (b)

III A spectral line is a dark or bright line in an otherwise uniform and continuos spectrum. The spectrum is obtained when emission or obsarbuon of light take place in a frequency range: In emission spectrum there are bright lines on a dark background. The spectrum emitted by atonic hydrogen has various spectral line. These are certain sets of spectral lives in the spectrum of hydrogen atom. Each such set is called spectral series. The wave length of radiation emitted during a transition from higher energy level to lower energy level is given by-

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

When R=1.101 x 10^7 m^{-1}, n_f & ni are lower & higher energy state respectively.

1. Which of the following transition corresponds to Paschen series-

a) $n_f = 1$, ni=2 to 00

b) n_f=2, ni=3 to 00

c) n_f=3, ni=4 to 00

d) n_f=4, ni=5 to 00

2. Which of the following spectral series lies in visible region-

a) Lyman series

b) Belmer series

c) Paschan series

d) pfimd series

3. The shortest wave length of lyman series is

a) 10.20 Å

b) 917 Å

c) 410 Å

d) 659 Å

4. The wavelength of H_2 line is -
   a) 1500 Å
   b) 8200 Å
   c) 6566 Å
   d) 4861 Å
5. Which of the following series lies in UV region-
   a) Belmer series
   b) Paschen series
   c) Branett series
   d) Lyman series

Nuclear Energy

IV. A Heavy nucleus breaks into comparatively lighter nuclei which are more stable compared to the original heavy nucleus. When a heavy nucleus like uranium is bombarded by slow moving neutrons, it splits into two parts releasing large amount of energy. The typical fission reacion of U-235 is, $_{92}U^{235}+_{0}n^{1} \longrightarrow _{56}Ba^{141}+_{36}Kr^{92}+_{30}n^{1}$+200MeV the fission of U-235 releases 200 MeV energy.

1. If 200 MeV energy is released in the fission of single nucleus of $^{235}U_{92}$.The fissions which are required to produce a power of 1 KW is
(a) $3.125x10^{13}$ (b) $1.52x10^{6}$ (c)$3.125x10^{12}$ (d) $3.125x10^{14}$

2. The release in energy in Nuclear fission is consistent with the fact that uranium has
(a) More mass per nucleon than either of two fragments
(b) More mass per nucleon as two fragments
(c)exactly the same mass per nucleon as the two fragments
(d) less mass per nucleon than either of two fragments.
3. when $^{235}U_{92}$ undergoes fission about 0.1% of the original mass is converted into energy.

The energy released when 1 kg uranium undergoes fission is

(a) $9x10^{11}J$ (b) $9x10^{13}J$

c) $9x10^{15}J$ (d) $9x10^{18}J$

4. An uncontrolled nuclear chain reaction form the basis of

(a) Bio-gas Plant (b) Hydro electric power station

(c) Nuclear reactor (d) atom bomb

5. Fission of a nucleus is achieved by bombarding it with

(a) proton (b) neutron (c) electron (d) X-ray

Answers:

Case Study Questions (III)

1. a) 2. a) 3. c) 4. a) 5. a)

Case Study question : (IV)

Ans. (1) (a) (2) (d) (3) (b) (4) (c) (5) (b)

SHORT ANSWER QUESTIONS (2 Marks)

1. Write one similarity and one difference between matter wave and an electromagnetic wave.

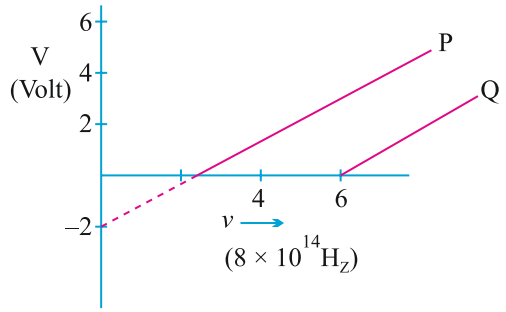
2. Does a photon have a de-Broglie wavelength? Explain.

3. A photon and an electron have energy 200 eV each. Which one of these has greater de-Broglie wavelength?

4. The work function of the following metal is given Na = 2.75 eV, K = 2.3 eV, Mo = 4.14 eV, Ni = 5.15 eV which of these metal will not give a photoelectric emission for radiation of wave length 3300 A° from a laser source placed at 1m away from the metal. What happens if the laser is brought nearer and placed 50 cm away.

5. Represent graphically Variation of the de-Broglie wavelength with linear momentum of a particle.

6. In a photoelectric effect experiment, the graph between the stopping potential V and frequency of the incident radiation on two different metals P and Q are shown in Fig. :



(i) Which of the two metals has greater value of work function?

(ii) Find maximum K.E. of electron emitted by light of frequency $\nu = 8 \times 10^{14}$ Hz for metal P.

7. Do all the photons have same dynamic mass? If not, Why?

8. Why photoelectrons ejected from a metal surface have different kinetic energies although the frequency of incident photons are same?

9. Find the ratio of de-Broglie wavelengths associated with two electrons 'A' and 'B' which are accelerated through 8V and 64 volts respectively.

10. Explain the terms stopping potential and threshold frequency.

11. How does the maximum kinetic energy of emitted electrons vary with the increase in work function of metals?

12. Define distance of the closest approach. An α-particle of kinetic energy 'K' is bombarded on a thin gold foil. The distance of the closest approach is '*r*'. What will be the distance of closest approach for an α-particle of double the kinetic energy?

13. An particle and a proton are accelerated by same potential. Find ratio of their de Broglie wavelengths. **Ans.** $[1:2\sqrt{2}]$

14. Draw a diagram to show the variation of binding energy per nucleon with mass number for different nuclei. State with reason why light nuclei usually undergo nuclear fusion.

15. What is the main difference between fission reaction and fusion reaction ? Give one example of each.

16. If the total number of neutrons and protons in a nuclear reaction is conserved how then is the energy absorbed or evolved in the reaction?

17. In the ground state of hydrogen atom orbital radius is 5.3×10^{-11} m. The atom is excited such that atomic radius becomes 21.2×10^{-11} m. What is the principal quantum number of the excited state of atom?

18. What are nuclear forces? Give their important properties.

19. Why is the density of the nucleus more than that of atom?

20. The atom ${}_8O^{16}$ has 8 protons, 8 neutrons and 8 electrons while atom ${}_4Be^8$ has 4 proton, 4 neutrons and 4 electrons, yet the ratio of their atomic masses is not exactly 2. Why?

21. What is the effect on neutron to proton ratio in a nucleus when β^- particle is emitted ? Explain your answer with the help of a suitable nuclear reaction.

22. Why must heavy stable nucleus contain more neutrons than protons?

23. Distinguish between isotopes, isobars and isotones with suitable examples.

24. What is a nuclear fusion reaction? Why is nuclear fusion difficult to carry out for peaceful purpose?

25. Write two characteristic features of nuclear forces which distinguish them from coulomb force.

26. Half life of certain radioactive nuclei is 3 days and its activity is 8 times the 'safe limit'. After how much time will the activity of the radioactive sample reach the 'safe limit'?

27. Derive $mvr = \frac{nh}{2\pi}$ using de-Broglie equation.

28. Draw graph of number of scattered particles to scattering angle in Ratherford's experiment.

29. If the energy of a photon is 25 eV and work function of the material is 7eV, find the value of slopping potential.

30. What is the shortest wavelength present in the (i) Paschen series (ii) Balmer series of spectral lines?

Ans. (i) 820nm, (ii) 365 nm

31. The radius of the inner most electron orbit of a hydrogen atom 0.53 Å. What are the radii of the $n = 2$ and $n = 3$ orbits. [**Hint:** $r = n^2 r_0$)

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

[**Hint :** K.E = – (T.E), P.E. = 2T.E]

33. Why is the wave nature of matter not more apparent to our daily observations ?

34. From the relation $R = R_0 A^{1/3}$ where R_0 is a constant and A is the mass number of a nucleus, show that nuclear matter density is nearly constant.

Ans. Nuclear matter density $= \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$

$$= \frac{mA}{\frac{4}{3}\pi R^3} = \frac{mA}{\frac{4}{3}\pi R_0^3 A}$$

$$= \frac{m}{\frac{4}{3}\pi R_0^3} = 2.3 \times 10^{17} \text{ kg / m}^3$$

= Constant

35. Find the energy equivalent of one atomic mass unit in joules and then in MeV.

Ans. $E = \Delta mc^2$ $\Delta m = 1.6605 \times 10^{-27}$ kg

$= 1.6605 \times 10^{-27} \times (3 \times 10^8)^2$

$= 1.4924 \times 10^{-4}$J

$= \frac{1.4924 \times 10^{-10}}{1.6 \times 10^{-19}} eV$

$= 0.9315 \times 10^9$ eV

$= 931.5$ MeV

36. Write four properties of nuclear force.

SHORT ANSWER QUESTIONS (3 Marks)

1. Explain the working of a photocell? Give its two uses.

2. Find the de-Broglie wavelength associated with an electron accelerated through a potential difference V.

3. What is Einstein's explanation of photo electric effect? Explain the laws of photo electric emission on the basis of quantum nature of light.

4. Light of intensity I and frequency v is incident on a photosensitive surface and causes photoelectric emission. Justify with the help of graph, the effect on photoelectric current when

(i) the intensity of light is gradually increased

(ii) the frequency of incident radiation is increased

(iii) the anode potential is increased

In each case, all other factors remain the same.

5. Write Einstein's photoelectric equation. State Clearly the three salient features observed in photoelectric effect which can be explained on the basis of the above equation.

6. Explain the effect of increase of (i) frequency (ii) intensity of the incident radiation on photo electrons emitted by a metal.

7. X-rays of wave length λ fall on a photo sensitive surface emitting electrons. Assuming that the work function of the surface can be neglected, prove that the de-Broglie wavelength of electrons emitted will be $\sqrt{\frac{h\lambda}{2mc}}$.

Ans. $E = \frac{hc}{\lambda} = \frac{P^2}{2m}$ $\therefore P = \sqrt{\frac{2mnc}{\lambda}}$, $\lambda_e = \frac{h}{P} = \sqrt{\frac{h\lambda}{2mc}}$

8. A particle of mass M at rest decays into two particles of masses m_1 and m_2 having velocities V_1 and V_2 respectively. Find the ratio of de-Broglie wavelengths of the two particles.

Ans. 1 : 1

9. Give one example of a nuclear reaction. Also define the Q-value of the reaction. What does Q > 0 signify?

10. Define atomic mass unit and electron volt. Derive relation between them.

11. Show that nuclear matter density is independent of A

12. what is mass defect of a nucleus ? Express it mathematically. How do your account for it ?

13. What is packing fraction ? Give its physical significance in relation to nuclear stability.

14. A nuclear bomb and a nuclear reactor work on the same principle. Explain why in one case explosion occurs and in the other energy is available at a steady rate.

15. Distinguish between nuclear fusion and fission. Give an example of each.

16. Explain the source of energy in the sun.

17. Obtain a relation for total energy of the electron in terms of orbital radius. Show that total energy is negative of K.E. and half of potential energy.

$$E = \frac{-e^2}{8\pi\varepsilon_0 r}$$

18. Draw energy level diagram for hydrogen atom and show the various line spectra originating due to transition between energy levels.

19. The total energy of an electron in the first excited state of the hydrogen atom is about – 3.4 eV. What is

(a) the kinetic energy,

(b) the potential energy of the electron?

(c) Which of the answers above would change if the choice of the zero of potential energy in changed to (i) + 0.5 eV (ii) – 0.5 eV.

Ans. (a) When P.E. is chosen to be zero at infinity E = – 3.4 eV, using E = – K.E., the K.E. = + 3.4 eV.

(b) Since P.E. = – 2E, PE = – 6.8 eV.

(c) If the zero of P.E. is chosen differently, K.E. does not change. The P.E. and T.E. of the state, however would alter if a different zero of the P.E. is chosen.

(i) When P.E. at ∞ is + 0.5 eV, P.E. of first excited state will be – 3.4 – 0.5 = – 3.9 eV.

(ii) When P.E. at ∞ is + 0.5 eV, P.E. of first excited state will be – 3.4 – (– 0.5) = – 2.9 eV.

20. What is unclear holocaust ?

21. Calculate the energy released in MeV in the deuterium-tritium fusion reaction:

$_1^2H + _1^3H \rightarrow _2^4He + n$

using data

$m(_1^2H) = 2.014102u$;

$m(_1^3H) = 3.016049$ u;

$m(_2^4He) = 4.002603$ u;

$m_n = 1.008665$ u,

$1u = 931.5$ MeV/c^2

LONG ANSWER QUESTIONS (5 Marks)

1. State Bohr's postulates. Using these postulates, derive an expression for total energy of an electron in the n^{th} orbit of an atom. What does negative of this energy signify?

2. Define binding energy of a nucleus. Draw a curve between mass number and average binding energy per nucleon. On the basis of this curve, explain fusion and fission reactions.

3. What do you mean by binding energy of a nucleus? Obtain an expression for binding energy. How binding energy per nucleon explains the stability of nucleus.

4. What is meant by nuclear fission and fusion. Draw Binding Energy Vs Mass Number curve and explain four important features of this curve.

5. Briefly explain Rutherford's experiment for scattering of α particle with the help of a diagram. Write the conclusions made and draw the model suggested.

NUMERICALS

1. Ultraviolet light of wavelength 350 nm and intensity 1 W/m^2 is directed at a potassium surface having work function 2.2eV.

(i) Find the maximum kinetic energy of the photoelectron.

(ii) If 0.5 percent of the incident photons produce photoelectric effect, how many photoelectrons per second are emitted from the potassium surface that has an area 1cm^2.

$$E_{Kmax} = 1.3 \text{ eV}; \; n = 8.8\times10^{11} \frac{\text{photo electron}}{\text{second}} \text{ or } _r = \frac{Nhv}{t} = nhv$$

2. A metal surface illuminated by 8.5×10^{14} Hz light emits electrons whose maximum energy is 0.52 eV the same surface is illuminated by 12.0×10^{14} Hz light emits elections whose maximum energy is 1.97eV. From these data find work function of the surface and value of Planck's constant. [Work Function = 3eV]

3. An electron and photon each have a wavelength of 0.2 nm. Calculate their momentum and energy.

(i) 3.3×10^{-24} kgm/s

(ii) 6.2 keV for photon

(iii) 38eV for electron

4. What is the (i) Speed (ii) Momentum (ii) de-Broglie wavelength of an electron having kinetic energy of 120eV?

Ans. (a) 6.5×10^6 m/s; (b) 5.92×10^{-24} kg m/s; (c) 0.112 nm.

5. If the frequency of incident light in photoelectric experiment is doubled then does the stopping potential become double or more than double, justify? (More than double)

Long Answer Question :

6. (A) Why wave theory of light could not explain the photoelectric effect? State two reasons. Draw graph between

(i) frequency v vs stopping potential V_0.

(ii) Intensity vs photoelectric current.

(iii) anode potential vs photoelectric current.

6.(B) A proton is accelerated through a potential difference V. Find the percentage increase or decrease in its de-Broglie wavelength if potential difference is increased by 21%.

Ans. (9.1%)

7. For what kinetic energy of a neutron will the associated de-Broglie wavelength be 5.6×10^{-10}m?

Ans.
$$\sqrt{2m_n \times \text{K.E.}} = \frac{h}{\lambda}$$

$\Rightarrow$
$$\text{K.E.} = \left(\frac{h}{\lambda}\right)^2 \frac{1}{2m_n}$$
$$= \left(\frac{6.625\times10^{-34}}{5.6\times10^{-10}}\right)^2 \frac{1}{2\times1.67\times10^{-27}}$$
$$= 3.35 \times 10^{-21}\text{J}$$

8. A nucleus of mass M initially at rest splits into two fragments of masses $\frac{M}{3}$ and $\frac{2M}{3}$. Find the ratio of de-Broglie wavelength of the fragments.

Ans. Following the law of conservation of momentum,
$$\frac{M}{3}v_1 + \frac{2M}{3}v_2 = 0$$

or
$$\left|\frac{M}{3}v_1\right| = \left|\frac{2M}{3}v_2\right|$$

$$\lambda = \frac{h}{mv} \Rightarrow \left|\frac{\lambda_1}{\lambda_2}\right| = \left|\frac{2\frac{M}{3}v_2}{\frac{M}{3}v_1}\right| = 1$$

9. An electron and a proton are possessing same amount of K.E., which of the two have greater de-Broglie, wavelength? Justify your answer.

Ans.
$$E_e = \frac{1}{2}m_e v_e^2$$

and
$$E_p = \frac{1}{2}m_p v_p^2$$

$\Rightarrow$
$$m_e v_e = \sqrt{2E_e m_e} \text{ and } m_p v_p = \sqrt{2E_p m_p}$$

But, $E_e = E_p \Rightarrow \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}} > 1$

$\therefore \quad \lambda_e > \lambda_p.$

10. The electron in a given Bohr orbit has a total energy of –1.51 eV. Calculate the wavelength of radiation emitted, when this electon makes a transition to the ground state.

Ans. 1028 A°

11. Calculate the radius of the third Bohr orbit of hydrogen atom and energy of electron in third Bohr orbit of hydrogen atom.

Ans. (–1.51 eV)

12. Calculate the longest and shortest wavelength in the Balmer series of Hydrogen atom. Rydberg constant = 1.0987×10^7 m^{-1}.

Ans. $\lambda_l = 6553$ A°, $\lambda_s = 3640$A°

13. What will be the distance of closest approach of a 5 MeV a-particle as it approaches a gold nucleus? (given Atomic no. of gold = 79)

Ans. 4.55×10^{-14}m

14. A 12.5 MeV alpha – particle approaching a gold nucleus is deflected 180°. What is the closest distance to which it approaches the nucleus?

Ans. 1.82×10^{-14}m

15. Determine the speed of the electron in $n = 3$ orbit of hydrogen atom.

Ans. $7.29 \times 10^5 ms^{-1}$

16. The three stable isotopes of neon: Ne^{20}, Ne^{21}, Ne^{22} have respective abundances of 90.51%, 0.27% and 9.22%. The atomic masses of the three isotopes are 19.99 amu, 20.99 amu and 21.99 amu respectively. Obtain the average atomic mass of neon.

Ans. 20.18 amu.

17. Obtain the binding energy of a nitrogen nucleus ($^{14}_{7}N$) from the following data: $m_H = 1.00783$ amu; $m_n = 11.00867$ amu; $M_N = 14.00307$ amu, Give your answer in MeV

Ans. 104.7MeV

18. A given coin has a mass of 3.0 g . Calculate the nuclear energy that would be required to separate all the neutrons and protons from each other. For simplicity assume that the coin is entirely made of $^{63}_{29}Cu$ atoms (of mass 62.92960 amu). The masses of proton and neutron are 1.00783 amu and 1.00867 amu, respectively.

Ans. 1.582×10^{25} MeV

19. Binding energy of $_2He^4$ and $_3Li^7$ nuclei are 27.37 MeV and 39.4 MeV respectively. Which of the two nuclei is more stable? Why?

Ans. $_2He^4$ because its BE/nucleon is greater.

20. Find the binding energy and binding energy per nucleon of nucleus $_{83}B^{209}$.
Given : mass of proton = 1.0078254 u. mass of neutron = 1.008665 u.
Mass of $_{83}Bi^{209}$ = 208.980388u.

Ans. 1639.38 MeV and 7.84 MeV/Nucleon

21. Is the fission of iron ($_{26}Fe^{56}$) into ($_{13}Al^{28}$) as given below possible?
$_{26}Fe^{56} \rightarrow {}_{13}Al^{28} + {}_{13}Al^{28} + Q$
Given mass of $_{26}Fe^{56}$ = 55.934940 and $_{13}Al^{28}$ = 27.98191 U

Ans. Since Q value comes out negative, so this fission is not possible

22. Find the maximum energy that β-particle may have in the following decay :

$_8O^{19} \rightarrow {}_9F^{19} + {}_{-1}e^0 + \bar{\nu}$

Given
$m\ (_8O^{19}) = 19.003576$ a.m.u.
$m\ (_9F^{19}) = 18.998403$ a.m.u.
$m\ (\_e^0) = 0.000549$ a.m.u.

Ans. 4.3049 MeV

23. The value of wavelength in the lyman series is given as

$$\lambda = \frac{913.4 n_i^2}{n_i^2 - 1} \text{ Å}$$

Calculate the wavelength corresponding to transition from energy level 2, 3 and 4. Does wavelength decrease or increase ?

Ans.

$$\lambda_{21} = \frac{913.4 \times 2^2}{2^2 - 1} = 1218 \text{ Å}$$

$$\lambda_{31} = \frac{913.4 \times 3^2}{3^2 - 1} = 1028 \text{ Å}$$

$$\lambda_{41} = \frac{913.4 \times 4^2}{4^2 - 1} = 974.3 \text{ Å}$$

$\lambda_{41} < \lambda_{31} < \lambda_{21}$

Answer to 2 Marks Question

1. Similarity : Both follow wave equation (partial differential equation)
dissimilarity : Matter waves
(a) cannot be radiated in empty space.
(b) are associated with the particles, not emitted by it

2. Yes, $\lambda = \frac{hc}{E}$

3. $\lambda = \frac{h}{p}$ for photon $P = \frac{E}{C}$ and $\lambda = \frac{hc}{E}$ for electron $P = \sqrt{2M\ E}$

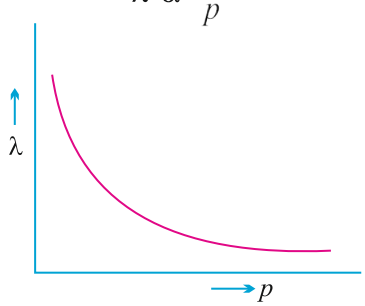
$\lambda_{photon} = 2.4 \times 10^{-8}$m, $\lambda_{electron} = 3.6 \times 10^{-10}$m

4. $\lambda = 3300A^{o}$, $E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{3300\times10^{-10}\times1.6\times10^{-19}}eV \approx 3.8$ eV

Work function of M_o & Ni > 3.8 eV hence no photoelectron emission from M_o and Ni.

5. $\lambda = \frac{h}{p}$

$\Rightarrow$ $\lambda\ \alpha\ \frac{1}{p}$



6. Q
K.E.$_{max} \approx 1.3$ eV As $\frac{hv_0}{e} = -2V$

7. $E = mc^2$, $hv = mc^2$, $m = \frac{hv}{c^2}$, no, it depends upon frequency.

8. $KE = hv - hv_0$. The electrons in the atom of metal occupy different energy levels, thus have different minimum energy required to be 'ejected' from the atom. So the e^- with higher energy will have higher kinetic energy.

9. Decreases, $\lambda = \frac{1}{\sqrt{V}} \therefore \frac{\lambda_1}{\lambda_2} = \frac{2\sqrt{2}}{1}$

11. $KE_{max} = h\nu - w_0 \Rightarrow KE_{max}$ decreases with increase in w_0.

12. Distance of closest approach is defined as the minimum distance between the charged particle and the nucleus at which initial kinetic energy of the particle is equal to electrostatic potential energy.

for α particle, $\frac{K\, Ze(2e)}{r} = \frac{1}{2} m v_\alpha^2$

$$r \propto \frac{1}{K.E.}$$

$\therefore$ r will be halved.

16. The total binding energy of nuclei on two sides need not be equal. The difference in energy appears as the energy released or absorbed.

17. $n = 2$ as $r_n \alpha n^2$

19. Because radius of atom is very large than radius of nucleus.

20. Due to mass defect or different binding energies.

21. Decreases as number of neutrons decreases and number of protons increases. $N \rightarrow P + {}_{-1}e^0$

22. To counter repulsive coulomb forces, strong nuclear force required between neutron-neutron, neutron-proton and proton-proton.

24. For fusion, temperature required is from 10^6 to 10^7 K. So, to carry out fusion for peaceful purposes we need some system which can create and bear such a high temperature.

25. Nuclear forces are short range forces (within the nucleus) and do not obey inverse square law while coulomb forces are long range (infinite) and obey inverse square law.

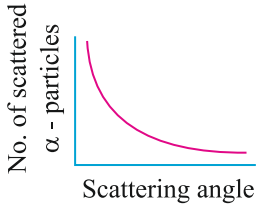
26. $$\left(\frac{A}{8A}\right) = \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

or $$\left(\frac{1}{2}\right)^{3} = \left(\frac{1}{2}\right)^{t/3}$$

or $$3 = \frac{t}{3}$$

$\Rightarrow$ $$t = 9 \text{ days.}$$

28.



29. $$V_0 = (E - \phi_0)/e = \frac{(25-7)eV}{e} = 18V.$$